Coastal Research Library 23

Charles W. Finkl
Christopher Makowski *Editors*

Diversity in Coastal Marine Sciences

Historical Perspectives and Contemporary Research of Geology, Physics, Chemistry, Biology, and Remote Sensing

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Coastal Research Library

Volume 23

Series Editor
Charles W. Finkl
Department of Geosciences
Florida Atlantic University
Boca Raton, FL 33431, USA

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Editors

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Editors
Charles W. Finkl
Coastal Education & Research Foundation (CERF)
Fletcher, NC, USA

Department of Geosciences
Florida Atlantic University
Boca Raton, FL, USA

Christopher Makowski
Coastal Education & Research Foundation (CERF)
Coconut Creek, FL, USA

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Festschrift in Honor of Assoc. Prof. Dr. Alexandru S. Bologa

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Contributors

Indira Deniz Alim Ovidius University of Constanta, Constanta, Romania

Eugen Anton NIMRD – National Institute for Marine Research and Development "Grigore Antipa", Constanta, Romania

Adrian Bavaru Faculty of Natural and Agricultural Sciences, "Ovidius" University of Constantza, Constantza, Romania

Academy of Romanian Scientists, Bucharest, Romania

University Ovidius of Constanţa, Constanţa, Romania

Rodica Bercu Faculty of Natural and Agricultural Sciences, "Ovidius" University of Constantza, Constantza, Romania

Ana-Maria Blebea-Apostu Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Bucharest-Măgurele, Romania

Romeo Boşneagu "Mircea cel Batran" Naval Academy, Constanta, Romania

Giuseppe Brancatelli Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy

Mihai Burcă Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy

Alina Buzarna-Tihenea (Gălbează) University Ovidius of Constanţa, Constanţa, Romania

Doina Carp Faculty of Mathematics and Computer Science, Ovidius University of Constanta, Constanta, Romania

Constance C. Charlier University of Arizona (retired), Axelrod and Associates Consultants, Santa Barbara, CA, USA

Roger H. Charlier Vrije Universiteit Brussel (Free University of Brussels), Brussels, Belgium

Alecsandru Vladimir Chiroşca Department of Structure of Matter, Earth and Atmospheric Physics and Astrophysics, University of Bucharest, Magurele (Ilfov), Romania

Gianina Chiroşca Doctoral School in Physics, Faculty of Physics, University of Bucharest, Magurele (Ilfov), Romania

Valentin Ciorbea Academy of Romanian Scientists, Bucharest-Constanţa, Romania

Doctoral School of Humanities – History, Ovidius University of Constanta, Constanta, Romania

Daniel Ovidiu Costea Ovidius University of Constanta, Constanta, Romania

Cristian-Sorin Danilov NIMRD – National Institute for Marine Research and Development “Grigore Antipa”, Constanta, Romania

Dănuț I. Diaconeasa National Institute for Marine Research and Development “Grigore Antipa”, Constanţa, Romania

Corneliu Dinu Faculty of Geology and Geophysics, University of Bucharest, Bucharest, Romania

Paolo Diviacco Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy

Boris V. Divinskiy The Southern Branch of the P.P.Shirshov Institute of Oceanology, RAS, Prostornaya, Gelendzhik, Krasnodar, Russia

Nicolae Doniță Academy of Agricultural and Forestry Sciences from Romania, “Gheorghe Ionescu-Sisesti”, Bucharest, Romania

Constantin Dovlete Environmental Radioactivity Laboratory, Bucharest-Afumati, Institute of Environmental Research and Engineering, Bucharest-Afumaţi, Romania

Wolf-Christian Dullo GEOMAR Helmholtz for Ocean Research Kiel, Kiel, Germany

Nicolae V. Dură Ovidius University of Constanta, Academy of Romanian Scientists, Constanta, Romania

Viktor N. Egorov Radiation and Chemical Biology Department, FSBIS Institute of marine biological research RAS (IMBR), Sevastopol, Russian Federation

Marius Făgăraș Faculty of Natural and Agricultural Sciences, Ovidius University of Constanta, Constanta, Romania

Sascha Flögel GEOMAR Helmholtz for Ocean Research Kiel, Kiel, Germany

Mădălina Galaţchi National Institute for Marine Research and Development (NIMRD) “Grigore Antipa”, Constanta, Romania

Stoica Godeanu Academy of Romanian Scientists, Bucharest, Romania

Mariana Claudia Gomoiu Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, Bucharest-Magurele, Romania

Sergey B. Gulin Radiation and Chemical Biology Department, FSBIS Institute of marine biological research RAS (IMBR), Sevastopol, Russian Federation

Mihaela Ivancia "Ion Ionescu de la Brad" University of Agricultural Sciences and Veterinary Medicine of Iasi, Iasi, Romania

Constantin Jurcă University Ovidius of Constanţa, Constanţa, Romania

Vera Kopiy The Institute of Marine Biological Research RAS, Sevastopol, Crimea, Russia

Ruben D. Kosyan The Southern Branch of the P.P.Shirshov Institute of Oceanology, RAS, Prostornaya, Gelendzhik, Krasnodar, Russia

Gabriele Kuby Rimsting, Germany

Alexander S. Kukushkin Marine Hydrophysical Institute – RAS, Sevastopol, Crimea, Russia

Gunnar Kullenberg IOC, Global Forum on Oceans, Coasts and Islands, Stromstad Academy, Stromstad, Sweden

Garabet Kümbetlian Academy of Technical Sciences of Romania, Bucharest-Constanţa, Romania

Elena Lazăr Romanian Academy, Patrimony Department, Bucharest, Romania

Walter Lenz International Commission of History of Oceanography, Hamburg, Germany

Aurel Lup Academy of Romanian Scientists, Bucharest, Romania

Mircea Maliţa Romanian Academy, Bucharest, Romania

Monica Marin University of Agronomic Sciences and Veterinary Medicine of Bucharest, Bucharest, Romania

Alexandru Marinescu Romanian Committee of History of Science and Technology, Bucharest, Romania

Răzvan Mateescu National Institute for Marine Research and Development "Grigore Antipa", Constanţa, Romania

Romul Mircea Mărgineanu Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Bucharest-Măgurele, Romania

Valodia Maximov National Institute for Marine Research and Development (NIMRD) "Grigore Antipa", Constanta, Romania

Raluca Melihov Ovidius University of Constanta, Constanta, Romania

Maria E. Mihailov National Institute for Marine Research and Development "Grigore Antipa" Constanta – Romania, Mamaia, Constanţa, Romania

Liliana Miron Ovidius University of Constanta, Constanta, Romania

Natalya Yu. Mirzoyeva Radiation and Chemical Biology Department, FSBIS Institute of marine biological research RAS (IMBR), Sevastopol, Russian Federation

Ioan Munteanu Repsol Exploration, Madrid, Spain

Aurel Năstase National Institute for Marine Research and Development "Grigore Antipa", Constanţa, Romania

Magda Ioana Nenciu National Institute for Marine Research and Development "Grigore Antipa", Constanţa, Romania

Simona Nicheva Executive Agency for Fisheries and Aquaculture, Bourgas, Bulgaria

Carmen Georgeta Nicolae University of Agronomic Sciences and Veterinary Medicine of Bucharest, Bucharest, Romania

Tatyana S. Osadchaya The A.O. Kovalevsky Institute of Marine Biological Researches (IMBR), Sevastopol, Russia

Iolanda Osvath Environmental Radioactivity Laboratory, Bucharest-Afumati, Institute of Environmental Research and Engineering, Bucharest-Afumaţi, Romania and Environment Laboratories, International Atomic Energy Agency, Monaco, Monaco

Nicolae Panin National Institute of Marine Geology and Geoecology, Bucharest, Romania

Aleksandr V. Parkhomenko Institute of Marine Biological Research A.O. Kovalevsky Russian Academy of Sciences, Sevastopol, Russia

Vasile Pătraşcu National Institute for Marine Research and Development (NIMRD) "Grigore Antipa", Constanta, Romania

Marin Petrişor Academy of Romanian Scientists, University Ovidius of Constanţa, Constanţa, Romania

Constantin Popa Faculty of Mathematics and Computer Science, Ovidius University of Constanta, Constanta, Romania

Dana Popa University of Agronomic Sciences and Veterinary Medicine of Bucharest, Bucharest, Romania

Violin St. Raykov Institute of Oceanology – BAS, Varna, Bulgaria

Andres Rüggeberg Département des Geosciences, Université de Fribourg, Fribourg, Switzerland

Chiara Sauli Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy

Daciana Sava Faculty of Natural and Agricultural Sciences, University Ovidius of Constanţa, Constanţa, Romania

Vasile Sârbu Academy of Romanian Scientists, Bucharest-Constanta, Romania

Sandu Sonoc Environmental Radioactivity Laboratory, Bucharest-Afumati, Institute of Environmental Research and Engineering, Bucharest-Afumaţi, Romania

University of Toronto, Toronto, Canada

Nicoleta Stanca Faculty of Letters, Ovidius University of Constanta, Constanta, Romania

Aleksandr Strezov Bulgarian Academy of Sciences, Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria

Cristina Şerban Faculty of Mathematics and Computer Science, Ovidius University of Constanta, Constanta, Romania

Henrieta Anişoara Şerban Romanian Academy, Institute of Political Sciences and International Relations "Ion I. C. Bratianu", Bucharest, Romania

Nataliya N. Tereshchenko The A.O. Kovalevsky Institute of Marine Biological Research of RAS, Sevastopol, Russian Federation

George Ţiganov Danube Delta National Institute for Research and Development, Tulcea, Romania

Cornel Liviu Ţugulan Radioactive Waste Management Department Laboratory, Horia Hulubei Institute for Physics and Nuclear Engineering, Magurele Bucharest, Romania

Alexandre Charles Thys Vrije Universiteit Brussel, Brussels, Belgium

Alexandra Nicoleta Unc Floreasca Emergency Hospital, Bucharest, Romania

Octavian Dumitru Unc Ovidius University, Constanţa, Romania

Ioana Vizireanu National Institute for Aerospace Research "Elie Carafoli", Bucharest, Romania

Violetta Yurakhno A. O. Kovalevsky Institute of Marine Biological Research RAS, Sevastopol, Russia

Yuvenali P. Zaitsev Department of Biological Science, Institute of Marine Biology – National Academy of Sciences of Ukraine, Odessa, Ukraine

Alexandru Bologa: Some Reminisces and Appreciation of His Devotion to Science, History, and Life

In spite of being born in Braşov, Transylvania, on September 8, 1947, and still loving mountains and forests forever, Alexandru Ş. Bologa's fate was tied to the sea. Coasts and oceans were his first scientific interest that set him on a course of scientific endeavors for the rest of his professional career. And although he is from the mountains of Romania, his love for the sea had him focus more on life-forms on the seafloor and in the water column.

His teachers from the German section of the first lyceum "Andrei Şaguna" in his hometown inculcated a general love for learning, and one of them inspired in particular his love for nature and biology. Alexandru graduated from the Faculty of Biology at "Babeş-Bolyai" University in Cluj-Napoca, in 1970, where he met outstanding professors that inspired him to emulate their examples to work in and help develop appropriate laboratories, archives, libraries, and museums. Cluj-Napoca remains till now his favorite city in Romania.

Later, in Constanţa, Alexandru was employed by the Romanian Institute for Marine Research, now referred to as the National Institute for Marine Research and Development (NIMRD) "Grigore Antipa", the new name for the research institute of 27 years ago. Dr. Bologa's main research endeavors began with his first love in marine biology, which included green, brown, and red seaweeds along the Romanian Black Sea coast. This early scientific interest was eventually extended to marine planktonic primary production, radioactivity and radioecology, bibliographies, and computerized databases. Last but not least, the fascinating history of the marine sciences was added over time to his repertoire.

His initial studies delved into marine flora and efforts to deal with this subject area in a broad ecological sense, as well as referring to certain more specific related aspects, fostered or directly brought about by meeting Dr. Maria S. Celan. She was duly noted by a most important Romanian predecessor, Dr. Grigore Antipa, who recommended her to Professor Ioan Borcea, the founder of the first Romanian marine research institution (the Marine Zoological Station at Constanţa, Agigea) in 1926. She became Romania's greatest marine algologist, after returning to her homeland with her valuable Ph.D. thesis obtained in Paris (1940). Her work set the stage and study basis of Romanian benthic algology. And, after Alexandru's father, she became his second role model. During Alexandru's university studies, Professor Dr. Ana P. Fabian, a plant physiologist, initiated his scientific research, becoming a third role model.

A generous chance invitation to complete Alexandru's desire to introduce the C^{14} method for estimating planktonic primary production and productivity came from the All-Russia Research Institute of Marine Fisheries and Oceanography (VNIRO) in Moscow. So he joined its 13th scientific cruise on board the R/V *Akademik Knipovich* in the east-central Atlantic Ocean in 1974. This experience offered both professional and personal attributes to Alexandru's career, for which he was sincerely grateful. The cruise went well, and after returning home, Alexandru was able to introduce the abovementioned method by liquid scintillation counting for the first time in Romania.

A totally new experience was found by joining three of the total four scientific cruises organized by his institute, within a major research contract, in Libyan territorial waters, on board of the Romanian trawler (adapted with laboratories) *Delta Dunării*, between 1975 and 1976. At this time, Alexandru faced many unexpected situational complexities. The biggest technological problem was related to the need of measuring the planktonic primary production of those waters using the chlorophyll method (in the absence of C^{14} facilities), but the procedure was complicated by the sea's extreme oligotrophic feature. This difficulty was related to the fact that he had to filter hundreds of liters of seawater with most of the results below the detection limit.

Another extreme training event in the fields of marine radioactivity and radioecology occurred at the IAEA's International Laboratory of Marine Radioactivity in Monaco (1986). This was the result of a frustrating yearlong confrontation with the communist authorities and their usual fearful attitude, *y compris*, concerning the freedom of travel. The instruction was, unfortunately, quite short (3 months allowed by the home country instead of the 1 year approved by Vienna) but nevertheless very welcomed. Alexandru succeeded in this effort, and it proved to be even more opportune because it took place immediately after the unforgettable Chernobyl tragedy. The anticommunist revolution that took place at the end of the 1980s brought immense joy for Alexandru to escape the undeserved and much too long communist nightmare for his country. Before the revolution, there were many more hopes than those that actually came true. But as they say, *hope dies last*.

Starting from 1990, Alexandru Bologa's professional multitasking activities included positions as scientific director of the NIMRD, associate professor at the University Ovidius of Constanţa, editor in chief of the institute's yearly scientific journal (*Cercetări marine: Recherches marines*), and chairman of the local subcommittee (which he founded in Constanţa in 1993) of the Romanian Committee of History of Science and Technology of the Romanian Academy, until his retirement in 2011. Other international responsibilities included being a national delegate to the International Commission for the Scientific Exploration of the Mediterranean Sea (CIESM) between 1993 and 2011, director at the International Ocean Institute (Malta) of the Black Sea Operational Centre (1996–2004), and national rapporteur to the Commission of Oceanography (International Union of History and Philosophy of Science).

Research activities in Romania have always been plagued by financial difficulties, not the least of which occurred during the postrevolutionary free market economy. Governmental support has declined constantly, and the NIMRD constantly has to prove its efficiency in agreement with economic and social development of today's society and its ever-expanding demands on financial resources. Despite all of the weaknesses of the present democracy in Romania, being not easy in many ways and far from perfection, Alexandru graciously witnesses the long-expected collapse of a harsh communist regime. Casualties of the socialist regime ranged from simple farmers to Romania's intellectual elite. Victims of this regime included many outstanding scientists of Romania, including remarkable biologists.

Alexandru's election as full member of the Academy of Romanian Scientists, Section Biological Sciences, was followed in 2009 by the prize "George Emil Palade" for *Romanian Contributions to Black Sea Related Marine Sciences*. A selection of 31 authored and coauthored professional articles was published by Lambert Academic Publishing, Saarbrücken, Germany (2012). Unfortunately, and for obvious reasons, the Black Sea was practically ignored by the Western world during the dark era of communism. The region became visible, interesting, and attractive to foreigners for various reasons, notwithstanding its geopolitical dimension, as well as scientific concerns, research, environmental protection, development, innovation, new discoveries, and regional and international cooperation. The oceanographic realm known as the Black Sea, so adequately named as an "unicum hydrobiologicum", by the Russian physical oceanographer N. Knipovich in the early twentieth century, is characterized by its large continental shelf, water stratification, lack of vertical mixing, highest H_2S content of deep waters worldwide, strong freshwater input, increased levels of nutrients and detritus, weak water mass exchange with the Mediterranean Sea, large spatial and temporal variability of physical and chemical properties, about half salinities of those noticed in the World Ocean, and slightly different composition of ionic ratios. Poorer flora and fauna have been previously compensated by the very high biological productivity. Relatively few alien species have entered this very particular oceanic environment. By the end of the fifth decade of the twentieth century, the Black Sea underwent major changes that contributed to a severe ecological disequilibrium. Considerable efforts have been devoted after 1990 for the rehabilitation of this still highly endangered sea. Within these joint contemporary concerns, the continuous development of Romanian oceanography has enriched Black Sea research and expertise capacity. Some of Alexandru's preoccupations and results have positively influenced this domain.

As organizer of a NATO Advanced Research Workshop in Constanţa on October 6–10, 1997, Alexandru was charged as a coeditor to ensure the high quality of the proceedings *Environmental Degradation of the Black Sea: Challenges and Remedies*, alongside with Professors Ümit Ünlüata and Şukru Beşiktepe from Turkey. The proceedings (Environmental Security – Volume 56, 1999) were published by Kluwer Academic Publishers (Dordrecht, the Netherlands) in cooperation with the NATO Scientific Affairs Division.

Alexandru Bologa is a member of numerous national and international scientific societies, such as Asociaţia Culturală Dobrogeţia, Liga Navală Română, La Maison Roumaine (France), the International Phycological Society, the International Union of Radioecology, and the Eco-Ethics International Union, among others. Dr. Bologa is a member of the editorial boards of *Noesis* and *Studii şi comunicări/DIS* (both of the Romanian Academy), *Studii şi cercetări de oceanografie costieră* (University of Bucharest), *Marea Noastră* (Constanţa), the International Ocean Institute (IOI) *Ocean Yearbook* (1996–2004), and the *Journal of the Black Sea/Mediterranean Environment* (TUDAV, Turkey).

Alexandru is an authorized translator and interpreter for the German language. As a multilingual, he loves reading and traveling, to enrich his knowledge base, feelings, and emotions sur place. In a word, Alexandru is a true scholar par excellence who is now enjoying his emeritus status.

As a final word in closing, I must sadly report our acknowledgment of the fact that the present leadership of the National Institute for Marine Research and Development (NIMRD) "Grigore Antipa," from Constanta, did not allow for some unknown reason the participation of its employees in the Festschrift. As the home institute of Alexandru, this situation was most regrettable.

Coastal Education & Research Foundation
Fletcher, NC, USA

Charles W. Finkl

Selected Publications of Alexandru Ş. Bologa

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Part I
Introduction

Chapter 1
The Sea, Cradle of Divine Spirituality

Constantin Jurcă and Alina Buzarna-Tihenea (Gălbează)

Abstract Across human history, countless scientific works about the sea have been written, and some of them have an eternal nature. The sea, blessed by God since the Genesis (*The Bible*. "The Old Testament. The Genesis") ("And God said, "Let the water teem with living creatures, and let birds fly above the earth across the vault of the sky." So God created the great creatures of the sea and every living thing with which the water teems and that moves about in it, according to their kinds, and every winged bird according to its kind. And God saw that it was good. God blessed them and said, "Be fruitful and increase in number and fill the water in the seas, and let the birds increase on the earth"." (*The Bible*. "The Old Testament. The Genesis", Ch. 1, verse 20–22, p. 2)), has generously offered the most diverse and necessary resources for the existence of humanity. In this respect, since the oldest times, the sea has generated a favorable climate for the development of trade, communication, civilization and great geographical discoveries.

The sea has the great merit of approaching the created man to his Creator. It was one of the main instruments whereby God revealed Himself, showing the power, greatness and beauty of His creation. "The Word of God" was spread by the waters of seas and oceans, to the most remote places of the world. The Savior's "Gospels" and Teachings were spread by the sea and by the roads crossing the Roman Empire. The first Christian communities and churches were established and fortified in seashore cities, and Christianity was spread by the sacrifice of Christ's disciples and apostles. The sea also consolidated the spirit of sacrifice and human solidarity. The law of retaliation (eye for eye, tooth for tooth) was replaced by the law professing the Love of God and of our fellow men. Moreover, the endless sea brings us closer to heaven, as it intermingles with the infinite horizon; the sea is a symbol of the union between the terrestrial level and the celestial one, as the sky mirrors itself into the sea.

C. Jurcă (✉)
Faculty of Law and Administrative Sciences, Ovidius University of Constanta, Constanța, Romania
e-mail: daniellajurca@yahoo.com

A. Buzarna-Tihenea (Gălbează)
Faculty of Letters, Ovidius University of Constanta, Constanța, Romania
e-mail: alina_buzarna84@yahoo.com

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In one of his works, the writer Giovanni Papini (Papini, G, Viata lui Iisus. Editura Orizonturi, Bucuresti, p 470, 2012) stated that, no matter what, Christ remains the beginning and the end, a beam of divine mysteries at the crossroads of two glimpses of human history. In our paper, we will attempt at presenting several excerpts from the Bible and from other works that describe the role played by the sea in the dissemination of Scriptures and in the evolution of Christianity. Moreover, with God's help, we also aim at revealing the sea as a "cradle" of miracles, whereby God's great plans were achieved and He revealed Himself as a "Loving Father" and Creator of the universe. The sea "provided fishers of men" and some of them became Christ's disciples. At His call, they left their ships and fishing tools and followed Him. This paper will reveal that the sea confirmed the Godhead of the Beloved Son, Jesus Christ. The sea, by its whims, often helped the Apostles, who spread the word of the "Gospel" and worshiped Jesus, who rose from the dead.

We will conclude our paper by an appeal addressed to our readers: the sea is a blessing from God and we will be held responsible to Him with regard to the way in which we respect, use and protect it and its beings. Those who love the sea are not only thinkers whose dreams float on its blue and soothing waters. They are managers and fully responsible to God for the achievement of His creation, including the sea. Watch the stormy sea, float on its furious waves and when restlessness starts to creep into your hearts, you will fully and profoundly understand the words of the wise Solomon, son of David: "The fear of the Lord leads to life, So that one may sleep satisfied, untouched by evil… The fear of man lays a snare, but whoever trusts in the Lord is safe" (*The Bible*, "The Old Testament. Proverbs of Solomon").

Keywords Sea • Creationism • God • Divinity • Spirituality

1.1 Introduction

Winter approaches. A cold late autumn wind is blowing on the deserted beach of the Black Sea. The sky is dark blue and the sun begins to rise. It appears slowly, in the distance, where the sky meets the sea. Hues of red, yellow, orange and blue take over the mighty sky that stretches over the sea waters, which are always greedy to grasp with their unsuspected powers and to swallow everything in their way. Now, it seems peaceful and clear… It appears to laugh, showing the shiny white teeth of its restless small waves that are approaching the shore… It is the well deserved time of reflection… Light begins to embrace the entire beach. I take a few steps along the shoreline, enchanted by the beauty of God's marvelous creation. Puzzled, I watch the sea again. Then, overwhelmed, I walk home, and I ask myself several questions. What mysteries and treasures are hidden deep under its waters? Where does the power and beauty of its fascinating colors and changing waters come from?

Scientists have sought, and they still seek, tireless and courageously, to unravel its hidden secrets. Whimsical and, sometimes, uncontrollable, with its threatening great waves, the sea defends its territory and the wealth of its treasures, hidden into its depths. Historians become famous when, after tireless searching, they discover relics of the past: fortresses, human settlements, ancient temples of deities, all swallowed by the sea. Monuments created with an amazing artistry... Solid walls and tall buildings rivaling those of the present times, built by modern means... Weapons, tools and crafts of the past, ships, coins, vases and amphorae expressing the continuity of the economic and commercial life...

Nowadays, the research in various fields is heading with great hope towards the discovery and capitalization of the immense reserve of natural resources and biological materials, which the divinity conferred by the waters of seas and oceans. Compared to the land, the water surface represents two thirds of the entire Earth, i.e. 361 million square kilometers, and the planetary oceans represent 98.8% of the hydrosphere.

This huge reservoir of resources hides, in deep waters, over 8 billion tons of oil and nearly 8,000 billion cubic meters of methane. Only under the Pacific Ocean, there are stored over 1,650 billion tons of ore (210 billion tonnes of iron; 43 billion tons of magnesium; 359 tons of manganese; 14.7 tons of nickel; nearly 10 billion tons of copper), ensuring thus the humanity's future needs of mineral resources. The sea water contains precious metals such as silver and gold, whose exploration and use will create an intense competition among the developed countries of the world in the twenty-first century (Ivan Sorin 2000).

However, the greatest wealth of the sea is represented by its salt, which covers a huge reserve of over 20 million cubic meters. The generosity of divine creation is also reflected by the fact that the sea provides food to the human being, created by God's hand, ensuring nowadays 25% of the necessary proteins, from fish and other marine animals. The peoples from the Far East procure from the sea almost 50% of the proteins necessary for human life. Additionally, this ressource, in its infinite vastness, also preserves huge amounts of other foods, such as plankton and seaweed. Of course, for a certain period, they will save mankind from the chronic hunger that worsens in time, until it reaches the limit described by the Bible, i.e. "the signs of the beginning of the end ..." "and, at times, there will be earthquakes, famine and plague" (*The Bible, The New Testament,* "The Gospel of Matthew").[1]

"The discovery of numerous chemicals and substances with valuable therapeutic properties in the composition of the seawater, sea plants and animals, also makes us consider the sea as a large pharmacy" (Ivan Sorin 2000: 5). The miraculous results

[1]Other signs of the beginning of the end ("of sorrows": "The Gospel of Mark", ch. 13, verse 8, p. 979): "For false messiahs and false prophets will appear and perform great signs and wonders to deceive, if possible, even the elect. Because of the increase of wickedness, the love of most will grow cold. But the one who perseveres to the end will be saved. And this gospel of the kingdom will be preached in the whole world as a testimony to all nations, and then the end will come" ("The Gospel of Matthew", ch. 24, verse 14).

of helio-marine cures are reflected by the sick people who, sometimes, come to the sea, leaning on crutches or using other means of transportation that facilitate their movements and, afterwards, they return home walking on their own feet, blessing and thanking God. All these make us name the sea "the cradle of divine creation", source of miraculous healing in this great natural "sanatorium". Thousands of people, guided and advised by those dressed in the white robes of righteousness – i.e. doctors – enjoy again the gifts that the divinity granted to the human being.

A question dealt with by the mankind for several millennia, also approached by scientists, philosophers and theologues, either from a materialistic or from a creationist perspective, is the one to which we seek to answer today calling on different arguments. How were the universe, the Earth and the sea created? Where did the germs of life appear? How did the human being appear and how did we evolve on Earth? For this purpose, we will refer briefly to some concepts developed throughout the distant history of mankind, which are also found in the mythology of many peoples (Mircea Eliade 2000).

1.2 The Sea: From Mythological to Biblical Significations

The rich mythology speaks of the primordial god of the aquatic chaos (Jean Chevalier and Alain Gheerbrant 2009; Henry Halley 1924).[2] In its turn, one of the oldest Chinese encyclopedias (Jean Chevalier and Alain Gheerbrant 2009; Henry Halley 1924) known today mentions the book of mountains and seas, which also makes refererence to the flood, which lasted hundreds of years by the condensation of clouds. Moreover, the Iranian mythology speaks of two deities of water that are considered creators of the mankind, i.e. goddess Anahita (the patronness of fertility) and god Apamnapat (the guard of waters). It is interesting that, in the ancient Greek mythology (Jean Chevalier and Alain Gheerbrant 2009; Henry Halley 1924), other characters related to the creation of the world also appeared. From the Chaos (representing the primordial state) the following characters were born: Gaia – the land; Erebor – the darkness; Nyx – the night; Hemera – the terrestrial light (the day) and Aither – the astral light; Uranos – the astral sky – and Pantos – the sea.

Influenced by the Greek mythology (Athens was the cultural center of the ancient world), the Roman mythology (Jean Chevalier and Alain Gheerbrant 2009; Henry Halley 1924) speaks of 12 deities, components of the divine council, including Venus and Neptunus. The latter corresponded, in the Greek mythology, to Aphrodite (the goddess of beauty, love and fertility, who was born of the hot and blue sea foam of Hellas) and to Poseidon (the god of the seas and oceans).

[2]Since 1924, Henry Halley's *The Bible Handbook* has known a continuous development: in 1924 it was a brochure of only 24 pages while the edition published in 1983, translated in Romanian by Doru Motz, has 850 pages.

According to ancient Greek stories (Jean Chevalier and Alain Gheerbrant 2009; Henry Halley 1924), Poseidon, the protector of navigation, was stirring the sea, hitting the shore and breaking the rocks with his trident.

However, none of the opinions expressed or the studies developed and published have a clear echo regarding the great and infinite perfection of the Universe created by God. When faced with reality, they reveal themselves as elliptical, lacking one or more essential elements in order to "stand up". In order to be completed, all or almost all make referrence to the future, to a moment when science will be developed enough in order to make them fully known. This is explained in an impressive way by the eminent scholar Saul of Tarsus, later known as Paul (after his meeting in Damascus with Jesus), a Jew and a Roman citizen who, subsequently to his conversion, was sent to proclaim "the divine Word" to the Gentiles (*The Bible – The New Testament,* The First Epistle of St. Paul to the Corinthians).[3] Nevertheless, people, in the convenience conferred by modern life, are not so concerned about the absolute truth and, from this point of view, they are satisfied with less and accept them as they are: interesting stories of the past. The same disinterest is also manifested towards the more recent studies on the creation of the earth and the sea and on their role in human evolution. Nowadays, the human being seems more interested in researching the cosmos, the universe, than the little blue planet where s/he lives and on whose existence the life of the entire humanity depends, both at present and especially in the future.

In this conglomeration of views, we will stop at only one, not because we are fervent supporters of creationism, but because this is the only perspective whose "truth" is several millennia old and because it is fully confirmed, without exception, through the history of mankind. Many of the recent archaeological discoveries, revealed by the research conducted in the ruins of biblical cities, are represented by documents that coincide exactly with the narrative of the Bible, chapter by chapter, verse by verse, of its books, "Gospels" and "Epistles" (*The Bible –The New Testament,* "The Gospel of Matthew").[4]

During our research, God provided us with Henry Halley's *The Bible Handbook*, which represented an extremely important source of inspiration that we have valorized in order to present the creationist perspective and the Divinity's relationship with the sea. According to the above-mentioned author, if the Bible is the

[3]"For now we see in a mirror dimly, but then face to face; now I know in part, but then I will know fully just as I also have been fully known (by Christ n.a.)" (see *The Bible, The New Testament,* "The First Epistle of St. Paul to the Corinthians", ch. 13, verse 12, p. 1123).

[4]"Heaven and earth will pass away, but my words will not pass away" (our Saviour Jesus said out of the Temple in Jerusalem) (see *The Bible –The New Testament,* The Gospel of Matthew, ch. 24, verse 35, p. 953); Idem: Psalm 102, verses 25 and 26: "In the beginning you laid the foundations of the earth, and the heavens are the work of your hands. They will perish, but you remain; they will all wear out like a garment. Like clothing you will change them and they will be discarded". For more information, see also "The prophet Isaiah", ch. 51, verse 6; "Jeremiah", ch. 31, verse 35 and 36, "The Gospel of Mark", ch. 13, verse 31; "The Gospel of Luke", ch. 21, verse 23; "The Epistle to the Hebrew", ch. 1, verse 11.

"Word of God",[5] revealed to the human being, as we believe, and if God knew from the very beginning that we would use the Bible as a primary tool for the knowledge of His creation, including of the human being, then why is it hard to believe that the very Word generously provides us with the absolute truth, which underlies the evolution of human history? In our opinion, this is an unquestionable historical reality.

Of course, in the context of divine creation, we are interested in the creation of the sea, in the broadest meaning. However, logically thinking, the creation can be accepted only with the creation of land. Amazingly, in the first Book of the Bible, i.e. the Genesis, the first chapter, verse 1, states that: "In the beginning God created the sky and the earth". Thus, He created the universe. Regarding the creation of the other elements in the following 7 days of the "Genesis" (ch. 1, verse 1–31 and ch. 2, verse 1–24), the Bible describes the modeling of the already created substance, the preparation of the land and sea surface for the creation of the human being and for the provision of adequate living conditions (Mircea Eliade 1986).[6] The chapters dedicated to the creation of the universe, from the Genesis, should not be viewed through the prism of cold and dry "mathematical reason". The full and delightful harmony with the current knowledge of biology and zoology is delightful.

For the purpose of our study, we are interested particularly in verses 6–7 and verse 10 of chapter 1, the Genesis. In this context, i.e. the act of divine creation, the extension called "Heaven" refers to the atmosphere or to the air layer situated between the earth covered with water and the clouds above, which appeared when the earth (which was created on the first day) had cooled. Verse 10 of this chapter states that "God called the dry ground "land", and the gathered waters he called "seas." And God saw that it was good". Contrary to the presumptive and incomplete opinions of some "evolutionist" authors, the Bible confirms with certainty that the creatures of the sea were created by "God's Word", while the man was made from dust, and God breathed into his nostrils the "breath of life". The Man, the superior being of creation, was honored by God, being made in "God's image and likeness" (Genesis, chapter 1, verse 24).

In the perfection of His creation, God said, "Let the land produce vegetation: seed-bearing plants and trees on the land that bear fruit with seed in it, according to their various kinds. And it was so. The land produced vegetation: plants bearing

[5]A widespread conception in the intellectual world, that remains even nowadays, is that the Bible is like a centuries-old story about the man's efforts to find God, arising from the experience of previous generations. At present, the confirmation of each event described in the Bible leads us to conclude that this grandiose and undeniable "book" is not a record of the man's efforts to find God, but, more exactly, God's desire to reveal Himself to man. He reveals His Will to humanity, given to the human being by the Creator Himself for science, education and guidance on the path that we need to follow in life, for our own good and eternal life, as designed since the creation (See Henry Halley 1924).

[6]According to the biblical chronology, the creation of the man took place around 4000 BC, but the universe was probably created a long time before (see Mircea Eliade 1986).

seed according to their kinds and trees bearing fruit with seed in it according to their kinds" (Book of Genesis, chapter 1, verse 11–12). Then, noting the perfection of His creation ("i.e. good"), God blessed them and told them: "Be fruitful and increase in number and fill the water in the seas..." (Book of Genesis, chapter 1, verse 20–22).

All these emphasize God's infinite wisdom (which could only be of divine nature) wherewith He carried out His great and perfect process of creation. The progression of this process is noteworhty: the first and the second day, the lifeless things were created; the third day, the plants were created and the fifth day, the animals were created (Henry Halley 1924). Through His act of creation, God establishes a perfect order, transforming the "chaos" from the edge of the galaxy, i.e. the Milky Way, into a small blue planet, expression of the necessary conditions for the existence of life. Every day of His creation, God put the universe in perfect order (*The Bible, The Old Testament,* the Genesis).[7]

Nevertheless, the Man's fall into sin (from the most wonderful and cozy place of God's creation – the Garden of Eden) led to the deterioration of his/her relationship with God. It started as a "chain disorder", as an existential change, as a new existential knowledge, characterized by a negative state (affective inversion), by a defensive emotional reactivity, by a harsh judgment against the fallen woman, a judgment on the man, a judgment of the earth (Ștefan Gae 2014).[8]

Referring to the top step (the sixth day), when God created the man, we often ask ourselves the question of how do we honor the Creator, Who gave us the mandate to master, work and keep His whole creation? In other words, to be good administrators. The tree of knowledge of good and evil, whose fruit was forbidden to the human being, and whereby, nevertheless, the man disobeyed and committed the original sin, was an expression of God's full authority. Only God, as a creator with the right to full ownership over all things, including biological life, had and currently has a divine and unimpeded right. We, humans, are granted only the other two legal attributes of ownership, i.e. possession and rational use (keeping). How ignorant or wrong we are when we consider ourselves as human beings with the right to full ownership! (We do not mean the absolute right of property, in a legal sense). In this regard, our Savior Jesus Christ wonderfully draws our attention on these things in one of His parables, i.e. "The Parable of the Rich Fool" (*The Bible, The New Testament,* "The Gospel of Luke").[9]

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[7]"God saw all that He had made, and it was very good" (See *The Bible, The Old Testament,* "The Genesis", ch. 1, verse 31, p. 2).

[8]In God's creation there is similarity between spiritual structures and structures of matter, between the spirit and the laws governing matter. In light of this similarity and the application of entropy in order to explain society, people in their behavior, their financial status, laws, show that all acts are governed by the same law – the law of Entropy (Ștefan Gae 2014: 117).

[9]"But God said to him, 'You fool! This very night your life will be demanded from you. Then who will get what you have prepared for yourself?' This is how it will be with whoever stores up things for themselves but is not rich toward God" (*The Bible, The New Testament,* "The Gospel of Luke", ch. 12, verse 20 and 21, p. 1005).

Neverthelss, the great danger to the world today, which is also the result of our poor administration of God's Creation, is obviously represented by pollution (Florica Brasoveanu 2016).[10] Since 1975, the United Nations Organization drew our attention to marine pollution, launching "The Blue Programme" for the protection of the Mediterranean Sea. Moreover, in one of its reports, the international environmental organization "Greenpeace" notes that, since 1945, over 1,000 accidents have taken place. Thus, all kinds of vessels with oil and various other charges, and even submarines with nuclear missiles, sinked, affecting sea waters (Florica Brasoveanu 2014: 76). Such an instance is represented by the Baltic Sea, where extremely harmful chemicals were discharged from the industry of riparian countries. Only within a year, over 70 thousand tons of phosphorus, 15 thousand tons of heavy metals and 250 thousand tons of chlorine were discharged into the sea. Over 400 thousand tons of hydrocarbons are discharged into the North Sea every year. Last, but not least, the Black Sea also represents one of the most obvious examples of pollution, where it was found that 90% of its waters are affected by this phenomenon, life being possible only to the depth of 80 m (Florica Brasoveanu 2013: 54).

All these instances reveal how God's immaculate creation is defiled by the human being itself, even at the expense of the life and health of the entire planet and, especially, at the expense of our very existence. Furthermore, as we may notice, the picture becomes even darker. God must have known beforehand what would happen and He must have planned His entire work, including human incarnation and the glorious world that will follow at the end, as shown in the last chapter of the last book of the Bible, i.e. the Book of Revelation. This should make us think about our prospective choices: the ephemeral life on a fleeting earth or the eternal life. In this respect, the Bible might help us decide knowingly.

1.3 The Sea in the Fulfillment of the Divine Creation Plan

The entire Divine Creation Plan, revealed by God in the Scripture, takes place and ends with the human being's redemption, through Christ's sacrifice and resurrection, which is an undeniable event, a historical reality confirmed daily in the complex process of the evolution of nature, society and humanity, in general. God created the human being for the purpose of living forever, with one condition: to obey Him. But the human being failed from the outset, miserably.

God designed and perfected a beautiful world, but the heavy burden of the earth, toil, pain and death fell upon the human being. In His infinite love towards His

[10]Marine pollution means the introduction by humans, directly or indirectly, of substances or energy into the marine environment, such as damage to biological resources, fauna and marine life, hazards to human health, hindrance to maritime activities, including fishing and other legitimate uses of the sea, impairment of the sea quality in terms of its utilization (Florica Brasoveanu 2016).

creation (*he Bible*, *The New Testament*, “The Gospel of John”)[11] (the man mainly), He sacrificed Himself, bestowing “Himself”, through His Beloved Son (*The Bible*, *The Old Testament,* “The Gospel of Luke”).[12] From the very beginning, in order to reveal and to accomplish His perfect plan, God chose a “Messianic” people, i.e. the Hebrew people, with a monotheistic faith, but who were sometimes unstable in their beliefs (being influenced by the deities of the neighboring peoples), and who were often disobedient. This also explains the GENERALIZED SEA – THE FLOOD!

However, in time, God prepared the right people, such as Moses, that would carry out His work. Moses was a great leader and organizer, implementing God’s salvation plan through His people. He wrote most of the Pentateuch,[13] benefitting from a good education and from the best living conditions, in a society with an advanced culture, miraculously prepared by God. Due to the author’s erudition and to the authenticity of its sources, the Pentateuch has become more and more respected. This is entirely explained and justified by the use of previous documents of old and sacred nature and, therefore, Moses did not amend or affect their integrity.

“The Generalized Sea” or The Flood is viewed, from our perspective, based on the Bible, as the sovereignty of God’s punishment (the Creator – the supreme judicial authority – intervenes, for a limited time period, in order to discipline the man who turned away from God’s perfect plan, ordained by Him just for the man’s sake, for the ultimate goal of salvation and eternal life. The man’s wickedness on earth was great and “every inclination of the thoughts of the human heart was only evil all the time” (see *The Bible*, *The Old Testament*, The Genesis, ch. 6, verse 5, p. 6). Abnormal marriages, triggered by lust and not by the traditional rules “enacted” by God, and the land filled with hatred and violence grieved God’s heart, making Him regret that He had created the man on earth (see *The Bible*, *The Old Testament*, The Genesis, ch. 6 verse 11 and 12, p. 7).

Jesus likened the time of His return on earth with the flood (*The Bible*, *The Old Testament,* “The Gospel of Matthew”)[14]: the phenomena that take place at present with the same destructive force of the people; the alarming official statistics on divorce cases; the breach of social life regulations (especially the increasing

[11]“For God so loved the world that he gave his one and only Son, that whoever believes in him shall not perish but have eternal life” (*The Bible*, *The New Testament*, “The Gospel of John”, ch. 3 verse 16, p. 1028).

[12]“. . .and the Holy Spirit descended on him in bodily form like a dove. And a voice came from heaven: “You are my Son, whom I love; with you I am well pleased”.” (*The Bible*, *The Old Testament,* “The Gospel of Luke”, ch. 3, verse 22, p. 990).

[13]The Genesis and the following four books of Moses are part of a number of five books known as *Moses’ Pentateuch*.

[14]“As it was in the days of Noah, so it will be at the coming of the Son of Man. For in the days before the flood, people were eating and drinking, marrying and giving in marriage, up to the day Noah entered the ark; and they knew nothing about what would happen until the flood came and took them all away. . .” (*The Bible*, *The Old Testament,* “The Gospel of Matthew”, ch. 24, verse 37–39, p. 953).

number of violent crimes); the demographic indicators expressing the true quality of life; the human being's morality and aggressive behavior towards the whole divine creation – all these make us wonder whether the time has come.

The description of the flood – the imaginary force of the waters which even today manifest in seas and oceans with the same power – is impressive. The gates of heaven and the fountains of the deep were opened. All the high mountains under the heaven were covered and all the flesh that moved on Earth perished (see *The Bible*, *The Old Testament*, The Genesis, ch. 7, verse 10–24, pp. 7–8). The waters grew increasingly larger and Noah's boat, built as God had commanded him, began to float. Every living thing on earth was wiped out from the Earth's surface: from humans to cattle; from creeping creatures to birds… all perished. Noah and his family, together with the beings and creatures saved in pairs, as God had commanded, stood in the ark 1 year and 17 days; they floated on water 5 months and they spent other 7 months on the vessel deck.

In line with the topic of our work, we can say that Noah was the first "sailor". Let us remember, however, that this profession, with its inherent roughness, requires courage, skill, and a great variety of knowledge. Noah had a special character. He was, as the Bible tells us (Book of Genesis, Ch. 6, verse 9) "a righteous man, blameless among the people of his time, and he walked faithfully with God", as many Cristian sailors do nowadays.

Without going into the scientific details of the rainbow that streaked the sky with its fascinating color at the end of the flood, we may state that, for the entire humanity, according to the Bible, it represents a sign of divine covenant. By it, God promised that there will not be other flood (Genesis, chapter 9, verse 8–17). Therefore, in human history, even without knowing its biblical meaning, the rainbow always produces within the human being a feeling of optimism, unchained joy, and peace. However, unfortunately, the following destruction of the Earth will take place by fire (*The Bible*, *The Old Testament,* The Second Epistle of Peter).[15] But that hour is known only by God, the Father, Who keeps His own time measure, as a mystery.[16]

Without seeking to go deep into the research of the origin and existence of the flood, we will list only the universality of this tradition in the myths of many peoples: the Babylonians, the Assyrians, the Egyptians, the Persians, the Hindus, the Greeks, the Chinese, the American Indians, the Brazilians, the Peruvians and even the Eskimos. All these peoples have information about a great flood that

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[15]"But the heavens and the earth which are now, by the same word are kept in store, reserved unto fire against the day of judgment and perdition of the ungodly men" (*The Bible*, *The Old Testament,* "The Second Epistle of Peter", ch. 3, verse 7, 8 and 10, p. 1198).

[16]"But of this one thing be not ignorant, my beloved, that one day with the Lord is as a thousand years, and a thousand years as one day" (*The Bible*, *The Old Testament,* "The Second Epistle of Peter", ch. 3, verse 8).

"But the day of the Lord shall come as a thief, in which the heavens shall pass away with great violence, and the elements shall be melted with heat, and the earth and the works which are in it, shall be burnt up." (*The Bible*, *The Old Testament,* "The Second Epistle of Peter", ch. 3, verse 10).

destroyed all mankind, except one family. Such a universal concept, which is rooted in the traditions and origins of many peoples, must be based on a historical fact, and not on an instinctive one. The civilization underneath the flood is so different from the one above it that many researchers, starting with C. L. Wooley, following deep excavations, concluded that there was a sudden and terrible interruption in the continuity of human history (Leonard Woolley 1929).

It is interesting to point out, however, without invoking concrete evidence, because they have been lost over the years due to some events, that Noah's ark was discovered, as stated by some publications from the past (in this respect, see "Russia: Suspicion On The Mountain, Time Magazine, 25 April 1949"; Bob Rickard and John Michell 2000; Eric H. Cline 2009). Thus, shortly before the 1917 revolution, the first news appeared in the press of that time, claiming that some Russian researchers would have noticed a huge vessel in the heights of the inaccessible glaciers on Mount Ararat. Although they would have reported this finding to the Russian government of that time, this information was not harnessed; on the contrary, it was lost in the mists of the revolution.

Next, we will refer briefly to some of God's miracles, where He used the sea and the people chosen and prepared by Him in order to fulfill His plans. However, we will place a special emphasis on only two of these events (where the sea played an important role), which took place in the early days of mankind, and which are described in the Old Testament of the Bible. These events also play a central role in Torra.

The biblical accounts show us the sufferings and the oppression undergone by the Hebrew people in 400 years of Egyptian slavery, especially after Joseph's death, under Pharaoh Amenhotep II, followed by Thutmose II. Meanwhile, the birth rate of the Hebrew people increased, although they were subjected to the hardest works specific to the grandiose constructions of those times and to field labor (farming the valley of the Nile, with two harvests per year, required great efforts). Nevertheless, the more oppressed the Hebrew people was, the greater their birth rate (*The Bible*, *The Old Testament*, The Book Exodus; The People of Israel in Egypt, ch. 1, verse 12). In order to prevent the increased share of the Israelites, the Pharaoh ordered (*The Bible*, *The Old Testament*, The Book Exodus; The People of Israel in Egypt, ch. 1, verse 22) to throw the boys into the river Nile and only the girls were kept alive.

The time had come for God's intervention. In order to protect His people, God chose a well-equipped man, prepared in advance with extensive knowledge, intelligent and educated, able to lead his people in those times of crisis. Moses's birth and salvation story (*The Bible*, *The Old Testament*, The Book Exodus, ch. 2, verse 2–10) is obviously exciting and miraculous; this made us grasp it in our work, even at the risk of its exhaustive nature.

In those extremely difficult conditions dealt with by the people of Israel, a woman from Levi's house (future ministers at the temple), conceived and bore a handsome son. In order to avoid him being killed, she hid him for 3 months. But his life was in danger. In order to save him, she made a "rush casket", well isolated with clay and pitch, and placed it among the reeds on the banks of the Nile. The baby's sister was lurking nearby, to see what would happen, and to intervene if necessary. Thus, God continued His perfect plan to rescue the people of Israel. The Pharaoh's daughter, who came down to the Nile to bathe, heard the baby crying. The girls who accompanied her saw that he was beautiful, born of the people of Israel. They needed a nurse to breastfeed him. Was his sister (who was nearby) called by accident? In turn, did she call the child's mother incidentally? Definitely not! The child was brought to the Pharaoh's daughter, who adopted him as her own son. Thus, Moses, besides the special education that he received at the Pharaoh's court, grew up in the tradition and faith of the Hebrew people. The Pharaoh's daughter named him Moses, which means "taken out" of water. However, in reality he was God's messenger (*The Bible*, *The Old Testament,* Paul's Epistle to the Hebrew, ch. 11, verse 23–27).

Moses is the most prominent man of the pre-Christian period. An entire life lived in different environments opened him new horizons. He spent 40 years at the Pharaoh's palace, as the adopted son of the famous queen Hatseput, with real chances to become the heir to the throne. The formation of his strong personality continued by another 40 years spent in the wilderness, in solitude; the harshness of his life as a pastor developed in Moses the traits of a consistent warrior and familiarized him with the harsh conditions of the desert, where he would lead the Hebrew people for another 40 years. Although he was commissioned directly by God to deliver the people of Israel, at the age of 80, we notice that He oscillated invoking all sorts of reasons. However, being assured of divine help, and being granted the power to work miracles, in the end, he left the desert and went to Egypt, where he met with his brother Aron and they went together to the Pharaoh.

Insisting in front of the Pharaoh, telling him that the God of the Jewish showed Himself and asked them to obey His voice, they asked: "Now let us take a three-day journey into the wilderness to offer sacrifices to the LORD our God" (*The Bible*, *The Old Testament,* The Book Exodus, ch. 5, verse 3). The perky and ruthless Pharaoh commanded the supervisors at the Israelites' workplace to worsen their working conditions, requiring them to produce the same number of bricks, without providing them the necessary straw. Moreover, he banished the officers of the people of Israel who went to complain, insulting them: "You are lazy!" Moses was disappointed; he turned to the Lord and asked: "Why, Lord, why have you brought trouble on this people? Is this why you sent me?" (*The Bible*, *The Old Testament,* The Book Exodus, ch. 5, verse 15, 17 and 22). Even nowadays, we behave like Moses. When God tests us, in order to prepare us for a work, we get discouraged at the first hurdle. In our opinion, in such moments, it would be a good idea to remember King David's famous "song": "Even though I walk/through the darkest valley,/I will fear no evil,/for you are with me;/your rod and your staff,/they comfort me" (Psalm 23, verse 3 and 4).

From that moment on, God began to carry out the liberation process of the people of Israel from the Egyptian slavery that had lasted 400 years, as He had decided in advance. The Pharaoh's disobedience and the hardness of his heart triggered ten plagues known and confirmed by human history, mostly by archaeological discoveries. The ten plagues were aimed against the gods of Egypt, in order to prove God's power against those lifeless deities, and to show His strength, the intervention of the Pharaoh's magicians being useless in front of God's miracles. The brief enumeration of those ten plagues will be accompanied by only a few lapidary explanations.

We might say that they represent the "overture" of God's great miracle: the Crossing of Red Sea, the final act of a complex nature, both protector and savior of the Hebrew people, on the one hand, and punitive and disastrous for the Pharaoh and his army, on the other hand. The historical documents (J. Ashton and D. Down 2006; D. Rohl 1995) mentioning this miracle, when the sea was God's main working tool, are true and impossible to refute. It is assumed that the crossing took place near the present-day Suez Canal. It is obvious that this miracle can be explained by its supernatural deployment. The waters were like a wall and it means more than a mere defense of the Hebrew people. There is no need to assume that there were vast amounts of water that defy the laws of gravity. The waters stood, like a perpendicular wall, on both sides. The Israelites went through the sea, on dry land (Book of Exodus ch. 14, verse 22 and ch. 15, verse. 12). This was a great miracle for those fleeing to save their lives. In these circumstances, they felt fully the hand of God, their Savior.[17]

For the first time, the sea, cradle of divine creation, was a working tool for the majestic perfection of God's plans, with a strong echo across the centuries. Looking at Moses and at the Red Sea, we express our admiration and gratitude that we have a great creator – a Father – Who leads the entire universe. Before concluding this part referring to one of the most wonderful and complex micracles of God's plan, we want to emphasize the fact that He used the sea (the stretch of water of His creation) in order to show His greatness, to make known His Word and Will, and especially His borderless forgiveness and kindness towards people. We also want to turn for the first time to the Mediterranean Sea, and, in the course of our paper, we will

[17]As described by the Scripture, the ten plagues were against the Egyptian gods:

(a) The first of the ten plagues turned the Nile waters into blood; the fish died, people could not drink water. The Nile was considered a god. Of the Egyptian deities, the bull was the most sacred animal, while the crocodile was reviled.
(b) The plague of frogs, lice and flies. The frog was also considered a god.
(c) The cattle plague, the black smallpox. It is significant that all the cattle of the Egyptians died, while almost none of the Israelis. Sores have covered both people and animals, and even the wizards.
(d) Locusts and darkness – this was one of the worst plagues; the insects ate everything. The work of God's hand is obvious: "Darkness" was a direct blow given to "Ra", i.e. the great god of the Egyptian Sun.
(e) The death of the firstborn. This plague was turned including against the Pharaoh's firstborn. Almost a year had passed since the crisis. The Pharaoh reluctantly gave in and the people of Israel could leave. Interestingly, with their departure, the decline of Egypt began. The Red Sea would be the one that would bring it down permanently. God can not compromise. The heart must be entirely given to the Lord. Emperor Asa would go through a bitter experience later in the 39th year of his reign (2 Chronicles, ch. 16, verse 12 and 13).

return to this topic because of its important role in the spread of Christianity and in strenghtening Christ's Church.

The Book of Jonah, from the Old Testament, describes a series of miracles that occur either on Mediterranean waters or in its coastal cities. This time, God used Jonah, who was a native and lived in a city, not coincidentally, near Nazareth, where Jesus was born. He was apparently a prophet recognized at Jeroboam's court, a personality in Israel. One day, he heard God's voice, Who sent him to Nineveh, the capital of the Assyrian Empire (900–607 BC). At that time, Nineveh was a thriving city, when the empire was increasingly recognized as a world power.

The Jews were highly conservative, believing that only them, the chosen people, belong to God. Our Jonah did not want to go and preach God's word to a sinful, unfaithful people. On the other hand, he knew that God is slow to anger and abounding in love, and if they returned from their evil way, He would forgive them. His goal was to save people at all costs. Thus, He would be placed in an unpleasant situation. Thus, our Jonah, instead of going to the north, to Nineveh, went to the opposite direction, towards the West, to the city of Tarsus, in distant Spain (it is assumed that it was the old Tortesseus fortress). He paid the voyage fare and boarded on the ship that was sailing towards Tarsus, along with other passengers (*The Bible*, *The Old Testament,* Jonah, ch. 1–4). Then, God began to make full use of the sea, with the creatures that had populated it since its creation. It seems that Jonah either did not read the Psalms of David or he did not master their teachings. He, as a great prophet, should have known that he could not hide from God (*The Bible*, *The Old Testament,* Psalm 139).[18] Nevertheless, he was calm after he had stepped on the boat and fell asleep. God stopped Jonah from his rebellious running through the storm aroused by the sea. His miracles succeeded one another, making God's intervention evident by their deployment and purpose.

The storm was getting stronger and the ship was about to sink. The helmsman went to Jonah and woke him up. They casted lots to find out who was the cause of this evil that had come upon them, and, not by chance, the lot fell upon Jonah. The men knew that he was fleeing from the Lord because he had told this himself. Frightened, they reproachfully asked him: "Why have you done this? What should we do in order to calm the sea?" He answered them: "Take me and throw me into the sea". Once they threw him, miraculously, the storm stopped. Another miracle is represented by the fact that when Jonah came to the sea, a fish was there, ready to catch him. The miracle was that the fish, although very large, could not stand Jonah in its belly and threw him away, not in the sea, but right on the seashore. We are dealing with a God Who is the creator and master of the entire nature, including the sea. He may prepare the storm and the whale and all the other things, where He wants them to be (Iosif Țon 2004: 330–331). After this harsh lesson of obedience

[18]"O Lord, thou hast searched me, and known me (...) If I take the wings of the morning, and dwell in the uttermost parts of the sea; Even there shall thy hand lead me, and thy right hand shall hold me" (*The Bible*, *The Old Testament,* "Psalm 139", verses 1, 9 and 10).

(it is almost impossible to resist into the whale's belly for 3 days without God's help), after He had saved him, God sent the prophet for the second time to Nineveh.

The result of Jonah's preaching was represented by the Ninevites' repentance, but also by the prophet's wrath, who saw his people's enemies escaping from divine punishment. After completing his mission, Jonah went out of the city and sheltered under a gourd that would give shade, in order to pass his wrath. The next morning, God made the gourd dry and Jonah got angry. Then, the Lord rebuked him because, in his anger, he wished to die. Then, God's generous answer followed, in which He expressed His love for the people from Nineveh, who had repenteded, and whom He forgave: "You have been concerned about this plant, though you did not tend it or make it grow. It sprang up overnight and died overnight. And should I not have concern for the great city of Nineveh, in which there are more than a hundred and twenty thousand people. . ." (Jonah, ch. 4, verse 10 and 11).

As several Christian authors stated in their writings, because of the story of the great fish, the unbelieving mind does not want to accept this miracle as a reality, considering it as an allegory or fiction. However, the divine nature of the book of Jonah, written in old age, is confirmed by a series of arguments, both in content and form.

Jesus's refferences to the Book of Jonah are likely to convince us that he really existed and that his experience was real (*The Bible*, *The Old Testament,* "The Gospel of Matthew").[19] For those who doubt the veracity of this miracle, the historical reality of the story is confirmed by another comment made by Jesus in "The Gospel of Luke", chapter 11, verse 32, in the New Testament: "The men of Nineveh will stand up at the judgment with this generation and condemn it, for they repented at the preaching of Jonah; and now something greater than Jonah is here".

In other words, if it were not for this miracle, the people of Nineveh would have remained impassive at Jonah's preaching. However, there are indications that, after this time, Nineveh experienced a series of reforms that led to a peaceful and thriving social life, and ultimately to economic prosperity. God never owes anything to anyone, He always forgives and blesses the ones who obey Him.

1.4 The Sea, a Working Vessel, a Testimony and Hope of Humanity

As shown in the second part of this paper, after the man's fall into disobedience, God, as a good and loving parent, decided to always guide our steps towards light, righteousness and truth. As human history shows God's punishments are limited in

[19]". . .He answered, "A wicked and adulterous generation asks for a sign! But none will be given it except the sign of the prophet Jonah. For as Jonah was three days and three nights in the belly of a huge fish, so the Son of Man will be three days and three nights in the heart of the earth" (*The Bible*, *The Old Testament,* "The Gospel of Matthew", ch. 12, verse 39–40).

time and space and they always have an educational purpose and a moral and spiritual recovery. God's revelation of "Self", His revelation to the being that He created, is gradual and progressive, and its essence and ultimate goal is represented by Jesus Christ, "His beloved Son", the hope of our salvation and eternal life.

This process had been revealed in perspective by God centuries before these events occurred, by the prophecies of the Scriptures.[20] The exact "dynamism" of their fulfilment is impressive: all the facts, all the details, all the prophecies made centuries before Jesus's arest and trial by the Sanhedrin and Pilate, His condemnation, crucifixion and resurrection from the dead, even the preparation of His tomb. Who could have intervened in these circumstances? The disciples forsook Him; Peter denied Him; Judas Iscariot betrayed Him; the Pharisees and the crowds that went before the cross of Calvary mocked Him (*The Bible, The Old Testament,* The "Book of Prophet Isaiah").[21] Moreover, the Sanhedrin (the Jewish Supreme Court at the time) asked Pilate to strengthen the measures to guard Jesus's tomb. Obviously, the one who watched the progress of the mankind rescue plan could be only one PERSON, i.e. GOD! What a miraculous and delivering medicine for our faith, whether weak or sick!

By studying the four "Gospels" in "The New Testament" of *The Bible*, we may notice again the role that God had reserved to His great and fascinating creation, i.e. the sea. Its mysteries (some still murky), its rich flora and fauna, its phenomena and whims that are unmanageable by the human being reveal a generous Creator, Whose kindness is infinite. One of the most glorious roles played by the sea is represented by the one where it revealed the Deity of Saviour Jesus Christ – Who incarnated as a man, in order to get to know us fully, with our joys, victories, sorrows and temptations and Who always interceded as our defender.

We will stop to only three of these miracles.

(A) Our Savior Jesus Chist often withdrew, alone, to the mountain, and, in fellowship with the Father, He would establish the course of His work on Earth. One of the most important was the choice of the Twelve Disciples, who would disseminate the Word of the "Gospel" and His teachings worldwide (*The Bible, The New Testament,* "The Gospel of Mark").[22]

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[20]In order to fully understand the prophecies of "The Old Testament", it is necessary to preserve their Hebrew nature also for the other people that came into contact with the Hebrew people throughout history.

[21]Isaiah was chosen in order to give the world the brightest book of prophecy. Isaiah is to prophecy what Shakespeare is to literature, Michelangelo to sculpture, Bach to music, the quality of his writing rising above the other prophets (See *The Bible, The Old Testament,* "The Book of Prophet Isaiah", ch. 53, verse 1–2, p. 725, written about 700 years BC).

[22]"Jesus went up on a mountainside and called to him those he wanted, and they came to him. He appointed twelve that they might be with him and that he might send them out to preach" (What obedience to the Father! Among them, He also chose Judah, whom He knew that would betray Him, in order to fulfill the Scriptures) (*The Bible, The New Testament,* "The Gospel of Mark", ch. 3, verse 13–14).

"The Sea of Galilee".[23] Simon, a famous fisherman, was packing up his fishing gear. He had got up early in the morning, when it had not been dawn yet, to cast his nets, but he caught nothing. Being a good professional and a strong character, he watched and grieved, as if with enmity, the blue and peaceful waters that seemed to have hidden the fish in their depths. Suddenly, he saw someone from afar approaching the place where he was standing. When that person got closer, he recognized his brother, Andrew, a disciple of John, the prophet from the wilderness. He embraced him happily and kissed him, asking him what he was doing on the seashore. Andrew's face was beaming with joy, as he said: "We have found the Messiah (which, translated means Christ)" (*The Bible, The New Testament,* "The Gospel of John", ch. 1, verse 41).

"The Gospels" do not tell us what was in Simon's heart. However, we think that, when he heard about God's Messiah, promissed by our Creator and expected to deliverer the Hebrew people, the hope revived in his heart and he left the nets that he was struggling to repair, the ark and his friends, and went with Andrew. Being brought to "Messiah", Jesus looked at him and told him: "Thou art Simon the son of Jona; Thou shalt be called Cephas (which means Peter)" (*The Bible, The New Testament,* "The Gospel of John", ch. 1, verse 42).

Then, the turn of the sea came to demonstrate, by undeniable facts, that Jesus Christ was the Lord, the Son of God. A little later, Simon Peter complained to Jesus that he had labored all night with his companions and that they had caught nothing. At Jesus's request, Peter sailed the ship away from the shore and he cast the nets again, although he did not hope to catch something (now it was too late, the sun had risen recently in the sky, and he was well aware of the secrets of his trade). After they had thrown the nets, they fished so many fish that their nets began to break, and their ships began to sink. His professional pride being affected and also ashamed by his attitude and weak faith, scared, Simon Peter threw himself at Jesus's feet, in tears, saying, "Lord, depart from me because I am a sinner" (*The Bible, The New Testament,* "The Gospel of Luke", ch. 5 verse 5–8). This fisherman, who could write, but who was not educated at the high schools of the antiquity, after three and a half years of experience with his Master, years of victories and failures, would write two "Epistles" of special beauty and spiritual value.[24]

We tried to reveal that, by means of the sea, the human being experiences feelings and aspirations, seeded in his/her heart from the very beginning by the Supreme Creator, God. Peter, a seaman, was, in fact, among the first called to be Jesus's disciples. Since the beginning of his discipleship, Jesus promised that he would be "a fisher of men". Willing, but often wrong, he was reprimanded and

[23]"As Jesus was walking beside the Sea of Galilee..." (see *The Bible,* "The Gospel of Matthew", ch. 4, verse 18).

[24]For instance, *The Bible, The New Testament,* "The First Epistle of Peter", ch. 2, verse 9, states: "But you are a chosen people, a royal priesthood, a holy nation, God's special possession, that you may declare the praises of him who called you out of darkness into his wonderful light". Idem, "The Second Epistle of Peter", ch. 3, verse 13, p. 1198: "But in keeping with his promise we are looking forward to a new heaven and a new earth, where righteousness dwells".

encouraged by the Lord. He was always among the first disciples. He was among the fishermen who, upon Jesus's call, immediately left their boats and fishing gear, and got to be part of the Savior's "intimate group". He always acted as a spokesman for the twelve disciples. Peter never had a blind faith. He witnessed the Saviour's work and he referred questions when the disciples were confused and did not understand Lord's work. His initiatives originated in his true heart, but with a limited thinking, typical of the human being, with natural solutions and resolutions in a spiritual context (for instances in this respect see *The Bible, The New Testament,* "The Gospel of Mark").[25]

We conclude this first illustration by asking ourselves: what would we do today if our Savior Jesus Christ called us to follow Him? Would we leave "immediately" our material goods, as Peter and his friends fishermen did? Would we leave our houses, cars, forests, lands and other material values, in which we place all our hopes, in this transitory life on earth? Of course not! We believe that they represent the safety of a prosperous life on Earth and a secure future (*The Bible, The Od Testament,* "The book of Deuteronomy").[26]

(B) We are facing the sea again. Jesus got down from the mountain, where he had chosen, in the morning, the twelve disciples, to accompany Him and to send them preach the Scriptures, giving them the power to heal the sick and those possessed by the devil. After He had met His relatives (who, in their disbelief, said that "He had gone crazy"), He talked with the scribes who had come down from Jerusalem, accusing Him of casting out devils, working miracles helped by demons (Beelzebub). After He had confronted them with logical and undeniable arguments (*The Bible, The New Testament,* "The Gospel of Mark"),[27] He headed home. Here, many people had gathered and He could not have lunch. Thus, He hoped that He could rest on the seashore. He was followed by the crowds and He began again to teach them. He sat in a boat on the sea and all the people stood on the shore and listened to Him. He taught them many things, speaking again in parables.

In the evening, after he had dismissed the crowd, Jesus asked his disciples, who were accompanying Him, to get to the other side. A great storm began and the large

[25]Peter, after seeing the glory of our Savior Jesus Christ, on Mount Tabor, when He transfigured and His clothes became dazzling white and there appeared before them Elijah and Moses, who were talking to Jesus, in his natural and naive enthusiasm, full of dread, he said "Rabbi, it is good to stay here. Let us make three tents: one for you, one for Moses and one for Elijah". Peter had not matured spiritually, he still needed experience (*The Bible, The New Testament,* "The Gospel of Mark", ch. 9, verse 2–5).

[26]"You may say to yourself, "My power and the strength of my handshave produced this wealth for me." But remember the Lord your God, for it is he who gives you the ability to produce wealth…" (*The Bible, The Od Testament,* "The book of Deuteronomy", ch. 8, verse 17 and 18).

[27]"So Jesus called them over to him and began to speak to them in parables: "How can Satan drive out Satan? If a kingdom is divided against itself, that kingdom cannot stand" (*The Bible, The New Testament,* "The Gospel of Mark", ch. 3, verse 23 and 24).

waves almost filled the boat with water. The boat was tossed by the sea and the disciples were terrified, but Jesus was sleeping peacefully. How much we would like to know the inner processes and the powers whereby His word quieted the raging sea waters! However, this happened only after the disciples came to Him and awoke Him, shouting desperately: "Lord, save us, we perish!" Jesus scolded His disciples by asking them: "Why are you afraid? Where is your faith?" The people in the boats that went with them at sea and those who were with the disciples in the boat were amazed and said "what man is this, whose command calmed and obeyed the winds and the sea?" (*The Bible, The New Testament,* "The Gospel of Luke", ch. 8, verse 23–27). The peace, the silence took over the world after the storm; the sea waters, tamed and docile, were carressing the shore.

I look now to the distant past of my childhood, when at the age of 7–8 years I was rescued from drowning by a strong arm. Then, like the disciples, I cried desperately to people to save me. And I was saved (as I would find out later) by God's strong arm. If I were to go through the storms of life, no matter how powerful they may be, I would no longer be afraid. The Lord is with me and, if I am in danger, I will call Him with faith and I will certainly be saved. He is faithful and, as He promised us, "I will never not leave you" (*The Bible, The New Testament,* "Apostle Paul's epistle to the Hebrew"), as He is the beginning and the end, at the crossroads of our history (Giovanni Papini 2012). [28]

(C) The miracle of the multiplication of bread shows us that the disciples needed a harsher lesson of faith, but full of wisdom.

Jesus was near the eastern shore of the Sea of Galilee,[29] not far from where the Jordan River flows into the sea. The Hebrew Easter was approaching, the crowds went up to Jerusalem to offer sacrifices at the temple. This time, Jesus did not go to the "Holy City". He celebrated the Easter by performing two of His greatest wonders, closely connected to each other; therefore, we will describe them together.

When Jesus got out of the boat, He saw that he was greeted by a large crowd. He was moved with compassion for them, because they were like sheep without a shepherd, and He began to teach them many things again. The day was almost over and the disciples came to Jesus and told Him that the place was desert. They asked Him to send the people away, to go into the country and to the surrounding villages to buy bread because they had nothing to eat. Jesus watched them, we think, with love and curiosity, as one watches his/her children, and He told them, as if smiling: "You give them something to eat". How surprising was the disciples' response and how similar, under those circumstances, with ours: "Shall we go and buy bread for two hundred lei and give them to eat?" (*The Bible, The New Testament,* "The Gospel of Mark",

[28]"Let your manners be without covetousness, contented with such things as you have. For he hath said: I will not leave thee: neither will I forsake thee" (*The Bible, The New Testament,* "Apostle Paul's epistle to the Hebrew", ch. 13, verse 5).

[29]The Sea of Galilee has a length of 25 km and a width of 11–12 km. It is 207 m below the sea level. Its lively shores knew a particular trade and economic development. There were ten cities on its shores, with a population of almost 15,000 each.

ch. 6, verse 34–44). It had been almost 2 years since they were together with the Lord, and they had seen so many miracles, they had heard so many parables and teachings, but they did not realize that the solution for any situation was always Jesus Himself. A prayer of faith would have been enough (and this would also be sufficient in contemporay crisis situations). We trust people, we trust our strength and discernment, we use the material values we hold and only when we fail we cry out to the Lord in tears. Seeing their confusion, Jesus took the initiative and asked them to go and see how much bread they had. They went and saw that they had only five pieces of bread and two fish. After Jesus had blessed them, lifting His eyes towards the heaven, He gave the bread and the fish to the disciples and asked them to share the food among the five thousand men, not counting the women and the children.

By reading the "Gospels", we notice that God liked order very much. He asked the people to sit down in groups of 50 and 100 ("The Gospel of Mark", ch. 39–40), around him. They all ate and were satisfied, and, at the end, they gathered twelve baskets of bread crumbs. It is noteworthy that waste was not done ("The Gospel of Luke", ch. 9, verse 17).[30]

John described the immediate effect of this miracle: when they saw what Jesus had done, the people said that He was truly the prophet that they had expected and they wanted to enthrone Him King ("The Gospel of John", ch. 6, verse 14–15). How ephemeral the human enthusiasm and gratitude are! Probably, also around the Easter preparation, many of them would be among those who would cry before the judgment seat of the Galilee procurator, Pontius Pilate, to Crucify Him, lying about Jesus and uttering a terrible oath, in order to convince Pilate (*The Bible, The New Testament,* "The Gospel of Matthew").[31]

Then, in order to awake them and make them aware of their mistakes, Jesus used the sea with all its power, as a blessing, working and disciplining tool. It was getting dark. After He had dismissed the crowd, Jesus went up the mountain to pray. Again, He was with His Father. It is noteworthy that, in order to prepare the next lesson of faith, before sending the crowd away, Jesus had asked his disciples to get into the boat and cross to the other side to Bethsaida Iulias, not far from Capernaum (See *Atlas Biblic* 1993: 12), the city where the Savior Jesus also did many miracles.

The disciples were sailing near the shore because of a strong wind storm. When He saw them how distressed they were, at about 8 km from the shore, Jesus came to them walking on the sea. It was after 3 am, "at the fourth watch of the night" (*The Bible, The New Testament,* "The Gospel of Mark", ch. 6, verse 41). Making a synthesis of the "Gospels", we notice the reaction of the disciples, who were still not fully convinced of the divine power of their Master. Thus, when they saw Him walking on the sea, they thought He was a ghost and cried. Because, in their despair,

[30]In a world of irrational consumption, dominated by waste, sick and hungry people, we should take into consideration Jesus's advice. He assures us: "Blessed are the merciful for they shall obtain mercy" ("The Gospel of Matthew", ch. 5, verse 7).

[31]"All the people answered, "His blood is on us and on our children!" (*The Bible, The New Testament,* "The Gospel of Matthew", ch. 27, verse 25).

they saw Him and were frightened, Jesus immediately told them not to be afraid. Then He got up on the boat.

After the sea had calmed down and the wind had ceased, all were amazed. They came to Christ, bowed and said, “Truly you are the Son of God” (“The Gospel of Matthew”, ch. 14, verse 33). Nevertheless, Peter, who wanted to show his faith to the other disciples, said courageously: “If it is really You, then command me to come to You on water”. “Come!” Jesus told him. Peter went down from the boat and went to Jesus. When he saw that the storm was strong and the waves were roaring wrathfully, he was afraid and began to sink. Startled, he cried for help. Immediately, the Lord stretched out His hand towards his apprentice and took him out of the water and led him to the ship, rebuking him: “You of little faith, why did you doubt?” (Charles Dickens 2010). This time, the lesson of faith given by their teacher was complete.

However, they still had much to learn. In the 40 days that had passed since the resurrection to the ascension in glory to our Heavenly Father, Jesus was concerned only with their preparation. They finally got the message of their mission (*The Bible, The New Testament,* “The Gospel of Matthew”).[32] We often get to another dimension, we often experience the same situations as Peter did. We start with momentum and, at the first storm that comes into our way on the road of life, we lose ourselves. We often cry in our prayers as Peter did: “Lord, save us!” And even if the answer does not come right away and we float for a while on the raging sea, the Lord will surely come, at the proper time, if we cry with faith (*The Bible, The New Testament,* “The Gospel of Matthew”).[33]

1.5 The Mirage of the Sea, an Epilogue of Christ’s Resurrection, Love and Christian Service

Easter had passed with its earthshaking events. Despite the measures taken by the Sanhedrin (the Jewish Supreme Court of the time, led by the High Priest), the news about Christ’s Resurrection spread quickly. Although the disciples had been told repeatedly and as clearly as possible that He would rise from the dead (*The Bible, The New Testament,* “The Gospel of Matthew”, ch. 16, verse 21; ch. 7, verse 9, 23; ch. 27, verse 63; “The Gospel of Mark”, ch. 8, verse 21; “The Gospel of Luke”, ch. 18, verse 33 and ch. 24, verse 7), at first, they could not believe that He would die. In three and a half years, they had seen so many miracles performed by their

[32]“Therefore go and make disciples of all nations, baptizing them in the name of the Father and of the Son and of the Holy Spirit, and teaching them to obey everything I have commanded you. And surely I am with you always, to the very end of the age.” (*The Bible, The New Testament,* “The Gospel of Matthew”, ch. 28, verse 19 and 20).

[33]“If you believe, you will receive whatever you ask for in prayer” (*The Bible, The New Testament,* “The Gospel of Matthew”, ch. 21, verse 22; ch. 17, verse 20).

Master, such as healing the sick, the blind, the lame, the lepers and, just before Easter, before many Jews, He had ressurected His friend, Lazarus from Bethany.

After His resurrection, as revealed by "The Gospel of Mark" (ch. 16, verse 9–14), Jesus appeared first to the women who, early in the morning, went to His tomb with embalming spices, and He told them tell the disciples ("My brothers") to go to Galilee, where they would meet. Then, He showed Himself, in a special manner, to two of his disciples, i.e. Simon and Cleophas, who, pressed by what had happened, and puzzled, were heading to the village Emmaus. Finally, He appeared to the eleven disciples whom He convinced that He was alive in the flesh, and scolded them for their disbelief and petrified hearts, for not giving credence to those who had seen Him ressurrected. Finally, He revealed Himself to Thomas, who would always want arguments and who believed in Jesus's ressurrection only when he saw Him in person.

Again, the sea blessed by God comes "to write", together with the disciples, a new page in human history, i.e. the beginnings of Christianity. As the Lord had commanded, the disciples returned to Galilee and resumed their former occupations, i.e. fishing, so necessary to their livelihood. Therefore, seven of the eleven disciples (*The Bible, The New Testament,* "The Gospel of John)"[34] headed towards the sea again (*The Bible, The New Testament,* "The Gospel of John", ch. 21, verse 1–20). It was a quiet evening. The Sea of Tiberias, with its calm waters, was waiting for them. So they prepared their fishing gear, climbed up the ship and went to the sea. They struggled all night, and with all their experience, they caught nothing. The dawn was approaching. Upset, they were sailing towards the shore when they noticed a lone stranger (Ellen White 2004: 757), who was watching them.

"Children" He asked them, "do you have something to eat?" At their response that they had nothing, He told them to cast the net on the right. Peter, remembering the beginnings of his apprenticeship, with the other disciples, threw the net and they could not drag it because of the multitude of fish. Then, John, who was younger and who could see better, told Peter, who was next to him: "It is the Lord!" Peter, whose conscience was three times burdened since he had denied the Lord three times at the hardest test of his faith – The Saviour's Trial (*The Bible, The New Testament,* "The Gospel of Mark")[35] – had been expecting this moment for a long time, and now was able to discharge this burden before God. Thus, with his hands trembling with emotion, Peter hastily put his clothes on, as he was naked, and plunged into the sea. When he reached the shore, he saw coal ember, fish laid thereon, and bread.[36]

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[34]The seven were Simon Peter, Thomas, Nathanael, John and James, sons of Zebedee and two other disciples (*The Bible, The New Testament,* "The Gospel of John", ch. 21, verse 2).

[35]"Immediately the rooster crowed the second time. Then Peter remembered the word Jesus had spoken to him: "Before the rooster crows twice you will disown me three times." And he broke down and wept." (*The Bible, The New Testament,* "The Gospel of Mark", ch. 14, verse 72).

[36]It is still a definite proof that Jesus rose from the dead, in flesh. His miraculous appearance to the meeting with the disciples prove Jesus's Divinity.

The other disciples came in their little ship, dragging the net full of over one hundred and fifty large fish, and although there were so many fish, to their amazement, the net was not torn. Jesus told them to bring some of the fish that they had just caught and come for lunch. No one dared to ask Him who He was, as the circumstances were obvious. Again, the sea helped them. They knew that He is the Lord. He was displaying the same care for them, as He had had every day, in three and a half years, when they had not suffered from hunger or thirst and had no care.

After lunch, the time came to discipline Peter, in love, and to release him from the burden that he had been carrying in his soul since Jesus's condemnation and crucifixion on the cross of Calvary. Aside from the other disciples, in a more favorable background, the Savior asked him, "Simon, son of John, do you love Me more than these?" "Yes, Lord," replied Peter, "You know that I love You". Then Jesus said, "Feed My lambs". The second time, the Lord asked the same question and the answer was the same. But it seems that Peter made a step forward on the path of service, as the Lord told him: "Sheperd My sheep!" When Jesus asked him the third time: "Do you love me?", Peter was grieved and his response was this time more emphatic: "Lord, thou knowest all things; know I love you". This time Peter's reward was higher, receiving the "mandate of mature servant", in the mission that he would have to achieve. The Lord said: "Feed My sheep!" From that moment on, Peter was not a fisherman anymore. Jesus made him a "fisher of men". He entrusted him with His herd, with His sheep, in order to take them to "green pastures and still waters and, there he shall lack nothing" (C.S. Lewis 2013: 135).[37]

Although some theologues argue that the event at the Sea of Tiberias represents a rebuke to Peter that he had returned to his old profession, we do not agree. He had chosen Peter earlier to be the "Rock" upon which the Lord would build His church and, despide any obstacle, His prophecy would be fulfilled.

Jesus provides us with a great, touching and divine example, using the story of the Sea of Tiberias. Jesus's generosity blends, this time, with the sea that offers an appropriate expression of His infinite love. We believe that Apostle Paul inspired himself from this event when he wrote the Epic of perfect love in his "Epistle to the Corinthians", ch.13, verses 4–8 (*The Bible, The New Testament,* "The First Epistle to the Corinthians", ch. 13, verse 1–13): "Love is patient, love is kind. It does not envy, it does not boast, it is not proud. It does not dishonor others, it is not self-seeking, it is not easily angered, it keeps no record of wrongs. Love does not delight in evil but rejoices with the truth. It always protects, always trusts, always hopes, always perseveres. Love never fails...".

The sea, which honored and is still honoring its Divine Creator, gentle and generous, provides the human being with its unsuspected resources. The sea embellishes life, nourishes and heals miraculously. Yet, in its love, it is whimsical

[37] In "Psalm 23", "The Lord is my shepherd" (*Dominus regit me*), our Saviour identified Himself. "Basically, the allegorical method of reading of the Psalms may require the highest authority possible".

and mischievous, just like people. It has contributed to the spread of the immortal teachings of the scriptures worldwide. The missionaries that travel the sea and the ocean waters take God's Word to the farthest corners of the world. For all these, we should love it and preserve its charm and beauty and enjoy its bounty, endowed by God. The seagulls cry, hovering over the land, looking for food. The fish is increasingly scarce. The human being should not complain but he/she should act with all his/her forces in order to preserve its treasures unspoiled. Let us not forget that, by respecting the sea, we respect God – the Trinity, i.e. Father, Son and Holy Spirit – Who created the universe, the heaven and the earth, Who has been watching over us, from the very beginning. Respect God's creation and you will be rewarded fully by God!

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Chapter 2
Dobrudja, in the Mesopotamia of the West

Marin Petrişor

Abstract Seen as a prolongation of the Scythian lands north of Black Sea, and consequently called *Mikrá Skythia* by Strabo, this region that belonged to the Getae, the south-Danubian branch of the Dacians, was early colonized by the Greeks, who founded a number of cities of great importance there, among them, Tomis, Constanta today, the place of exile of the poet Ovidius, who wrote his *Tristia* here, conquered and colonized by the Romans later on, Dobrudja, through which the Slavs poured into the Byzantine Empire and constituted themselves as peoples, has a rich, fascinating and tumultuous history, like the waves of the *Akšeina* Sea, "the black and dark sea" in the ancient scholar's *Geography*, which the Greeks somehow attempted to "tame" by means of an antonym: *eúxeino*s (*Pontos Eúxeinos*, "welcoming, hospitable sea"). Like the history of these lands, the name of Dobrudja has aroused strong passions and sparked off heated debate among historians and linguists, who have not yet reached a satisfactory conclusion as regards the origin of the toponym in discussion. Romanian scholars, among them, researchers of great authority, such as Nicolae Iorga, Vasile Pârvan, Radu Vulpe, C. Brătescu, proposed *Dobrotič* as etymon, the name of the *strategos* of Slav origin, to whom, at the end of the fourteenth century and the beginning of the fifteenth century, the Byzantine emperor entrusted the governorship of the *thema* lying between the Danube and the Black Sea (it was from him that Mircea the Elderly, Voyvod of Wallachia, took possession of the land by force). In a study published in *Limba română*, 1965, no. 1, issued by the Romanian Academy, we rejected this etymon, on the grounds that the same name is mentioned, much earlier, in the travel account of Idrissi, the Arabic traveler, who, somewhere between 1110 and 1146, crossed the south-Danubian *Bergăn* on his way to Kiev. The discovery of a tenth century *taktikon*, a list of Byzantine offices, dignities, and titles, in the royal medieval library of El Escorial, including the *strategoi* and the *catepani* of the Mesopotamia of the West, has re-opened the discussion on the origin and, especially on the evolution of the name of Dobrudja province, which is, in fact, the result of a long chain of linguistic calques, closely connected to the location of the territory near the great river that almost surrounds it.

M. Petrişor (✉)
Academy of Romanian Scientists, University Ovidius of Constanţa, Constanţa, Romania
e-mail: mpetrisor88@gmail.com

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From early times, Dobrudja, a significant part of the Romanian ethnogenetic space, arouse much interest among researchers for its millennial problems, many of which have remained open until today. We have been especially preoccupied with the origin of its name, which, for many scholars, remains an elusive enigma. In 1965, we published an article (Petrişor 4: 433–437) in a journal of the Romanian Academy, in which we proposed an etymon that, later on, we abandoned, although the great Romanian Slavist and dialectologist, Emil Petrovici had expressed his support for it. In the years that have passed since then, we have searched for an answer, re-reading the bibliography of the problem and closely studying the works which continued to appear after that moment. It became obvious that finding an answer was possible only by carefully analyzing the long history of the province, which, officially, bore more names, given by the peoples who inhabited it, or who traversed it, lured by the splendor of Byzantium. All this time we have always believed that there must have been a name given by the autochthonous population too.

The earliest inhabitants of the land stretching between the Danube and the Black Sea were the Thracians.[1] Occupying the center of the Balkans Peninsula, the Thracian tribes[2] eventually reached the Danube and the Black Sea, and peopled both banks of the sacred river, which they made an axis of their existence. For our particular problem, we are interested in the Getae,[3] who lived on the right bank of

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[1]A branch of the Indo-Europeans of the *satəm* type, arriving here with the great Sumerian migrations, begun in the period which the *Old Testament*, corresponding to The Babel Tower, and located in the north-east of the Balkan Peninsula. Their neighbors, deriving from the same family, however from the grouping *kentum*, included the Greeks, the Armenians (who later migrated into the Caucasus), the Illyrians and the Latins (who, after the Trojan war, migrated across the land, while a part of them crossed the Mediterranean, settled in Lavinia, as it is narrated in the *Aeneid*). Archeological research dates the migrations of the Sumerians to the end of the Bronze Age, that is before the year 1200 BC, which corresponds with the disarray of the tribal society, and the movement toward a superior epoch, i.e., the Iron age (1200–450 BC.), a process in which the Thracians played an active role. The Thracian ethnos defined itself in the region between the Rhodope Mountains, the Northern Carpathians, the Black Sea and the rivers Vardar, Morava and Tisa. The main tribes were the Geto-Dacians, the Odrisi, the Besii, the Moesians and the Tribalii (cf. Costin Scorpan (1997); D. Berciu (1965, I: 57–62).

[2]Like the Tigris and the Euphrates of Mesopotamia which they had left behind, the Danube was a sacred river, which, in the *Old Testament,* bears the name of *Φυσών* (*Fisón*), and springs from Paradise (cf. A. Lambrino (1924, 2[e] partie: 191–213; P. Popović (1936: 161–176); N. A. Oikonomides (III (1965), no. 1–2: 60).

[3]The Getae, which the Greeks called *Getai* and the Romans, *Getae*, then *Geti*, are mentioned by Herodotus, on the occasion of expedition of Darius, the Persian king, who came to Scythia Minor to punish the Scythians, in the years 512–514 BC. The Getae fiercely resisted his army. The Greek historian enthused about them, and writes that „of the Thracians, they are the bravest and the most honest". Yet, at the same time, he criticizes them for the recklessness of opposing Darius. Living in the latter half of the sixth century BC, Hecateus of Miletus is the first of the classical writes to

the river, while the Dacians (Berciu and Pippidi 1965, I: 99–105; 1928/2003: 177–178; Scorpan 1997), whose territory was known under the name of Dacia, settled on its left bank, quickly enlarging their vital space. In time, they made a single people, and under their king Burebista (82–44 BCE), and formed a centralized slave-owning state.

During the Iron Age, the Thracian tribes moved toward full scale slave-labor relations of production. For a while, the Getae tribes led a flourishing and peaceful life, yet, about the beginning of the 1st millennium BC, they were faced with a large wave of migratory peoples, coming from the north and the east. About the year 1000 BC, the Cimmerians invaded the region. In the eighth century BC, the Scythians, a numerous people who had settled in the steppe north of the Black Sea, forced their entrance into the Getic province. A second wave of Scythian migrators penetrated into the space inhabited by the Getae, and finally settled there, often siding with the Getae in their conflicts against other migrants, or even against the Romans. The traces they have left, to which the archaeologist and historian Vasile Pârvan makes frequent references, indicate their strong presence in the province. The Scythians who settled in the Getic province were eventually absorbed by the autochthonous population. *Zaldapa*, the name of the stronghold they raised here, as well as those of the rivers *Asampaios* and *Kalabaois* have been lost (Pârvan 1926: 32 ff). The period coincides with the colonization of the Black Sea coast by the Greeks, to whom the Getae opposed no residence, conscious as they were of the advantages that the presence of such well-known traders and navigators offered.

Firstly, the Greeks proposed to turn the sea with its unhospitable name into a hospitable one, and thus, Ἀξείνος, which, in the idiom of the Getae have meant "bluish-grey, dark, inhospitable" (figuratively), by reference to similar word from Persian, was replaced by Ευξείνος "hospitable".[4] Starting with the latter half of the seventh century, the Greeks set up a number of city-states, starting from the north to the south of the Black Sea coast. Firstly, between 657 and 656 BC, colonists from Miletus founded Histria (Ἰστρίς, Ἰστροος, Ἰςτροπόλις), in the north, then, in the sixth century BC, those from Heraclea Pontica set up the city-state of Callatis

signal the presence of two Getic tribes on the right bank of the Danube. The Dacians are mentioned later on, at the beginning of the second century BC (cf. Radu Vulpe 1968, II: 29); C. Daicoviciu, (SCIV, VI, 1955, no. 2: 50 ff). After the creation of a Dacian centralized state by Burebista, appellations such as *Daco-Getae* or *Geto-Dacians* appear more frequently in documents. We should underlie that the name *get* was mostly used by the Greeks, while the Romans favored the term *dac*.

[4]D. M. Pippidi doubts the meaning of the initial word, and even considers it wrong (Berciu and Pippidi 1965, I: 145). We believe that *Akšeina* can be reported to another topic name form the Getic province, i.e., *Axiopolis*, a Greek citadel, founded by the colonists of Miletus, today *Carasu*, from Turk. *cara* "black" and *su* "flowing water, river". In the present day Romanian province, there is a town with the name of *Cernavodă* „black water", in Old Slavic, yet it is an officially given name, in a period that preceded the change of some Turkish settlements. By contrast, the name of the sea – the *Black Sea* – has preserved by means of calque. The Slavs, who disappeared in the process of symbiosis and bilingualism, perhaps named it *Çernoe more* "black sea", thus contributing to the preservation of the meaning of the word from antiquity.

(Καλλατίς) in the south, at about the same time when another group of Miletus colonists established Tomis (Τόμις), located between the two, and which, in time, became the most important Greek colony in the region, a kind of eternal city, where the poet Ovidius lived and died in exile. The city is attested by the Byzantine historian Kedrenos, under the name of *Constantia,* which it received from emperor *Constantius*, son of Constantine the Great.[5]

Although the province between the Danube and the Black Sea is not a continuation of Scythia, since the Danube Delta lies between them, however the Greeks called it *Mycra Scythia*.[6] The preponderance of the Getae in Mycra Scythia is supported by the presence the *davas* (*"dava"*, city in the language of the autochthonous population): Capidava, Sucidava, Zisudava, Muridava, Buteridava (Pârvan 1912: 29; Pârvan 1923: 112.). The Getae were the protagonists of the most important events in the history of the province, and kept close contact with their brothers, the Dacians, on the left bank of the Danube.

Its inhabitants passed through a difficult period, at the end of the third century BC, when the Celts[7] invaded and settled in the southern plain zones of the province, to be closer to the Roman Empire. There they set up the cities of Aliobrix, Arrubium and Durostorum, which the Romans turned into administrative centers when they took possession of Scythia Minor. Under the form *Silistra*, a Turkish adaptation of the Slavic from *Drsita*, the toponym has been preserved until nowadays. It is the name of a Bulgarian town, at the border that divides the former Scythia Minor between Romania and Bulgaria.

A peaceful period followed that gave the people here a brief respite, which allowed the Greek cities to flourish. Meanwhile, the Scythians, who had settled among the Getae, had been partially assimilated by the latter. At the end of the first century, a conflict began, which lasted for a while, between the Macedonians, in alliance with the Bessi of southern Thrace, led by their king Lysimachus, and the Getae, led by King Dromichaetes. Some of the cities were temporarily lost, yet they were eventually restored to the Getae, through a brotherly peace treaty (Berciu and Pippidi 1965: 132–136).

It was during this period that Burebista, "the first and the greatest of the Thracian Kings", master of the lands north and south of the Danube, united, under his rule, all the Dacian and Getic tribes, and pushed the eastern border of his centralized state to the Black Sea coast (Berciu and Pippidi 1965: 287). Unfortunately, in the year

[5]See for details D. M. Pippidi, in (Berciu and Pippidi 1965, I:139 ff). The founding of the Pontic cities in the Getic is part of a colonization process, which continued with the setting up of new colonies in Crimea and on the Asian coast of the Azov Sea. During the rule of Emperor Constantius II, *Tomis* became *Constantia* and *Constantiana* [391, 421, 445], an name it has preserved until today.

[6]The name of the province, under the form *Μικρά Σκυθία*, appears for the first time in Strabo's' *Geografia*, VII 4, 5 and 5.12.

[7]The Celts are a branch if the Indo-Europeans, from the group *kentum*, who arrived in Central and Western Europe a in the sixth – seventh centuries BC. They passed through Transylvania and settled in the north of the Getic province, where they were utterly defeated by the Romans.

44 BC, the Dacian king was murdered by a criminal hand, in the same way as Caesar, the Roman emperor, was killed. Following this event, the Geto-Dacian state disintegrated, and, for the autochthonous population, a troubled period followed, which allowed the Romans, who have reached the Danube through the conquest of Thrace and Moesia, to penetrate into Scythia Minor, up to the mouths of the Danube. Now, *Micra Scythia* became *Scythia Minor,* a name which was mostly used in official documents, as the natives preserved the one given by their ancestors, and which we are going to reconstruct here. Likewise, *Pontus Euxeinos* became *Mare Nostrum* and *Pontus Sinister.* The metaphorical name given by the Greeks disappeared, while the ancient name, *Akšeina* survived, adapted and calqued by the autochthonous population, who eventually Romanized.

Starting with 15th AD, under Emperor Tiberius, the Romans began the pacification of *Scythia Minor* (Pârvan 1923/2000: 55–62). V. Pârvan writes that Emperor Claudius also had an important contribution to this, and that "in the times of the Flavian emperors, Dobrudja was full of Romans" (63–78).

Now that the Getae had been appeased, the Romans turned to the Dacians, on the left of the Danube, in order to put an end to their frequent and harassing incursions into Moesia. In the year 86th AD, Emperor Domitian, divided Moesia into *Moesia Superior* and *Moesia Inferior*, the latter including *Ripa Traciae*, which stretched along the Danube, and *Scythia Minor*.[8]

The first confrontation, north of the Danube, concluded in the year 89 with heavy losses for the army of Domitian. A peace agreement was negotiated, and Dacia became a client state of the empire. Emperor Trajan (98–117 AD) decided to transform Dacia into a Roman province. The two military campaigns of 101–103, and 105–106 AD, respectively led to the conquest of Dacia was conquered; its king, Decebalus committed suicide to avoid being captured by the victors. A rapid colonization followed, with populations brought from all the Romanized provinces, and the territory was joined to *Scythia Minor*. All these created favorable conditions for the formation of the Romanian people and of the Romanian language, one of the ten Romance languages, of which today only nine are still being spoken, after the disappearance of the Dalmatic language.[9]

For the problem we are interested in, and we would like to draw attention to a piece of information provided by the historian Cassius Dio, LXVIII, 12.2,[10]

[8]Lat. *ripa* has passed into Romanian: *râpă* „fallen cliff", yet its other meaning, i.e., „plains along an important flowing water", has come down to us by means of the word *vale*: *Valea Dunării, Valea Oltului, Valea Prahovei*. We underline The autochthonous population' preoccupation of naming their places after the rivers that crossed their territory should be highlighted. Paerticular attention was given to the Danube, the sacred river: *Ripa Traciae*, "the Land to the Istros", *Podunavia*, perhaps *Bărăgan*, whose consonants *brg*(*n*) may hide the idea of "river bank", "water".

[9]For the colonization of Dacia and Scythia Minor see V. Pârvan (1923/2000: 123–134; V. Pârvan (1972, *passim*); Al. Arbore (1928/2003: 177 ff).

[10]All the information in Radu Vulpe (Vulpe and Barnea 1968, I: 93–124); with different commentaries, V. Pârvan (1926: 120–122; C. Daicoviciu (1960, I: 308).

namely, that in the year 105 AD, between the two Daco-Roman wars, King Decebalus asked Emperor Trajan to restore *τήν τε χώραν μέχρι του Ἴστρου* („the land to the Danube") to him.

After the conquest and the subsequent transformation of Dacia into a Roman colony, a century and a half of *pax romana* followed. In the year 212, Emperor Caracalla issued his well-known edict (*Constitutio Antoniniana*), which granted Roman citizenship to all free men in the empire. By the end of the third century AD, the Goths, a branch of the Germanic tribes who would conquer, later, the center and the western parts of the empire and would cause in 476 AD the fall of Rome, and implicitly of the Western Roman Empire, raided Dacia and the present day Transylvania. Under their pressure, to which one should add the danger posed by other migrant barbarians coming from the north, in 271 AD, Emperor Aurelian withdrew the Roman army and administration from the region. The Romans continued to pay attention to Dacia, as an outpost in the way of migrators. The reign of Constantine the Great (306–337) was a glorious one for the empire, as the emperor issued the Edict of Milan in 313, which granted religious liberty to the Christians, moved the capital to Byzantium in 330, and fortified the northern frontier. He had some cities in the region rebuilt, and had the foundations set for new ones, such as Constantiana, Constanta today.[11]

Toward the end of the fourth century, the situation in *Scythia Minor* turned serious, because the *foederati* Goths broke the peace treaty concluded with Constantine the Great and allied themselves with the Visigoths, and the Huns of Attila. At the end of the fifth century, the Slavs, led by Avars and Bulgarians, forced their way into the Eastern Roman Empire, which, ruled by emperors of Greek ancestry, gradually Hellenized, a process that began with the officialization of Greek in administration. For a short period of time, the reign of Justinian (527–565) brought peace to the empire, as he successfully opposed the Slavs, who attempted to conquer Byzantium. It was Justinian who had Dacia and in *Scythia Minor* built and rebuilt, it was he who gave the country new laws, *Noveles,* however written in Greek. After him, Emperor Fokas decreed Greek as state language, yet he could not repel the Slavs, who eventually settled south of the Danube. During this period, Dacia and *Scythia Minor*, whose autochthonous population had concluded the process of Romanization, were lost forever. South of the Danube, in the following two centuries after Justinian, Byzantium was faced with increasing difficulties to respond to the growing power of Bulgarian tsardom. Under the circumstances, Byzantium required assistance from Kiev: an army led by Prince Svyatoslav was sent by land and by water. In a succession of military campaigns, between 968 and 969, Svyatoslav annihilated the Bulgarian state, yet he refused to leave the liberated territory. In a decisive battle, Byzantium succeeded in chasing him away, however

[11]Emperor Constantius II (337–361) rebuilt the Greek cities, defended the Christian rite, strengthened the fortress *Constantiana,* not far away from the former city of Tomis; its name survives in contemporary *Constanţa*, after and intermediary phase, when it was known as *Constantia* (with Constantin Porphyrogennitos: *Κωνσταντίας*) (cf. Ion Barnea in (Vulpe and Barnea 1968, I: 391).

not without honoring the Ukrainian prince for his contribution to the defeat of the Bulgarian tsardom. Taking advantage of the situation, Emperor John Tzimiskes placed the border on the Danube in 972 once more. He then engaged in the administrative organization of his empire, now the Byzantine empire, dividing it into several *themata*, i.e., administrative and military units, each of them led by a *strategos* having the title of duke (or *katepâno),* and by a military chief, with full powers. With new forces, the empire engaged in battles of defending the right bank of the Danube from the danger of the invasion of the Pechenegs, who eventually entered and settled in the region located between the Danube and the Black Sea. It was under these circumstances that the former *Scythia Minor* became the *thema* of *Paristrion.*[12]

Researchers have reconstructed a list of seven dukes of *Paristrion* from the nineth century: Simeon, Kataxalon, Kekaumenos, Mihail, Romanos Diogenes, Isaac Komnenos, Nestor and Leon Nikorites (Arbore 1928/2003: 300–301).

The Vlachs, the name under which Romanians were known in the Middle Ages, are first documented in this period (Arbore 1928/2003: 302). In the following centuries, the administration of Paristrion was entrusted to senior vassals to the empire, whose name have come down to us: Miltzes, Balica and Dobrotič, to which the name of Mircea cel Bătrân (Mircea the Elderly),[13] the ruler of Wallachia ("the Country of the Vlachs") should be added. In 1417, a year before he died, he lost it in to the Turks. For the next four centuries, the region was under the rule of the Ottoman Porte. It was returned to the modern independent Romanian state, after the Russian-Romanian-Turkish War of 1877–1878 (Rădulescu and Bitoleanu 1998: 335 ff.). Colonized with Turks and Tartars, with Ukrainians, Russians, Germans, Armenians, Greeks, and Bulgarians, nevertheless the land between the Danube and the Black Sea has preserved its Romanian identity, and could serve as a model of friendly interethnic relations.

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With such a rich and troubled history, the Getic province bore several conjectural names, given or taken, through calque, by the numerous peoples in their passage to the heart of the Roman Empire, who established relations with the natives, and became, as a result of the process of Romanization, part of the Romanian people. However, despite the great number of such names, there must have been one, given by the natives, which we are to reconstruct, by analyzing all the others, and by briefly reiterating some data presented at the beginning of our study.

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[12]For the whole period, with the events that followed in the Byzantine Empire, Dacia and Scythia Minor, see Al. Arbore (1928/2003: 297–300).

[13]Al. Arbore points out that all these vassals had been linked to the Emperor ever since they used to administer Paristrion (1928/2003:302).

At their coming on the seashore of Pontus Euxinus, starting with the seventh century BC., the Greek colonists called the Getic province ***Μικρά Σκυθία*** *(Micra Scythia), which the conquering Romans translated into* ***Scythia Minor****, which lasted throughout the whole period of Antiquity and the beginning of the Middle Ages in the Balkans.* It was an artificial name, which the autochthonous population did not use, but which, in the manner of other names, circulated in administration, history and geography and nautical books. It disappeared when, at the end of the 1st millennium AD, the Byzantine Empire, defeated and obliterated the Bulgarian Empire of King Simeon. Pushing the border to the Danube, the empire regained the province and organized it administratively as the *thema* of ***Paristrion*** or ***Paradunavion****, after the name of the river in its Greek and Latin pronunciation respectively.* We recognize in these names two derived nouns, with the following structure: the prefix/the preposition *para* (demanding the genitive case) + the lexical root *Istr*(*os*)/*Dunav* + desinence *-ion*. This name lasted from the year 1000 (approximately) until 1417, when the province was conquered by the Turks and incorporated into the Ottoman Empire.

During the four centuries when it bore these official names, the province was also known *White Wallachia* or *Asen's Walalchia*, in the chronicles of the French crusaders Guillaume de Rubrouquis (1253) and Geoffroy de Villehardouin (1212), both terms being bookish (Petrişor 1965: 434). In the fourteenth century, Leunclavius calls it *Dobritza* and *Dobritze* (435).

Leaving aside other fanciful etymologies, we should mention that some prestigious Romanian philologists and historians, such as Vasile Bogrea, Nicolae Iorga, Radu Vulpe, Constantin Brătescu, Nicolae Bănescu, believe that *Dobrogea* has its etymon in the name of Dobrotič, despot of the whole province from 1354 to 1386, before coming under the rule of Mircea the Elderly, and was then conquered by the Turks (Petrişor 1965: 435).

Our intervention in the above-mentioned work came after we studied the article of the linguist Vasile Bogrea (1921, II: 33), who, although a defender of the *Dobrotič etymon*, gives a detail, as a matter of mere curiosity, namely that the wife of Svyatoslav, Prince of Kiev, who fought in favor of Byzantium against Simeon, the Bulgarian king, was called Dobrodeja. Although there are some difficulties to explain, especially the final part of the word, we thought that this name might be the much-searched for etymon, considering that, after entering into the possession of the Ottoman Porte, Dobrudja was the apanage of another woman of high rank, Valide Sultan (mother -sultana) (Bogrea 1921, II: 33).

Not long after that, we saw the closeness between the two names as a simple paronymy, because the passing of *de* from *Dobrodeja* to *ğe* could not convincingly accounted for, either in the Ukrainian that was spoken in Kiev, or in Romanian. Our mistrust in the *Dobrotič* etymon turned into conviction, when we reread the travel journal of Idrisi,[14] who, during his lifetime (1110–1164), passed through the province and made a stopover in „*Bergean*", on his way to Kiev. This happened

[14]In our article of 1965, we treated the information of Idrisi superficially, as a mere curiosity.

more than two centuries earlier than the times when the Byzantine official lived and worked. We were prompted to ask ourselves whether there might be a connection between the *Bergean,* from the journal, and the *Bărăgan,* the large plains on the left of the Danube, still bearing this name, as both of them seemed to attach to a common, or related etymon. Thus, all of a sudden, the situation turned more complicated and more interesting.

The much-regretted Greek historian and classical philologist N. A. Oikonomides from Athens wrote a study on the history of the territory of the Lower Danube, at the beginning of the Middle Ages, to which we had previously paid too little attention, yet which guided us onto a more promising path. In this article, the author relates of his chance of coming across a *taktikon*, that is a list of high Byzantine officials from the last quarter of the tenth century, which he dated to the years 975–979 (1965: 57, 73–74).[15] This *taktikon* contains vital information about the Byzantine provinces, at a time when the empire was at its peak, after the crushing victory over the Bulgarians, and when its north-eastern border reached the mouths of the Danube once more. It was the period when the empire was organized in *themata*, led by a *duke* (*katepano*) and a military *strategos*.

For the history of the province between the Danube and the Black Sea, and for the problem we had proposed to solve, the *taktikon* is extremely important, because it provides us with the names of seven dukes from the *themata* close to the imperial borders, of eleven *strategoi* from the older, central *themata*, and the names of other 70 *strategoi* of larger territories, or settlements. A duke and a *katepano* of Mesopotamia (*duce* and *katepano* being synonyms!) are mentioned among others. According to N. A. Oikonomides, the presence, on the list, of a *strategos* from the Mesopotamia of the West (*ό στρατηγίς μεσοποταμία της δύσεως*) seemed to indicate that there were, in fact, two Mesopotamias: the Sumerian one, in the Middle East, and another one, somewhere in the west, which he attempted to locate (57 ff.). The author is convinced that the Mesopotamia of the West was a different kind of *thema*, since the former was said to be ruled by a duke, while for the latter, only its Greek equivalent was given. The Greek historian localizes the *strategos* in the Mesopotamia of the West, an entirely convincing detail, in our view (57).

For the author, the western frontier of the *thema* is clear: it is the Danube, the sacred river, springing from heaven, like the Tigris and the Euphrates of ancient Mesopotamia. On the other hand, the eastern frontier needed to be located more precisely, since the *Scorialensis*, the *taktikon,* "the only Byzantine sources of its kind" (58) offered him no help. Fortunately, he did find some precious information in *De Administrando Imperio*, the book of Emperor Constantine Constantin VII Porphyrogennetos. It signals the presence, north of the Black Sea, of the Hungarian migrators, who, in alliance with Byzantium attempted to defeat King Simeon of

[15]This catalog of the eleventh century contains extremely important documents regarding the Romanians. It was discovered in the library of the Escorial, the former capital of the Spanish kings. This one, together with other documents from the ninth – eleventh centuries has inspired reversal works, which have already been publishes. See notes 1, 2 on p. 57 and notes 3, 4, 5 on page p. 58.

Bulgaria in 896. However, the Bulgarian king, allied, with the assistance of the Pechenegs, crashed the Hungarians and drove them away from the land they had occupied temporarily. These then moved to the west, and settled in their present homeland (68).

One should notice that the space which the Hungarians settled is written either as a compound common noun, *Ἀτελκούζου* (*Atelkuzu*), or as separate nouns *Ἐτελ/και/Κουζου* (*Etel/and/Kuzu*), the latter variant being more credible, since the former does not observe the features specific of agglutinant languages (Hungarian, Turkish etc.), which characterize by vowel harmony. In the former word, *e*, a front vowel, appears with vowels from other series of classification.

In his study, N. A. Oikonomides uses the commentaries made by Gy. Moravcsik, which are rather contradictory. At the beginning, the latter asserts: "It no doubt represents the Old Hungarian Etel-Küzu, which means 'between the river' or 'Mesopotamia'. Then, he ends by saying: "it may also mean 'the territory of, or about a specific river' (the Volga..., or the Don or the Dnieper)" (69). He then goes on to identify the rivers mentioned in that second text: *Βαρούχ* seems to be the Pecheneg name of the Dnieper, *Κουβου* is identified with the Bug, *Τρουλλος* is the Dniester, *Βρουτος* – the Prut, while *Σέρετος* – is the Siret. Analyzing the texts referring to the Atelkuzu location, we believe that, in this case, we are dealing with a large border *thema*, situated beyond the frontiers of the empire, with an administration, whose main task might have been to survey the migratory peoples, who could thus move rather freely. To monitor such a large area, that stretched from the Dniester to the Siret, the local administration had to be vigilant, well-trained troops needed to be deployed there. If anything significant had happened there, chroniclers would have recorded the event, as they did for other smaller ones, the more so as the empire was facing one of its worst crisis, and particular attention was given to the decentralized territorial administration, with a view to keeping it under control.[16]

[16]N. A. Oikonomides (1965) relies on two fragments, from the Chronicle of Constantine the Porphyrogennetos: A. (In the eleventh century, the Hungarians were living "*είς τόπους έπονομαζομένους Ἀτελχούζου, έν οίς τόποις τά νυν τό των Πατζινακιτων έθνος χατοιχει*" [in a place called Atelkuzu, where now the nation of the Pechenegs is living] (ch. 38, 29–31), and somewhere else, "*ό δέ τόπος έν ώ πρότερον οί Τουρχοι ύπηρχον, όνομάζεται κατά τήν έπουυμίαν του έχεισε διερχομένου ποταμου Ἐτέλ χαί Κουζου, έν ώ άρτίως οί Πατζιναχιται χατοικουσιν*" [and the place where before there exist the Turks, is called after the river that crosses the region Etel and Cuzu, where only the Pechenegs live] (cf. 40, 22–25). B. The geographical localization: "*Ὁτι ό τών Πατζιναχιτών τόπος, έν ώ τω τότε χαιρω χατώχησαν οί Τουρχοι, χαλειται χατά τήν έπουυμίαν των έχεισε όντων ποταμων οί δέ ποταμοί είσίν ούτοι ποταμός πρωτος ό χαλούμενος Βαρούχ, ποταμός δεύτερος ό χαλούμενος Κουβου, ποταμός τρίτος ό χαλούμενος Τρουλλος, ποταμός τέταρτος ό χαλούμενος Βρουτος, ποταμός πέμπτος ό χαλούμενος Σέρετος.*" [That the place of the Pechenegs, in which at the time the Turks were living, is called after the name of the rivers three; and the rivers are these: the first is called Baruch, the second is called Cubu, the third is called Trullus, the fourth is called Brutus, and the fifth is called Seretus.] (ch. 38, 66–71). In our opinion, the Mesopotamia of the West was a large territory stretching between the five great rivers, whose western border was at the mouths of the Danube, which the presence of the two rivers, *Βρουτος* and *Σέρετος* seem to suggest too. The Istros was a scared river, a condition in the Greek antiquity for the existence of a Mesopotamia (69).

This might be the reason why, N. A. Oikonomides searched for the Mesopotamia of the West in other areas, and placed it in the bend that the Danube makes from the north to the south. On its way to the Black-Sea, the majestic river branches out, creating two fairly large islands, surrounded by its waters. However, living conditions are harsh here, since they are often flooded because of rainfalls and ice.

We accept that, though singular, the Escorial *taktikon* provides tangible proof that the Mesopotamia of the West did exist, yet as a surveying *thema*, with the Danube, the river springing from Paradise, as its western border. This also holds true for Dobrudja, "the land between the Danube and the Great Sea", as Mircea the Elderly designates it in his princely title.

Starting form the idea that, from the dawn of history, the Danube has played a crucial role in the life of the autochthonous population, we need to substantiate whether this has produced any significant effect on the name of the province as well.

Indeed, no matter how surprising this may be, as we were when we began to understand that the data in the bibliography corresponded to our own expectations, and even before it became sacred in a mythology, an existential axis for the natives, possessive vainglory for the Roman and the Byzantine empires, the name of Dobrudja has been hiding in its original name, for millennia. To this end, we must return to the sources, once more. Primitive peoples usually give simple names to the places that constitute their vital space, with no determiners: the Dacians called *Apo*[17] the Caraş, a river that, nowadays marks the Romanian-Serbian border, the Hungarians named their lake *Balaton*, the Turks perceived the peninsula through which they passed in then partially settled, as a mountain plateau, and consequently termed it *Balcan*, the Slavs called *Grădişte* the place where once used to be a fortress (from *grad* „citadel", with the suffix -*işte*, which indicates something that has disappeared). In Romanian toponymy, my great professor Iorgu Iordan recorded *Trăvăi* (Between Valleys), *Trâmpoaie* (Between the Branches of a River, or Between Rivers), in the area of Sarmizegetusa, the capital of Dacia, *Întregalde* and *Trăgalde* (Between Rivers/Ponds), *Suplac* (Under Lake). Romanian *Trăvăile* has an equivalent in French toponymy: *Entre-Vail*, attested in the year 958 under the Latin form *Intervalles* (Iordan 1963: 494 ff.).

In Transylvania, in the so-called Dacian zone, Mircea Homorodeanu recorded *Trăpăraie* (Between Streams), that is a small Mesopotamia (1969: 107).

The Thracians named the great river simply *Dana*, probably meaning "river", a much-discussed hydronym in Romanian linguistics,[18] and that is why we do not

[17]The name *Apo*, which the river from Western Banat used to bear, is a proof that, in Romanian, the word inherited from Latin existed in the autochthonous language too, with the group *qu-* + *a, e* > *p*: cf. Lat. *aqua* > Rom. *apă*, like Lat. *equa, eque* > Rom. *iapă, iepe*. The conclusion we can draw proves to be very interesting, namely that the plural *ape* is synonymous to *râuri* ("flowing waters"), therefore, with the same meaning as the autochthonous word *dana* "flowing water"

[18]Vasile Frăţilă, in his *Studii de toponimie şi dialectologie* [Studies in Toponymy and Dialectology] (2002), provides a very useful synthesis of the Romanian hydronyms existing in the autochthonous linguistic stratum.

propose ourselves to elaborate further on it. We shall only add that we do not see the etymon *Dunaris*, proposed by V. Pârvan, who most likely thought it to be specific to the Thracian area of the Indo-European framework, as a form which could thus justify possible intermediary stages that had proved valid in the case of other forms from the nearby area: *D*(*u*)*nister* > *Dnister* > *Nistru* and *D*(*u*)*niper* > *Dniper* > *Nipru*. For our own ancestors, we invoke the theme *dana*, cu *á* > *å* > *o* > *u*: *Dana* > *Dåna* > *Dona* > *Duna*. The final part of the word, −*re*, could rather be a case desinence. This particle appears in several words inherited from the Dacian language: *brusture*, *mazăre*, *viezure* etc.[19] The name of the citadels in –*ris*, mentioned in the bibliography, may be Latinized or Hellenized, and therefore bookish.

Now we return to the relation of Cassius Dio, LXVIII, 12.2, who tells us, in Greek, that, in the year 105, that is before the second Daco-Roman war, Decebalus demanded that Trajan return him "the land to the Danube" (*τήν τε χώραν μέχρι του Ἴστρου*), *a very precious piece of information, because this must have been the true name of the province. We recognize it in the name of the thema Paristrion/Paradunavion as well, an exact copy of the autochthonous name (**the land**) **to the Danube**), which, in the process of the symbiosis and bi-lingualism, the denationalized Slavs calqued and thus brought into Romanian. The Byzantines calqued it in the same manner*. They could use both variants, yet, in the end, borrowed the autochthonous population's form, because, by 1000, the Slavs in Dobrudja had already been absorbed by the Romanians.

In conclusion, in the period preceding its being taken over by the Turks, the name *Dobrogea* was a calque, followed by an adaptation to a language totally different, both typologically, and genealogically.

Turkish, a language with vowel harmony, acquired the real name from the autochthonous population: *Dobrega*. This name presented a vowel discordance *o...e... a*. Through assimilation, the front vowel *e* turned into *o*, a back, round vowel. In Turkish toponymy (that of Dobrudja included) there are numerous topical names in *-če* and *-ğe*: *Ağiğa*, *Borunğa*, *Čalmağa*, *Sarağa*, *Hasanča*, *Nazarča*, *Omurča*, *Tulča* etc. Framed in the Turkish system of toponymy, and in order to

[19]The vowel *á* from the etymon **Dánare*, became *u* buy means of an intermediary phase *å*, can be met in the names of the rivers *Mureş*, the final evolution of *Máris*, as it appears, together with other close forms, in the documents of Antiquity. The same vowel *á* became *o* in *Olt*, *Someş* a.s.o. The phenomenon is not Slavic, as it was believed, for the reasons shown by E. Petrovici, namely that in Slavic the vowel *á* was preserved. Starting with the third century BC, in inscriptions, the name of some Dacian fortresses present the oscillation *á*/*ó*: *Sucidáva*/*Sucidóva*, *Pelendáva*/*Pelendóva*. The problem is thoroughly commented upon by V. Frăţilă (2002: 13–19), who pleads for the idea that, in this case, we are faced with a phenomenon that probably occurred in the Dacian language. It has survived in the Daco-Romanian dialectal space, in an idiom from north-western Oltenia: *cåp*, *cå̆să*. It also appears in south-western Banat, and in the in the Country of Haţeg, i.e., over a territory that correspond to historical Dacia. The same phenomenon appear in Istro-Romanian, a dialect that severed from what Sextil Puşcariu called the area of western Romanian (Petrişor 1994: 106–107, 190–191, notes 28 and 29).

correspond to its system of pronunciation, *Dobrega* became *Dobroğa*, which Romanians write as *Dobrogea*.

The toponym of *Dobrogea* (*Dobroğa*), on the phonetic form of which the Slavs that became part of Romanian people and of the Turkish-Tartar minorities living in the region have somewhat left their mark, remains a subject of debate for linguistics, but at the same time, for history and sociology, as part of the Romanian people's millennial existence.

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Chapter 3
Dobruja: A Unique, Intercultural and Spiritual Realm at the Black Sea

Elena Lazăr and Henrieta Anişoara Şerban

Abstract Dobruja is a unique intercultural, spiritual and geographical landscape, an inspirational land, blessed over the ages by the dark depths of the Black Sea. Although here was sentenced to exile the great poet Ovidius and the cold winds by the Black Sea drove him to write the elegy entitled *Triste*, the uniqueness of Romanian Dobruja unfold in a variety of unparalleled characteristics: one can think of the Monument Trophaeum Traiani from Adamclisi and the ancient cities Capidava, Tomis, Callatis, Enisala, Vicina, Troesmis, Ibida or Sacidava; we can mention the numerous monasteries (15 only in Tulcea county), the buried Church from Istria, the tiny straw Churches from Ostrov; one should talk about the variety of cultures and religious denominations – 18 of the 20th Romanian minorities live here and, also, in Dobrudja, one can find the only Muslim village of Romania (the former Başpînar or Başpunar, now called Fântâna Mare found on the UNESCO world patrimony waiting list); one should recall the great landform variety and another could talk about "Movile" Cave, unique in the world, which presents an ecosystem which is independent of the Sun. This land also contributed with numerous scientific, cultural and religious personalities to universal and national knowledge. Among these, it is our honour to include a brief scientific portrait of Professor Alexandru Bologa celebrated at the same time with the 150 year anniversary of the Romanian Academy.

Keywords Black Sea • Dobruja • Uniqueness • Culture • Spirituality

E. Lazăr (✉)
Romanian Academy, Patrimony Department, Bucharest, Romania
e-mail: elenalazar1968@gmail.com

H.A. Şerban
Romanian Academy, Institute of Political Sciences and International Relations "Ion I. C. Bratianu", Bucharest, Romania

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3.1 Introduction

Dobruja is a unique intercultural, spiritual and geographical landscape, an inspirational land, blessed over the ages by the dark depths of the Black Sea. Although here was sentenced to exile the great poet Ovidius and the cold winds by the Black Sea drove him to write the elegy entitled *Triste*, the uniqueness of Romanian Dobruja unfold in a variety of unparalleled characteristics: one can think of the Monument Trophaeum Traiani from Adamclisi and the ancient cities Capidava, Tomis, Callatis, Enisala, Vicina, Troesmis, Ibida or Sacidava (Ganciu 2016); we can mention the numerous monasteries (15 only in Tulcea county), the buried Church from Istria, the tiny straw Churches from Ostrov (Ionescu 2014); one should talk about the variety of cultures and religious denominations – 18 of the 20th Romanian minorities live here and, also, in Dobrudja, one can find the only Muslim village of Romania (the former Başpînar or Başpunar, now called Fântâna Mare found on the UNESCO world patrimony waiting list); one should recall the great landform variety and another could talk about "Movile" Cave, unique in the world, which presents an ecosystem which is independent of the Sun. (Worldwideromania 2016).

This land contributed with numerous scientific, cultural and religious personalities to universal and national knowledge. Among these, it is our honour to include a brief scientific portrait of Professor Alexandru Bologa. It is as if this fascinating realm by the sea transposes into culture and spirituality the exceptional geographical characteristics.

3.1.1 Black Sea, the Geostrategic Neighbour

Gheorghe Brătianu, a Romanian historian, member of an important cultural and liberal statesmen family dedicated to the Black Sea a treaty entitled *Marea Neagră. De la origini până la cucerirea otomană* [*The Black Sea: From the Origins, Until the Ottoman Conquest*]. Although it has been already written in in 1948, due to the political vicissitudes that the author endured until the end of his life during communism, the book was published for the first time only in 1988, toward the end of the communist regime. There he explains the dual, contradictory at times and intricate role of unity and division played by the Black Sea for the populations developing around its shores. Black Sea became in times a theatre play for a continuously developing play: universal history. Black Sea is a source of inspiration. In this respect, Gheorghe Brătianu wrote in his book regarding the Black Sea as well about the symbolic, historical and international relations role of the Black Sea. In this book the very destiny of Europe is viewed as progressing toward unity and it is interpreted in correlation with the complex importance of the Black Sea, a sea uniting like a magnet people, countries, cultures (Indo-European, Greek, Sarmatian, German, Geto-Dacian, Hun, Byzantine, Ottoman, Turkish, Romanian etc.)

and diplomatic strategies (Thiers, Guizot, Palmerston, Cavour, Disraeli, Bismarck, Kemal Mustafa and many other). Gheorghe Brătianu noticed that it is difficult to gather around an almost insulated sea from the great routes of navigation of the world, which surface does not reach the double of the surface of the great interior lakes separating Canada from the United States, a most representative series of personalities, who, keep though the fore of the historical world stage. He also emphasized the paramount role played by the Black Sea in the evolution of the Romanian state and politics, including the Black Sea in the national and international contexts of each epoch, inter-relating the East and the West, over the centuries. A commentator noticed that this work represents a correspondent of the F. Braudel's study of Mediterranean Sea and we can easily situate this extraordinary interpretation of the Black Sea in the universal and national spiritual and erudite patrimony. (Brătianu 1988).

3.1.2 Dobruja by Any Other Name Would Be as Interesting...

The story of the name Dobruja is either connected to a ruler named Dobrotitsa (Bulgarian despot fourteenth century) or to the derivations of the name given in Turkish to Proto-Bulgarians (that is, Bordjan or Brudjars) hypothesis sustained as well by the Arab writers and by the Romanian historian and politician who approached the correlations among culture, geostrategic position and history. (Wikipedia 2016a, b, c).

The myriad of names provided for Dobruja is fascinating (Wikipedia 2016a, b, c): Dobrudža (Bulgarian, Serbian, Croatian, Czech, Estonian, Finnish, Latvian, Slovene), Dobrogea (Romanian, Swedish), Dhovroutsá (Greek), Dobroedzja (Dutch), Dobroudja (French), Dobruca (Turkish), Dobrudja (alternate version in English), Dobrudscha (German), Dobruża (Polish), Dobrudzsa (Hungarian), Dobrudscha (German), Dobrugia (Italian), Dobruja (Catalan, Portuguese, Spanish). This way we understand that Dobruja became relevant for all these nations and this can only happen when the historical and cultural complexities of a specific geographical area become part of the universal heritage. (Wikipedia 2016a, b, c).

3.1.3 The Ethnic Structure

The ethnic structure in Dobruja is diverse and varies in Northern Dobruja and in Southern Dobruja. According to the last census conducted in 2011, in the Northern Dobruja there are 897,165 people of which Romanians 751,250 (83.7%), Bulgarians 58 (0.01%), Turkish 22,500 (2.5%), Tatars 19,720 (2.2%), Russian-Lipovan 13,910 (1.6%), Ruthenian 1177 (0.1%), Dobrujan-Germans 166 (0.02%), Greek 1447 (0.16%) and Roma 11,977 (1.3%), while in the Southern Dobruja aut of a total of 283,395 there are 192,698 (68%) Bulgarians, 106,568 Turkish 72,963 (25.75%) Roma 12,192 (4.3%), Tatar 808 (0.29%) and Romanians 947 (0.33%). (Wikipedia 2016a, b, c).

The most important cities in Dobruja are Constanţa, Tulcea, Medgidia, Mangalia (in Romania) and Varna, Dobrich and Silistra in Bulgaria. (Wikipedia 2016a, b, c).

In Romania, at October 7, 2015, in order to emphasize and celebrate the date of November 14, 1878, the date of the union of Dobruja with the Romanian Principalities, President Klaus-Werner Iohannis promulgated the law stating the date of 14th of November as *Dobruja Day*. (Monitorul Oficial 2015).

3.2 Spirituality, Culture, Science

Spirituality embraces in Dobruja the concept of *symphonia*. A myriad of religious cults live together in harmony in this blessed land: Muslims; Russian, Romanian, Greek and Bulgarian Orthodox; Jews, Catholics, other cults and atheists, too. Most numerous are the Orthodox, followed by Muslims, Catholics and Jews. There are numerous Churches and monasteries in Constanţa County, among which interesting and well-known are St. Andrews cave and Dervent Monastery. (Ciocioi 2013) Among the monasteries from Tulcea we notice Manastirea Halmyris, dedicated to the Martyr Saints Epictet and Astion, in Murigiol town. These saints have their relics kept at this monastery and these are the oldest relics venerated on the Romanian territory. We may also think about the sacred triangle formed by the villages Izvoarele, Satu Nou and Strunga with their tiny straw churches, which are part of a spiritual environment marked by Christian and Muslim Churches alike and part of a patrimony environment dignified of greater respect. The above-mentioned sacred-triangle churches were found near the cave of Saint Andrew the Christian forerunner of Romanians. (Chiriluţă et al. 2015).

In a more reflective perspective, Dobruja is a concrete realm of wonders of different natures: cultural, spiritual, geographical. In a philosophical interpretation we can say that, confronted with the colour-changing immensity Black Sea on a daily basis, the people from this part of the world had a special landscape horizon by which they were stimulated to scrutinize their souls and meditate about spiritual matters.

In a way the Black Sea might have inspired a sense of immortality, a poetic force and a reflective force in the people living its shores. Also we can notice a vein of cultural optimism in their creative lives extremely different from the tone in the *Triste*. What is cultural optimism? Instead of considering as Oswald Spengler did that culture is like a biological organism and it is subjected to temporal decay one may embrace the idea of immortality of culture and spirit, not confinable into a body decay metaphor. The paradox of a permanently changing and permanently similar sea is a metaphor for permanence and creativity in themselves. When we accept this perspective, we can extrapolate it and understand the Black Sea a version of the transcendent space which induces a spiritual and cultural immortality, as well as a spiritual and cultural fervour throughout Dobruja. At the intersection of cultural styles which are reinforcing each other, Dobruja gives the world the gift of a special historical, cultural, spiritual and scientific symphony.

3.2.1 A Kaleidoscope of Dobrujan Personalities

3.2.1.1 Members of the Romanian Academy of Dobrujan Origin

PETRE T. FRANGOPOL was born May 26, 1933, at Constanţa and he is a Chemist, Honorary Member of the Romanian Academy (24 October 2012). (Rusu 2016, 626–7) He studied the radioisotopes, radio pharmaceutics the marked organic compounds, organic scintillators, stable free organic radicals, spin markers, the modification of bio-membrane functions and structure under local anaesthetics. Petre T. Frangopol introduced as a Romanian premiere chemical, physical and mechanical methods in engineering. He introduced new methods of research in Physics and Chemistry. Petre T. Frangopol introduced also the scientometric methods in the implementation of the database „Science Citation Index" (1998) at the National Council of Scientific Research in Higher Education (1998). Professor Frangopol was actively involved in science policies and wrote in this respect 5 volumes titled *Mediocritate şi excelenţă – o radiografie a ştiinţei şi a învăţământului din România/Mediocrity and Excellence – a radiography of science and higher education in Romania*. In 2004 he published *Elite ale cercetătorilor din România: matematică – fizică – chimie/The Elites of Romanian Research in Mathematics, Physics, Chemistry*. He was awarded "C. Miculescu" Prize of the Romanian Academy (1990). (Rusu 2016, 626–7)

ARAM M. FRENKIAN (1898, Constanţa –1964, Bucharest) was a Romanian philosopher and linguist Post Mortem Member of the Romanian Academy (March 24, 2006). He was Head of Department at the Institute of Logic of the Romanian Academy (1964), important author in many of contemporary publications („Codrul Cosminului", „Făt Frumos", „Revista de filosofie", „Revue des études indo-européennes", „Studii clasice", „Studii de literatură universală" etc.) and preoccupied by problems of esthetics, especially by the relation of art with the theory of knowledge, illustrated in numerous books such as *L'Art et la connaissance*, 1922; *Mimesis şi muzica. O contribuţie la estetica lui Platon şi Aristotel*, 1932. Professor Frenkian was dedicated to the study of Ancient Greek philosophy: *Études de philosophie présocratique* (2 vol., 1933–1937); *Héraclite d'Ephèse* (1933); *Le ré alisme grecque* (1939); *Le postulat chez Euclide et chez les modernes* (1940); *La mé thode hippocratique dans le „Phèdre" de Platon* (1941); *L'Orient et les origines de l'idéalisme subjectif dans la pensée éuropéenne* (1946); *Scepticismul grec şi filosofia italiană* (1957); *Înţelesul suferinţei umane la Eschil, Sofocle şi Euripide* (posthumous, 1969). His creation reserved a special attention for the universe of the poetry of Homer: *Le Monde homérique. Essai de protophilosophie grecque* (1934);

Le Problème homérique (1935); *Epopeea lui Gilgamesh şi poemele homerice* (1950). Academician Frenkian translated in Romanian from the works of Aristotle, Sextus Empiricus, Plotin, Eschil, Sophocles, Plato and other classics. His inclinations towards mathematics are pregnant in several studies and articles, such as: *Studii de matematică sumero-akkadiană*, 1953; *Le postulat chez Euclide et chez les modernes*, 1940. (Rusu 2016, 628).

NICHOLAS GEORGESCU-ROEGEN (Nicolae Georgescu) (1906, Constanţa – 1994, Nashville, S.U.A.) was an economist and "father of ecological economy and bioeconomy" as well as a mathematician of Romanian origin, USA citizen. (Rusu 2016, 651–2) Honorary Member of the Romanian Academy since July 3rd, 1990. He was also a specialist in statistics and contributed to the volume dedicated to economy in *Enciclopedia României* (1938–1943, coord. Dimitrie Gusti). He emigrated in the USA in 1948 and continued his activity, highly recognized in the above mentioned fields – "Distinguished Professor Emeritus" of Vanderbilt University (Nashville). Among his numerous publications we are mentioning selectively: *Toward a human economics* (1974); *Mechanistic dogma and economics, Methodology and Science* (1974); *Energy and Economic Myths* (1975); *Bioeconomic aspects of entropy* (1975); *Technology and economic policy* (1975); *Economics or bioeconomics* (1976); *Energy and economic myths. Institutional and analytical economic essays* (1976); *The Steady State and Ecological Salvation* (1977); *Bioeconomics: a new look at nature of the economic activity* (1977); *Matter matters too* (1977); *Prospects for growth: changing expectations for the future* (1977); *The role of matter in the substitution of energies* (1977); *Écologie et politique* (1978); *Sun! A handbook for the solar decade* (1978); *The feeding web: issues in nutritional ecology* (1978); *Matter: a resource ignored by thermodynamics* (1978); *Technology assessment: the case of the direct use of solar energy* (1978); *Energy and matter in mankind's technological circuit* (1978); *Myths about energy and matter* (1978); *Energy policy: the global challenge* (1979); *Demain la décroissance: entropie – écologie – économie* (1979); *Energy analysis and economic valuation* (1979); *Methods in economic science* (1979); *Entropy and economic myths* (1980); *Energetic dogma, energetic economics and viable technologies* (1982); *La degradation entropique et la destinée prometheique de la technologie humaine* (1982); *Energia e miti economici* (posthumous, 1998) etc. Member of the Academy of Sciences and Letters from Toscany, Honorary President of the European Society of Bioeconomy Studies, honorary member of the USA Economics Association, member of the American Academy of Arts and Sciences, honorary member of „Phi-Beta-Kapa" at Vanderbilt University and *Doctor honoris causa* of Florence and Strasbourg. (Rusu 2016, 651–2).

MARIAN TRAIAN GOMOIU (1936, Bazargic, Bulgaria) is a biologist and an oceanologist, academician since 2015 (Correspondent Member since 1993). (Rusu 2016, 695–6) He studied in Bulgaria, then Romania (Constanţa and Cluj), then in Denmark (Zoological Museum, Institute of Physiology and Marine Research Station Helsingor, 1969–1970) and in the USA (Duke University Marine Laboratory Beaufort, North Carolina, 1974). Since his PhD in 1973 he worked as a researcher at the Oceanology Laboratory, Constanţa, at the Biology Research Center of the

Romanian Academy, which became the Institute of Biology "Traian Săvulescu" (1959–1970), at the Romanian Institute of Marine Research in Constanţa, nowadays titled "Grigore Antipa" National Institute of Marine Research and Development (1970–1990). He is tenured Professor at Constanţa University, Ecology (Ecology Department) and PhD advisor; he was Governor of the Danube Delta Biosphere Reservation (1990–1993) and vice-General Director of the Romanian Marine Geology and Geoecology Center (1994–2009). His research approached zoological marine taxonomy, acquatic ecosystems, ecological prognosis, studies of impact, environment protection and nature preservation etc. In biological ecology his works approached the benthos and mainly the molluscs and he brought ecological contributions of descriptive and comparative nature to the assembly of the benthal or autectologia biocenosis assembly, as the first Romanian researcher who made direct observations on the componence of the bental biocenosis of the sea, through scuba-diving. He perfected the methodology of research for benthos and he contributed importantly to the knowledge of the phenomenon of the eutrophication of the Black Sea and his ecological research of marine fauna was accompanied by the problem of ecological revigoration of the marine areas of medium depths by the construction of artificial recifes and he conducted many national and international research projects concerning Black Sea ecosystems. Academician Gomoiu is member in the redaction colleges of several scientific publications: *Journal of Romanian Biology-Zoology*; *GeoEcoMarina*; *Analele Universităţii «Ovidius» Constanţa, Biologie*; *Analele Universităţii din Oradea. Fasc. Biologie*; *Travaux du Muséum National d'Histoire Naturelle «Grigore Antipa»* etc. The results of his research are in over 200 scientific works published in Romania (150 articles and books) and abroad (50 works), among which, more recently, are: *Spatial trends in sediment structure and benthic activity in relation to the Danube plume on the Black Sea continental shelf* (1999); *Naval transport development and marine ecosystems disturbance* (2000); *Biomass and size composition of the comb jelly Mnemiopsis sp. in the northwestem Black Sea during spring 1997 and summer 1995* (2001); *Benthic Nutrienr Cycling and Diagenetic Pathways in the North-western Black Sea* (2002); *The Black Sea – a Recipient, Donor and Transit Area for Alien Species* (2002); *New Approaches in the Assessment of the Black Sea Ecosystems* (2004); *Aperçu écologique sur les zones humides. Cas particullier: Delta du Danube* (2004); *Restoring the Black Sea in times of uncertainty* (2005); *Influence of the Danube River inputs on C and N stable isotope ratios of the Romanian coastal waters and sediment (Black Sea)* (2007); *On the specific and ecologic biodiversity of the Danube River – Black Sea Canal (DRBSC)* (2008); *Present state of benthic ecosystem in Razelm-Sinoie Lagoon Complex (RSLC)* (2008); *Recovery or decline of the northwestern Black Sea: A societal choice revealed by socio-ecological modeling* (2009); *Zonele umede – Abordare ecologică. Studii de caz: Dunărea – Delta Dunării – Câmpia de Vest a României* (2010); *Investigating hypoxia in aquatic environments: diverse approaches to addressing a complex phenomenon* (2013) etc. (Rusu 2016, 695–6).

He took part in national and international oceanological expeditions and in 2003 led, as Chief Scientist, in the Black Sea, at the bord of the oceanological research ship of the Bulgarian Academy of Sciences, "Akademik" the international expedition "The control of eutrophication, the dangerous substances and adequate measures to restore the ecosystem of the Black Sea". President of the National Committee of the International Union of the Biological Sciences and of the Biology Division for the Environment in this Committee, President of the Commission of Oceanology and Limnology of the Romanian Academy, Vice- President of the Romanian Society of Ecology, member of the Commission of Ecology of the Romanian Academy of the Romanian Society of Ornithology, of the Romanian Society of Biological Sciences, of the International Commission for the Scientific Exploration of the Mediterranean Sea (CIESMM), of the Italian Macalogical Society, of the International Association for the Study of Meiobenthos, of the Romanian Society of Limnology, of the Romanian Society of Ichthyology, of the USA Association for the Development of Science, of the Nord American Society of the Specialists in Benthos etc. He received Professor of honour distinction of the "Al.I. Cuza" University, Iaşi, Biology Faculty; *Doctor honoris causa* of "V. Goldiş" University, Arad. He was distinguished with the "Emanoil Teodorescu" Prize of the Romanian Academy (1987), with the special Prize at "Ovidius" National Book Show Room in Constanţa (2003) for the volume *Ecologie. Metodologii pentru ştiinţele ecologice*, as well as "The 2009 Black Sea Medal" "for remarkable contributions to the protection of Black Sea", awarded by the "Permanent Secretariat of the Commission on the Protection of the Black Sea against Pollution". He received the "Scientific Merit" diploma from the Academy of Sciences of Moldova Republic. (Rusu 2016, 695–6).

LUCIAN GRIGORESCU (1894, Medgidia, Constanţa County – 1965, Bucharest) was a painter, a participant in the National Integrity War in Dobruja (1916) and Moldavia (1917) and a Correspondent Member of the Romanian Academy since November 2, 1948. (Rusu 2016, 711) He benefited from the French school superior education and he was influenced at first by André Derain and then by impressionism. Lucian Grigorescu was mainly a landscape painter, known throughout Europe for his sensitivity to colour and for the bright harmonious tones of his works. Main exhibitions: Paris Official Show Room and Bucharest Exhibition (1927), open at the Congress of the Latin Press; Iaşi, 1918; Bucharest, 1920, 1921, 1934, 1935, 1937, 1938, 1940, 1942, 1946; Paris, 1926, 1937, 1961; Berlin, 1926; Haga, Amsterdam, Brussels, 1936; Bern, Stockholm, 1948; Minsk, 1959; Budapest, 1959, 1962; Belgrad, Bratislava, Prague, Cairo, Alexandria, 1960; Ankara, Istanbul, Damasc, 1961; Dresden, 1963; Venetia Biannual, 1942, 1956. Important works: *Stejari pe malul Neajlovului, Comana, Femeie stând, Autoportret, Peisaj din Mangalia, Peisaj din Balcic, Vechi cartier în Bucharest, Catedrala Notre Dame, Turnul Bărăţiei, Amatoarele de artă, Piaţă din Cassis, Peisaj din Martigues, Natură moartă cu râşniţă şi fructe, Natură moartă cu pepene galben, Arlechin, Răsărit de soare, Interior cu statuie albă* etc. State Prize Laureate (1955), "Master Emeritus of Arts" and "Artist of the People" (1965). (Rusu 2016, 711)

EUGENIU IVANOV (1933, Dorobanţu, Constanţa County) is a Romanian physicist and Correspondent Member of the Romanian Academy since 1996. PhD in Physics under the coordination of Horia Hulubei – topic: *The Study of Izomere*

States Sn^{115} excited by the reaction In^{115}(p,n). (Rusu 2016, 842–3) Stages of specialization completed in U.S.S.R., Italy and Germany and a lifework dedicated to the cyclotron from Măgurele Platform, initiated and then coordinated by him. He was visiting professor at the Hahn-Meitner Institute in Berlin (in 1975 and 1976). He elaborated the method of the pulse fascicule at the cyclotron which was undertaken afterwards at TANDEM accelerator; he established a cryogenics laboratory, a Laboratory of Hyperfine Interactions recognized worldwide as prestigious in the field. He conducted research collaboration projects with institutes and universities in Erlangen, Konstanz, Lyon and Orléans and among the applicative researches conducted at the cyclotron we are mentioning the studies of the solids and the iradiation with rapid neutrons in biological purposes. During more than 40 years of scientific research he discovered over 100 new nuclear izomers, with lifespans of micro- and mili- seconds; he conducted measurements of nuclear magnetic moments and nuclear and quadrupolar electrical moments, permitting to obtain informations regarding the nuclear structure, especially for the nucleons with valence around the magical numbers. Using the pulse fascicule technique he perfected nuclear methods to study the dynamics of the punctual form irradiation imperfections in metals; he also studied the gradients of the electrical fields in binary metalic materials, using nuclear probes in excited nuclear states. He elaborated many techniques with several applications tribology, medicine, biology and environment and published important studies: *O metodă simplă de obţinere a impusului zero la Ciclotron* (1962); *Short-Lived Isomers Observed in Alpha-Particle Bombardaments of Natural Elements* (1966); *Nuclear isomers with half-lives in the 30–3000 μs range, excited in 24 MeV alpha-particle bombardment on natural targets* (1967); *Lifetime and g-Factor of the 181 keV Level in ^{78}Br* (1971); *Quadrupole Moments of High Spin Isomeric States in Sn Isotopes* (1976); *Radiation Damage Effects of the Quadrupole Interaction of Tin in Cadmium* (1977); *Metodă rapidă de analiză a azotului pentru determinarea conţinutului în proteine al cerealelor* (1985); *Studiul compoziţiei elementare a unor mostre de sol lunar prin metode nucleare la Ciclotronul IFIN* (1986). (Rusu 2016, 842–3)

GEAVIT MUSA (1931, Palazu Mare, Constanţa County – 2010, Bucharest) was a physicist, Correspondent Member of the Romanian Academy since 2009. (Rusu 2016, 178–9) He established new laboratories of research at “Ovidius” University and he sustained a top scientific activity in plasma physics and its applications in technical domanins, in the conversion of the thermic energy in electrical energy (he obtained a higher efficiency generator), in physical processes of ultra high vacuum (Comşa-Musa vacuum pomp) and in the study of the optical properties of an extended range of systems (the opto-galvanic effect). He studied monocolor plasma displays and established a pilot line for their production at Cinescope Industries, Bucharest and his research led to the discovery of the thermal ionic arch in vacuum, obtaining plasma with special properties allowing for the formation of thin adherent, low rugosity and compact nanostructured layers. He emphasized the “M effect”, consisting in the reduction of the emission specter to only one line and his research resulted in new approved products: stabilovolt tubes, tritium selfluminescent tubes, stroboscopic tubes with special characteristics, signaling lamps, detecting tubes with flame. He elaborated new technologies, such as: plasma generated ultrafine dusts of TiO_2; the synthesis of acetiliene in carbon in plama jet etc. and published numerous specialized studies: *The dielectric barrier discharge- a powerful microchip plasma for diode laser spectrometry* (2001, in collaboration); *Spectral plasma temperature determination of the thermionic vacuum arc in the titanium vapors* (2001, in collab.); *Diode laseraided diagnostics of a low pressure dielectric barrier discharge applied in element selective detection of molecular species* (2002, in collab.); *Thermionic Vacuum Arc – a new method for thin film deposition* (2002, in collab.); *Polar recombination (ion-ion recombination) as a main process explaining M-effect* (2003, in collab.); *Diamond like nanostructured carbon film deposition using thermionic vacuum arc carbon plasma* (2004, in collab.); *Studies on the Thermionic Vacuum Arc discharges in the vapors of Cu-Ag and Cu-Sn alloys* (2005, in collab.); *Thermionic Vacuum Arc (TVA) – Carbon thin film deposition* (2005, in collab.) etc. He was the President of the Section of plasma physics of the Romanian Physics Society, awarded with "C. Miculescu" Prize of the Romanian Academy. (Rusu 2016, 178–9)

VIRGIL TEODORESCU (1909, Cobadin, Constanţa County – 1987, Bucharest) was a writer and a Correspondent Member of the Romanian Academy since 1974. (Rusu 2016, 716) He edited journals such as "Era nouă", "Fapta", "Reporter", "Tânăra generaţie" and had a literary debute at "Bilete de papagal" under the pen name Virgil Rareş (1928) and he constitued the Romanian surrealist group, together with Gherasim Luca, Paul Păun, Gellu Naum and D. Trost. He published the volumes: *Poem în leopardă* (1940); *Diamantul conduce mâinile* (1940, in collab.); *Blănurile oceanelor* (1945); *Critica mizeriei* (1945, in collab.); *Butelia de Leyda* (1945); *Infra-Noir* (1947, in collab.); *Au lobe du sel* (1947); *La provocation* (1947); *Scriu negru pe alb* (1955); *Drepturi şi datorii* (1958); *Semicerc* (1964); *Rocadă* (1967); *Corp comun* (1968); *Repausul vocalei* (1970); *Vârsta cretei* (1970); *Poemul întâlnirilor* (1971); *Sentinela aerului* (1972); *Ucenicul nicăieri zărit* (1972); *Heraldica mişcării* (1973); *Poezie neîntreruptă* (1976); *Ancore lucii* (1977); *Armonia contrariilor* (1977); *Legea gravitaţiei* (1979); *Culminaţia umbrei* (1980); *Cât vezi cu ochii* (1983); *Un ocean cu licheni, urmat de Poemul regăsit* (1984) etc., but he also wrote a theatre play in one act (*Pisica de mare*; *Dreptatea mării*) and translated from the works of Paul Éluard, A. S. Puşkin, Alain Prévost, Henryk Ibsen, Antioh Cantemir, Guillaume Apollinaire, Prosper Mérimée, William Shakespeare, Romain Rolland etc. He was Vice-President (1972–1974) and President (1974–1977) of the Romanian Writers Union and he was distinguished with "Tudor Vladimirescu" Order, class I (1984). (Rusu 2016, 716)

KRIKOR H. ZAMBACCIAN (1889, Constanţa – 1962, Bucharest) was an art critic and collector, Correspondent Member of the Romanian Academy since 1948. (Rusu 2016, 870–1) He visited the main European museums and he was a friend of the great Romanian artists of his times – Alexandru Ciucurencu, Nicolae Dărăscu, Iosif Iser, Theodor Pallady, Gheorghe Petraşcu, Camil Ressu, Jean Al. Steriade, Francisc Şirato, Nicolae Tonitza etc. – who knew and appreciated him for his vast knowledge of the arts. The fortune inherited from his parents he invested in the works of art, collecting over the years an impressive collection of art works donated to the Romanian state in three successive stages: 1947, 1957 and 1962. He donated inclusively the house where he lived, a house built according to the project of the architect C. G. Galin, which became a museum. He authored several books: *Pagini de artă* (1938; 2nd ed. in 1943, 3rd ed. in 1965); *N. Grigorescu* (1945); *Gh. Petraşcu* (1945); *Theodor Pallady* (1945); *Nicolae Tonitza* (1955); *Cornel Medrea* (1957); *Însemnările unui amator de artă* (1957; 2004, 2nd ed.); *Corneliu Baba* (1958); and he signed also numerous articles for journals and magazines, dedicated to the Romanian artists and their exhibitions. (Rusu 2016, 870–1)

ROMEO ŞTEFAN BELEA (1932, Tulcea, a county and a municipal in the North of Dobruja, near the Danube Delta) is architect and a Correspondent Member of the Romanian Academy since 2010. (Rusu 2016, 163–4) After his PhD in Architecture in 1973 he secured a Ford grant for urbanism and territorial improvement at Brussels in 1976 and then he became a remarkable presence at the national (Bucharest, Craiova, Iaşi, Piteşti, Ploieşti) and international (Austria, Germania, Maroc, Polonia, Siria) architecture contests. He has designed the National Theatre in Damascus, a high building of luxury apartments in Beirut, the Olimpic Pool, the multifunctional Arena and the Sports Hall in Tripoli, “Ouzoud Waterfall” Hotelul in Maroc etc. He wrote, in collaboration, the volume *Desenul în arhitectură, construcţii şi urbanism* (1962). He is a member of the Romanian Union of Architects, founding member of the Romanian Order of Architects, member in the Urbanism and Territorial Improvement Commissions in the Ministry of Transportation, in the Town Hall of Bucharest City, sector 1 Mayor’s Office, distinguished with “Work Order”, class III (1960) and class II (1970), the Cultural Distinction of the Romanian Academy (2001), the National Order “Faithful Service”, Chevalier degree (2002), “Academic Merit” Diploma of the Romanian Academy (2005). (Rusu 2016, 163–4)

CONSTANTIN I. BRĂTESCU (1882, Câşla, called now Mineri, Tulcea County – 1945, Bucharest) was a geographer and Correspondent Member of the Romanian Academy since 1919. (Rusu 2016, 370–1) After his PhD in 1920 he was a Dean at the Sciences Faculty in Cernăuţi (1930–1933) and a Professor at the Faculty of Sciences in Bucharest (1938–1945) and he was one of the founders of the journals “Arhiva Dobrogei” and “Analele Dobrogei”, of the “Dobrogea” Cultural Society and among the organizers of the Regional Museum of Dobruja. Professor Brătescu was a promotor of the conceptions of regional physical geography, applied for the first time in the analytical study of Dobruja, he elaborated an original theory concerning the dating of terraces, as well as of the level oscillations of the waters and of the Black Sea basin during Quaternary, and he inaugurated in the geomorphological research the morphoclimatic, on the basis of the fossil soils. Professor Brătescu championed the establishment of the balance between general and regional geography, giving precedence to the latter. The results of research were published in numerous books and studies, among which: *Forme de relief din Muscel* (1911); *Metoda geografică şi cercetările etnografice* (1913); *Lacul Mangalia* (1915); *Mişcări epirogenetice şi caractere morfologice în bazinul Dunării de Jos* (1920); *Contribuţiuni la studiul Deltei dunărene* (1921); *Lacul Taşaul* (1922); *Delta Dunării. Geneza şi evoluţia morfologică şi cronologică*

(1923); *Noile numiri de sate din Dobrogea Veche* (1924); *Istoria, obiectul şi metoda geografiei* (1925); *Coasta de răsărit a Constanţei* (1926); *Pământul Dobrogei* (1928); *Clima Dobrogei* (1928); *Profile cuaternare în falezele Mării Negre* (1933); *Asimetria văilor* (1937); *Morfologia Cadrilaterului* (1937); *Contribuţii la cunoaşterea văii Nistrului* (1941); *Oscilaţiile de nivel ale apelor şi bazinului Mării Negre în Cuaternar* (1942); *Evoluţia Câmpiei Române* (1944) etc. and he was a Member of the Academy of Sciences in Bucharest (1935). (Rusu 2016, 370–1)

ALEXANDRU CIUCURENCU (1903, Tulcea – 1977, Bucharest) was a painter and a Correspondent Member of the Romanian Academy since 1963. (Rusu 2016, 370–1) He was a student of George Demetrescu-Mirea and Camil Ressu, and later, in Paris, at the Julian Art Academy, where he studied with André Lhote, working in his studio and he was nominated Professor (1945) at the Painting Academy, next to Camil Ressu and Cornel Medrea. Between 1957 and 1968 he was the Rector of "N. Grigorescu" Institute of Arts in Bucharest and after his official debute in 1930 at the Official Show Room of Arts; in 1934 he had his first personal exhibition and then many more, almost annually. Since 1964 he had ample retrospectives in the country (1964, 1972) and abroad (Athens, Belgrad, Berlin, Budapest, Cairo, Damascus, Edinburgh, London, Moscow, Paris, Prague, Sofia, Tōkyō, Warsaw, Venice, Wien, Zürich etc.). His works – portrets (*Sică Alexandrescu*, *Ion Dumitrescu*, *Gh. Oprescu*, *Dr. N. Dona*, *K. Zambaccian*, *Mihail Jora*, *Alfred Alessandrescu* etc.), compositions (*Treieriş*, *Epilogul răscoalei*, *Femeie cu chitară*, *Femeie citind*, *Spălătoreasa*, *Călcătoreasa*, *La oglindă*, *Pod peste Dunăre*, *Jucătorii de şah*, *Odalisc*ă, *Femeie în gri*, *Peisaj cu căpiţe*, *Femeie culcată* etc.), landscapes (*Peisaj din Tulcea*, *Peisaj la Şelimbăr*, *Peisaj de iarnă*, *Peisaj din grădină*, *Sere la Mogoşoaia*, *Seră la Căciulaţi* etc.), still lifes and flowers (*Natură statică cu flori*, *Natură statică cu ulcior şi ceapă*, *Ciclamene*, *Cărţi şi pipă* etc.), odalisques etc. are included in important museums in Bucharest, Braşov, Cluj, Craiova, Iaşi, Sibiu, Târgu Mureş etc. He was a member and secretary of the Union of the Artists in România. For his activity he was distinguished with the "Work Order", class I (1948), with the "Ion Andreescu" Prize of the Romanian Academy (1956), with the Order "Steaua R.P.R.", class III (1959) and he received the titles "Master Emeritus of Art" (1956) and "Artist of the People" (1964). (Rusu 2016, 370–1)

RADU CODREANU (1904, Tulcea – 1987, Bucharest) was a biologist and a cytologist, academician since 1974 (Correspondent Member since 1963). (Rusu 2016, 384) Follower of Emil Racoviţă both at the Department of General Biology and in the field, in general, he made a series of expeditions investigating hydrobiology, the zoology of invertebrates and the evolution of the organisms in various zoological stations: Wimereux, Roscoff, Paris, Grenoble, Monaco (1924–1939). In 1939 he defended his PhD thesis at Sorbonne, then he was Professor of general biology and invertebrates zoology at several universities in the country, he contributed to the reorganization of the Research Biological Station at Sinaia and he discovered new species and genera (*Frontonia branchiostomae*, *Polycladodes voinovi*, *Palaeodendrocoelum romandanubiale*, *Ctenicella amesophleba* etc.). He published over 230 works concerning invertebrates, parasitology, theoretical general biology, cytology and the systematic study of pretiste, systematic morphology and the zoogeography of the turbelariate, Black Sea fauna, especially on *Riocefali* and *Epicaride*, parasite shellfish, which phylogenetic relations he studied in comparison with their new forms from the Mediterranean Sea, Atlantic Ocean, Red Sea and Indian Ocean, among which *Données biologiques et statistiques sur un Pagure Diogenes pugilator (Roux) de la Mer Noire et ses crustacés parasites* (1941); *Evoluţia fiinţei organizate* (1944); *Biologia generală. Cercetare istorică şi cauzală a formelor organizate* (1946); *Ecologia marină* (4 vol., 1969) etc. and he edited two important works: *Probleme de biologie evoluţionistă*, *taxonomie şi speciaţie* (1978) and *Probleme de ecologie terestră* (1978). He was a Member of the Society of Zoology in France, a Member of the Association of Protistologists of French language, a Member of the Association of the Protistologists and he was *Professor Emeritus* (1964). (Rusu 2016, 384)

GEORGE GEORGESCU (1887, Sulina, Tulcea County – 1964, Bucharest) was a bandmaster and a Correspondent Member of the Romanian Academy since 1963. (Rusu 2016, 648–9) George Georgescu was part of the string quartet of Henri Marteau as a cellist, but he abandoned this carreer after an accident in 1916. He specialised at Berlin, Hochschule für Müsik, in the art of conducting with Arthur Nikisch and Richard Strauss and he debuted in 1918 at Berlin Philarmonica as a conducter. George Georgescu was the bandmaster of "George Enescu" Symphonic Orchestra in Bucharest, for more than four decades (1920–1944, 1947–1964); he was director of the Romanian Opera (1922–1926, 1930–1933, 1939–1940) and conductor at the New York Philarmonica (1926–1927). He approached a vast and varied repertoire: from the preclassical music to the contemporary (Romanian and foreign) music and he left an impressive discography (the integral of the symphonies of Ludwig van Beethoven, and works of George Enescu, Johannes Brahms, Richard Strauss, Richard Wagner, Hector Berlioz, Franz Schubert, Paul Dukas, Maurice Ravel, Theodor Rogalski, Mihail Jora, Alfred Alessandrescu etc.). He completed numerous tours, alone or with Bucharest orchestra, in great musical centers, European and American, as one of the most important conductors of his times and he was distinguished with the "Work Order", class I and he was "Artist of the People". (Rusu 2016, 648–9)

ION JALEA (1887, Casimcea, Tulcea County – 1983, Bucharest) was a sculptor academician since 1963 (and Correspondent Member of the Romanian Academy since 1948). (Rusu 2016, 852) He debuted with the drawing *The Proletarian* in the magazine "Vremuri noi". In 1915 had the first personal exhibition with works inspired from the Romanian fairytales (*Sfarmă-Piatră, Briar, Remuşcarea* etc.). He followed Julian Academy in Paris (1915–1916), where he encountered Auguste Rodin and Antoine Bourdelle. He took part in the War of National Integrity, Moldavia front, where after an injury he lost his left arm, however, the memory of war, its horrors and the gratitude for the heroes fallen on the battle field appear in his war inspired sketches presented in a collective exhibition organized at Iaşi by the war artists and later in the *Monument of the French soldiers fallen on Romanian territory* (Bucharest, 1922); the *Monument of railway heroes* (Bucharest, 1923); the *Monument of the Romanian soldiers, former prisoner of war in Germany* (at Dieuse, France), as well as in the bas-relief of the *Mărăşeşti Mausoleum*, realized with Cornel Medrea. His work was displayed at the Romanian Atheneum, at the Official Show Room, at the House of Arts, at "Dalles" Hall. Since 1932 until 1942 he was Professor at the Belle Arte Academy in Bucharest, and then Director in the Ministry of Arts. The dominant themes in his artistic creation are mythological and folkloric: *Hercule doborând centaurul, Minerva, Bacante, Arcaş odihnindu-se*. The vocation of monumental sculpture found fulfilment in: *Monumentul eroilor ceferişti* (Bucharest, 1923, with Cornel Medrea); *Lupta lui Hercule cu Centaurul* (Bucharest, 1925); *Spiru Haret statue* (Bucharest, 1935); *Monumentului infanteriei* (Bucharest, 1936), the busts of *Mihai Eminescu* and *Octavian Goga* (Bucharest, 1943), the statues of *George Enescu* (Bucharest, 1971) and *Mircea cel Bătrân* (Tulcea, 1972), the equestrial statue of *Decebal* (Deva, 1978), the statuary group *Dragoş Vodă şi Zimbrul* (Câmpulung Moldovenesc, 1978) etc. He decorated with statues and reliefs the pavilions of Romania at the world exhibitions from Paris and New York. In his small dimension sculptures he was inspired by the life of workers and peasants (*La sapă, Muncitori cărând saci, Cu cobiliţa, Lăptăresele* etc.). He was member and then president of the Union of Artists in Romania (1957–1969) and he was awarded at the International Exhibition from Barcelona (1932) and at the International Exhibition from Paris (1937); "Master Emeritus of Art" and "Artist of the Pepople". (Rusu 2016, 852)

GRIGORE C. MOISIL (1906, Tulcea – 1973, Ottawa, Canada) was a mathematician and academician since 1948. (Rusu 2016, 131–2) After his PhD in 1929 he had study stages in Paris (1930–1931, 1932) and in Rome (1931–1932) and in 1931 he became Docent in Mathematics; since 1939 he was Professor of the first modern algebra course in Romania at Iaşi University in 1939. He taught also logic and the theory of demonstration, topology etc. At Bucharest University, invited in 1942, until 1973, he taught at the Faculty of Sciences, then at the Faculty of Mathematics and Physics and at the Faculty of Philosophy. Professor Moisil had courses of mathematical analysis at the Institute of Geology and Technical Mining in Bucharest (1948–1951), organized the Computer centre of Bucharest University (in 1962) and he was nominated Honorific Director; Head of Department for Applied Albegra at the Institute of Mathematics of the Romanian Academy (1949–1973). Grigore C. Moisil was the ambassador of Romania in Turkey (1946–1949). He founded the School for the Algebra of Logics and Algebraic Theory for Automatic Mechanisms and he elaborated foundamental studies of continuum mechanics, mathematical analysis, the partial differential equations theory, mathematical physics, the algebra theory of automatic mechanism, differential geometry, the theory of probabilities, mathematical linguistics etc. Professor Moisil was a pioneer of the application of the functional analysis in mechanics and in differential geometry and he studied continuum mechanics, quantum field mechanics and functional differential geometry. His research brought about interesting results in non commutative algebras, in the representation of the infinite Abelian groups and he was preoccupied with the application of the algebraic methods in mathematical logic (1936–1946); the latter represented one of the predilect directions of research, whithin which he studied the algebra of logic and the algebraic structure for the propositional calculus; he built an algebraic model for the tri- and tetravalent Lukasiewiczian logics, known nowadays as the "Lukasiewicz-Moisil algebras". In 1960 he developed a pioneering activity in mathematical linguistics, studying the automatic computer translation of logical models of language and the automatic cataloguing and indexation of published works and he published numerous works, among which *Logique modale* (1942); *Fundamentele matematicii* (1949); *Introducere în algebră. Inele şi ideale* (1954); *Teoria algebrică a mecanismelor automate* (1959, translated in Czech, English and Russian); *Circuite cu tranzitori* (2 vol., 1961–1962); *Teoria algebrică a mecanismelor automate* (1962); *Funcţionarea reală a schemelor cu contacte şi relee* (1965); *Teoria algebrică cu contacte şi relee* (1965); *Încercări vechi şi noi de logică neclasică* (1965); *Zastovanie algebr Lukasiewicz do teorii ukladov po przekaznikovo-stykovich* (2 vol., 1966–1967); *Elemente de logică matematică şi teoria mulţimilor* (1968); *Essai sur les logiques non chrysippiennes* (1972); *Lecţii despre logica raţionamentului nuanţat* (posthumous, 1975). Professor Moisil was a member in the redaction colleges of scientific journals such as *International Computing Center Bulletin*, *Automatisme*, *Journal de Mécanique* etc. and Member of the Academies of Sciences in Bologna, Messina and Warsaw, Member of the Royal Society of Sciences in Liège, of the International Institute of Philosophy in Paris, of the Mathematical Society in France, of the Association for Symbolic Logic in Oslo, Vice-President of the International Union of History and Philosophy of Science, and *Doctor honoris causa* of the Academy of Sciences in Bratislava. Professor Grigore C. Moisil was distingushed with the Bulgarian Order of Saints Cyril and Methodius; he was a Laureate of the State Prize (1964) and "Scientist Emeritus" (1964). (Rusu 2016, 131–2)

GHEORGHE MUNTEANU-MURGOCI (1872, Măcin, Tulcea County – 1925, Bucharest) was a geologist, geographer and soil scientist who became a Correspondent Member of the Romanian Academy since 1923. (Rusu 2016, 168–9) After his PhD in München in 1900 – *Über die Einschlüsse von Granat-Vesusianfels in dem Serpentino des Parângu-Massiv's (Rümänien)* – he worked in the Department of Mineralogy of Bucharest University and, in paralled, he taught high school physics and he elaborated hand books. Among these are *The Atlas of Geography* and *The Geography of Romania for the forth grade of High School*, considered the "first general scientific work of Romanian geography". Docent in Applied Mineralogy since 1903 on the basis of a monography concerning the ores of succinum in Romania and then he taught applied geography at Bucharest University (*On the ores and geological minerals in industry and agriculture*) and he was Head of the Agricultural Geology Department of the Institute of Geology in Bucharest (1906–1925). Since 1908 he was Professor of mineralogy and geology at the National School of Bridges and Roads (since 1920, The Polytechnic School and nowadays the Polytechnic University). He founded the Association for the Advancement of the Geology Sciences in the Carpathians (1922). His scientific research was focused on the geology of the central area of the Meridional Carpathians and he elaborated the first detailed geological map of Parâng mountain mass, with 20 separations of crystalline geological and sedimentary formations, including the main tectonic lines. Using optical and chemical analyses he defined a new mineral (which he named "lotriţ", from the name of the Lotru Mountain, and which was rediscovered afterwards by two American mineralogists in 1925 who called it "pumpellyt"). The regional research begun in Lotru and Parâng Mountains was continued in different parts of Oltenia region in Romania, especially in the Mehedinţi Plateau and Cerna Valley, in Godeanu and Banat Mountains and then in Timok Valley and in North West Bulgaria, and he was the first specialist to raise in the Romanian Carpathians the problem of physical strata overthrust and he was the first geologist who called the attention on the importance of the mass movements ("mezocreatice") in the formation of the whole Alpine range. He was the founder of the Romanian soil science school (see also the publications *Zonele naturale de soluri din România*; *La carthographie des sols en Roumanie*; *Études sur les sols arables de la Roumanie*). Professor Munteanu-Murgoci initiated the elaboration of the first soil general map, at a scale of 1/2,500,000, followed by correlative maps of flora and climate, on which basis were to be delimited the natural regions of Romania and his research included preoccupation for the economic aspects correlated with the geological research and contributed greately to the knowledge of the subsoil of the country, to the discovery and capitalization upon its riches. He was the first to research in detail geomorphology, stratigraphy, the tectonics of the hillside areas of Oltenia; he documented for the first time the conditions of oil ore in Oltenia (*Terţiarul din Oltenia cu privire la sare, petrol şi ape minerale*, 1907). Researching the geological matters regarding the oil and gas resources in Romania, he investigated the regions with salt geological structures in Muntenia and he elaborated studies of the succin ores, insisting on the specificity of the amber ores in Buzău region (*Zăcămintele succinului în România (Chihlimbar romanit). Monografia unui mineral din ţară*, 1902). He completed a geomorphological study of Northern Dobruja (*Cercetări geologice în Dobrogea nordică, cu privire specială la rocile paleozoice şi eruptive*, 1911), which consecrated him as a forerunner of a science which methods he applied before the genuine establishing of this scientific domain – Speleology or Spelaeology – investigating caves and karst features in the calcareous rocks in Romania and prepared descriptions of caves. He presented his research in over 200 works and together with N. Iorga and V. Pârvan he was a founder of the Institute of South-European Studies in Bucharest; in 1908, he founded *Revue du Pétrole*. (Rusu 2016, 168–9)

OREST TAFRALI (1876, Tulcea – 1937, Iaşi) was a historian and a writer who became a Correspondent Member of the Romanian Academy since 1936. (Rusu 2016, 695) After his PhD at Sorbonne in 1912 he was a Secretary of the National Museum of Antiquities (1904–1905) and Profesor of classical languages at "St. Sava" College in Bucharest (1905–1906); teaching assistant of Romanian language at École des Langues Orientales in Paris (1912–1913), and since 1913 Professor at the Department of Archeology and Antiquities of Iaşi University; as a substitute Professor at the Department of ancient History he gave a new impulse to the studies in the field (*The Historical Sources of the Greeks and the Romans*, Lectures, 1927). (Rusu 2016, 695) In 1916 he sustained the opening of a Museum of Antiquities at Iaşi University, the first of this kind in Moldavia. (Rusu 2016, 695) In 1927 he founded the journal *Arta şi arheologia*. Specialist in ancient history, archeology and

Byzantine studies he published numerous works, among which *Sur les réparation faites au VII^e siècle à l'église St. Demetrius à Salonique* (1900); *Mélanges d'arché ologie et d'épigraphie byzantines* (1913); *Evoluţia arheologiei şi rezultatele exploraţiunilor arheologice* (1913); *Bizanţul şi influenţa lui asupra ţării noastre* (1914); *La Roumanie transdanubienne* (1918); *Manual de istorie antică* (1921, in collab.); *La cité pontique de Dionysopolis* (1927); *Les tumuli de Callatis* (1928). Author of works concerning ancient Romanian art and Byzantine art in South-Eastern Europe: *Biserica domnească: datele clădirii şi decorării* (1915); *Iconografia Imnului acatist* (1915); *Les fresques de l'église St. Nicolas de Curtea de Argeş* (1919); *Manual de istoria artelor* (2 vol., 1922,1927); *Les fresques des é glises de Bucovina* (1924); *Le trésor byzantin et roumain du monastère de Poutna* (2 vol., 1925); *Le monastère de Soucevitza* (1929); *Monuments byzantins de Curtea de Argeş* (2 vol., 1931) etc. He debuted in with the short story *Axiopolis*, published in *Adevărul literar* (1903), and continued with the volumes: *Scene din viaţa dobrogeană* (1905); *Idyle din viaţa antică* (1935); *Povestirile lui Moş Vremelungă* (1937). Orest Tafrali was a Member of Honour of the Romanian Numismatic Society, a Member of the Academy in Athens (1913) and of the Archeology Institute in Sofia (1928), a Correspondent Member of „Kondakov" Institute in Prague (1930), a Member of Honour of the Association for Byzantine Studies in Athens (1931) and of the Association for the Advancement of Greek Studies in France. (Rusu 2016, 695)

3.2.1.2 Historical, Artistic and Ethnic Personalities

The Dobrujan constellation of historical, ethnic and artistic personalities are too numerous to exhaust here, however, many of them illustrate a historical symphony and confluence of ideals and lives, which makes them worth evoking, albeit partially. Among these, AHMET NURMAMBET (1893–1953), a Dobrujan-born Crimean Tatar, is regarded as an officer who had a brilliant career in the Romanian Army. (Agi-Amet 1999, 262–3) He was the father of the well-known traditional folk singer KADRIYE NURMAMBET. (Agi-Amet 1999, 262–3) His uncle, Col. REFIYÎK KADÍR inspired him to follow the military career. (Agi-Amet 1999, 262–3) In 1900 he was a student at the Military secondary school in Iaşi. In 1909, after graduation, he entered the military service and became second lieutenant of cavalry. The World War I found him in the 12th Roşiori Regiment, mounted unit, and he took part in the battles of Oituz and Mărăşeşti. Following the reorganization of the Romanian Army his regiment was included in the 40th Infantry Regiment, the 9th Infantry Division, initially stationed in Constanta, but then transferred to nowadays Dobrich, in Bulgaria. In historical turmoil, at the beginning of World War II in 1940, Romania lost Southern Dobruja to Bulgaria, and he was appointed as commander of a garrison Northern Medgidia where he lived with his family and where he had an accomplished military career, awarded military orders and medals. (Agi-Amet 1999, 262–3)

His uncle, Col. REFIYÎK KADÍR (1878, Constanţa – 1929, Dobrich) is esteemed as a hero of the Romanian Army, whose military career begun at the Military secondary school in Iaşi. Taken prisoner while fighting in World War I, by the end of the war, once released, he served in the garrisons of Chernivtsi and Kishinev and returned to Dobruja, he linked his name to the 40th "Călugăreni" Infantry Regiment in Pazarjik (Dobrich). He was a friend of Senator Selim Abdulakim and Nicolae Iorga. (Agi-Amet 1999, 142–3)

KADRIYE NURMAMBET (1933, Dobrich – 2009) was not just a Tatar, Crimean, Dobrujan folk singer and *The Nightingale of Dobruja*, a darling of the scene of Romanian Athenaeum, with discs released at Electrecord, in 1960, 1963, 1974, 1980, 1982, and 1989, a folklorist contributing to Golden Sound Archive of the Ethnography and Folklore Institute of Bucharest. (Wikipedia 2016a, b, c) She was also a lawyer educated at the University of Bucharest, and the first female Crimean Tatar lawyer in Romania (serving in the Constanta Bar Association). (Wikipedia 2016a, b, c).

EMIN BEKTÓRE (1906–1995) was a Dobrujan, Crimean and Tatar folklorist, ethnographer, lyricist and a militant for ethnic Tatar causes. (Wkipedia 2016a, b, c) He was educated in Romania, organized several Crimean Tatar folk groups, writing and directing school plays (*Bora*, *Kîrîm*, *Kók-kóz Bayar*). In 1930, in Constanta, he found the Crimean Tatar journal *Emel*. After a decade Bektóre immigrated to Turkey continuing there his Tatar folklore activities, teaching and initiating ethnography and folklore initiatives in Turkey. He contributed decisively to the inclusion of Crimean Tatar ethnic dance and music in the educational curriculum in the province of Eskişehir. (Wikipedia 2016a, b, c).

The historian of Dobrujan origin, KEMAL KARPAT (Kemal Haşim Ömer, born in 1923, at Turda), Professor and White House consultant (for Carter, Reagan and Bush, on Eastern matters), a polyglote (Romanian, Turkish, Tatar, English etc.) is especially proud of his roots. (Gazetarul 2015) He lives in the USA and he was recently celebrated by the Democratic Union of the Muslim Turkish Tatars in Romania, Bucharest branch. At the occasion he mentioned: "I left Romania 73 years ago, but I strived to cultivate my native tongue, the language in which I read hundreds and hundreds of novels, the language in which I initiated myself within the world of research and universal knowledge. I tried to keep the Romanian languagefor the love I felt for it, for its beauty and its sonorities. I was born in Dobruja and all my life I remained a Dobrujan. The land has its charms and the tremendous power to remain deeply in the souls of the people". His walk down the memory lane evoked the map of Dobruja in his study, the Carpathian Mountains in his soul and spirit (which he had never seen, but were evoked by his new name, Karpat, which he decided to adopt) and also the figure of the Romanian Queen Mary who left her heart at Balcic. After his PhD in Public and Political Law at the Law Faculty of the University in Istanbul, he begun his academic career in the USA where he lived since 1950. He had a PhD as well from the New York University, in 1957, where he became Government Professor (1962–1967). He was scientific researcher at Harvard University (1960–1961). Since 1967, he was Professor at Wisconsin University, until 2003, when he retired, aged 80, and with the academic title of *Distinguished Professor*. (Gazetarul 2015).

3.2.1.3 Spiritual Personalities

The erudite ARCHBISHOP OF TOMIS, TEODOSIE, is an outstanding complex personality, which combines theological science, philosophy and the art of oratory. A Plenary Member of the Academy of Romanian Scientists, the Section of Philosophy, Psychology, Theology and Journalism, Eminent doctrinarian theologian, he impresses by the oratorical gift, perfectly balanced in terms of idea and pathos, by the convincing argument and by the charm of genuine Romanian language, where the archaic and the modern elements meet to address both the soul and the spirit, to cultivate interfaith dialogue. (Marcus 2015) After the graduation of the Faculty of Theology in Bucharest, he dedicated himself to the monastic life, going upwards in church hierarchy and conducting, at the same time, educational, scientific and publishing activities. He owns two PhDs, in Theology with a thesis on *The Book of Psalms*, and in Musical Sciences with a thesis on *the music of the Old Testament*. As a Professor at the Faculty of Theology, at "Ovidius" University in Constanţa, he takes active part in national and international Congresses, seminaries, scientific sessions sustaining the spiritual development, the spiritual ideals and the spiritual unity of Romanians everywhere, as well as faith as a factor of spiritual balance for the human being, the necessary ecumenical approach of spirituality at Cernăuţi or Boian (Ukraine), at New York, Stockholm, Roma, Torino, Barcelona. (Marcus 2015) Archbishop of Tomis published 10 books for Bible study, concerning the pastoral missionary life of the Church, the life of the Christians in Dobruja, explanations of the Bible terms, or of the Holy Scripture in music. He sustains a rich journalistic activity as author and member of the committees of redaction of eight journals, specialized magazines and daily newspapers. He published over 50 articles in journals and over 600 articles in newspapers and magazines. He is involved in the development of civil society and in promoting the philanthropic spirit in Romania, taking care personally of 30 Christian foundations and associations with charitable missions. His theological research was materialized in writing and publishing books, articles, studies, but also in the papers presented at national and international congresses, seminaries and scientific sessions. The central theme of many of the papers presented is promoting the spiritual unity of the Romanians, through the strong ties of the Orthodox faith, which was proven as hearth of the continuity of the identity of the Romanian people wherever they are. (Marcus 2015) In 2002, the President of Romania awarded him the *Order of the Star of Romania in rank of Chevalier*. "Father, Dobruja awaits you for 2,000 years!" said Father Arsenie Papacioc to the Archbishop Teodosie when he was enthroned at Tomis, in 2001. One could say that the great confessor of Romanians was not wrong. From then and until now, the apostolic Dobruja has reborn. God gave him the grace and the power to stay his course. (Marcus 2015) Archbishop Teodosie founded several exquisite monasteries in Dobruja in serene environments suitable for recollection. Since his enthroning in Constanţa county were built 78 churches, 30 monasteries, three affiliates, 19 chapels and in Tulcea county 32 churches and 10 monasteries. Among the beautiful monasteries in Constanţa county we are mentioning Strunga (Annunciation Church), Crucea, St. Ioan Casian, St. Dionisie, St. Filip (Adamclisi), Colilia and the Ascension Monastery (from the International Cemetery of Military Honour from Mircea Vodă). People benefit from his Christian devotion at varied occasions – scientific sessions, retirement homes, underpriviledged children homes, detention places. (Chiriluţă et al. 2015).

An outstanding cultural achievement of Archbishop Teodosie is the male choir "Armonia" of the Archdiocese of Tomis, which often performs on the stage of the Romanian Athenaeum, Romanian Opera or at the Romanian Radio Hall, as well as abroad, at Jerusalem, in the USA, Switzerland and other countries. (Ciocioi et al. 2013) The choir obtained prestigious prizes such as the double gold medal at "World Choir Games" in 2012 in the USA, the great prize of the section Male Choir in 2013 at Graz, in Austria, two gold medals at the sections of Folklore and Male Choir and one at Sacred Music, at Riga, July 2014, la Riga – Latvia, gold medal and the grand prize at the section Male Choir and gold medal at Sacred Music, First Place and gold medal at Sacred Music at the World Music Olympics (the 8th World Choir Games), the trophy and the title of world champion at the Section Male Choir, Riga, Latvia, 5–12 iulie 2015, gold medal at the Section for Chamber Choirs at "European Choir Games" and "Grand Prix of Nationes" (Magdebourg, Germany), gold medal at the sections Chamber Male Choir and a cappella Sacred Music at the "World Choir Games", Sochi 2016. Also, under the Archbishop's supervision TEODOXA choir attained a higher level of interpretation and performance of the musical works, as well of the Church hymns as of the songs from the popular or international repertoire. Teodoxa obtained the gold medal (July 2015) at Magdeburg (Germany), at the "European Choir Games", at the Section for Chamber Choirs, gold medal at the Section Male Chamber Choir and silver at the Section for a cappella Sacred Music at the "World Choir Games", Sochi 2016. (Chiriluţă et al. 2015; Ciocioi et al. 2013).

At the initiative of the Archbishop of Tomis, June 2004, the Forum of the Three Religions was established. (Ionescu 2014) Constanţa was chosen especially because there one can find several religious denominations living together in harmony, mutual respect and understanding. Founders were Archbishop of Tomis, Teodosie, Monseniore Ştefan Ghenţa, of the Roman-Catholic Church and Bagij Sanghirai, the head of the Muslim Cult in Romania. A participant to the Forum was also Priest Steve Hugh from the World Forum and a representative of the mosaic cult. The common message was that the spiritual leaders should convince their faithful followers that "there is only one God, who wants to be peace". (Ionescu 2014).

ARCHBISHOP VISARION BĂLŢAT is the head of the younger Diocese of Tulcea, a decision sanctioned by the National Church Assembly meeting on the 4th of March 2005. His Grace Visarion Răşinăreanul was elected as Bishop of the Diocese of Tulcea on the day of the Annunciation in the year of salvation 2008, at the Episcopal Cathedral of Tulcea, with the participation of central and local authorities, of many believers from Tulcea and other areas of the country, of His Beatitude Patriarch Daniel assisted by a group of 12 bishops installed as titular bishop of Diocese of Tulcea Priest Visarion Bălţat, PhD. (Tulcea Orthodox Episcopate 2016) His excellency is a citizen of honour of Zărneşti and Răşinari cities. Archbishop Visarion Bălţat published over 200 articles in religious journals in the country, but also in regular publications. Among his books we mention: *Mergând* *învăţaţi*, Sibiu, 2001; *B.O.R. văzută de călătorii străini (sec. XV- XIX)*, Sibiu, 2001; *Logos şi Cultură*, Sibiu 2005. He received the Gold Medal "St. Ap. Pavel" from the Diocese of Veria (Greece) and other national and international diplomas and medals. (Selejan 2012).

BAGIJ SANGHIRAI, former Head of the Muftiate in Romanian, was followed by MUURAT IUSUF the current Head of the Muslim Cult in Romania (born August 18, 1977 at Medgidia, Constanţa County) was elected at September 15, 2005 when he was only 28 years old, the youngest in this office, with 19 votes of the 25 expressed by the members of Sura-Islam (a Synode Council) composed of 15 clerics, 8 laymen, the Mufti in office and the director of "Kemal Atatürk" Theological College. (Muftiyat 2016) He studied in Turkey where he graduated from the Theological High School of Edirne in 1994. Then, during 1995–2000, Muurat Iusuf followed the Faculty of Theology of the "19th May" University in Samsun. After graduation he worked in the service of the community. In Romania, he taught Islamic religion at "Constantin Brâncuşi" School in Medgidia and High Schools "Traian", "Ovidius" and at "Mircea cel Bătrân" National College in Constanţa and in 2001 he was nominated as Member of the National Commission for the elaboation of the national syllabuses programmes for the theological disciplines. Since 2001 he was Cult Consellor for the Mufti Muslim Office in Romania. He continued the graduate studies at the Faculty of Theology of the Valahia University în Târgovişte graduating the Master's with the thesis *Juridical Islamic and Christian Ethos in Dobruja*. At present he is a PhD candidate of the Faculty of Theology, "Ovidius" University, Constanţa, under the scientific coordination of Professor Priest Nicolae Dură, PhD, working on the thesis *Human Rights in conformity with the Islamic Law and the Canonic Law*. He is a speaker of Arab, English, Romanian and Turkish. (Muftiyat 2016).

His Scientific Master's and the PhD studies develop the idea that monotheistic religions have in common the ten commandments which are easing our lives and the pursuing of intercult good relations."What is a joy, for Dobrujan muslims, is that we are living with our Christian brothers in good convivial terms. we are proud of this model which His Excellency the Archbisop, myself, and the representatives of the other cults attempt to continue to promote and it is a source of pride that we are Romanian citizens and we can promote our religious identity on this Dobrujan lands, too", declared for *Constanţa NEWS* Mufti Iusuf Muurat. (Andrei 2016).

Another important idea in his social and religious activity as well as in his scientific works is the one captured in a few words by His Excellency the Archbishop of Tomis, Teodosie: "Muslims here in Dobruja are very warm people. They always want to help. We know that since the beginning of freedom in Dobruja, these Muslim Turkish and Tatar belivers were always ready to help Churches. There are no conflicts among the Orthodox Christians and the Muslims and for me the Mufti is someone close to me, who is a partner in helping the peers in need. Charity is both in Orthodoxy and in Islam extremely pleasing in the eyes of God and people are brothers when they join their forces to do good. And we feel close to each other because if He set us next to each other, we should respect this boundless love, freed from ethnic or faith limits." (Boioglu 2016)

In May 2016 at the Faculty of Theology, "Ovidius" University, Constanţa, invited as honorary guest **University Professor Sheik Abdullah Bin Abdulmohsen Al-Turki, PhD, General Secretary of World Muslim League and leading personality of the Islamic world to give a talk on *Man in the Conception of the Muslim Religion*. At the occassion the Rector of** "Ovidius" University, Professor Sorin Rugină and **Professor Sheik Abdullah Bin Abdulmohsen Al-Turki, PhD, signed the intention letter for a colaboration agreement between** "Ovidius" University and the World Muslim League for intercultural and inter-religious dialogue, with the support of Archbishop Teodosie and Mufti Iusuf Murat. (Predescu 2016).

Priest Ieronim Iacob, became the new Monsenior of the Basilique Saint Anton after the retirement of the former monsenior Ştefan Ghenţa. (Candet 2011) He was born in Moldova near Mirceşti, the domain which Vasile Alecsandri immortalized in his poems in a Catholic village attested since the fourteenth century and in a Catholic family. He was certain of his Catholic vocation and followed this educational path, at first in Romania and then in Italy where he studied the archives and worked as a capelin in a hospital in Siena. He became a priest in the year that preceded the Revolution, at first as capelin priest, then bishop vicary, aid of the Bishop in Archdiocese in Bucharest and Iaşi. (Candet 2011).

During 1994–1996, we worked at Năvodari, at the foundation raised by Father Solomon completed while I were there. Then, he went at Bucharest at Laymen Theological Institute (1996–2000). Since 1997 and until 2000 I was priest and first Catholic chapellin and he worked in the Ministry of National Defence. With Romania's accession to NATO, he worked there, too. Since the fall of 2000, he received a grand from the Pontifical Georgian University, Church History specialization and he studied the archives of Fide propaganda, studying also a part of the Romanian history (1847–1914). In august 2015 he was nominated Monsenior of Saint Anton Basilique with about 500 families in his care. (Candet 2011).

3.2.1.4 Anniversary Snapshot: Biologist ALEXANDRU-ŞERBAN BOLOGA

Last but not least, the very reason for our incursion in the Dobrujan spirituality and culture, ALEXANDRU-ŞERBAN BOLOGA is a biologist and Full Member of the Academy of Romanian Scientists, the Section of Biology Sciences. Born on the 8th of September at Braşov and a graduate of the Biology Faculty, Specialization Botanics of Babeş-Bolyai University in Cluj-Napoca in 1970, Professor Alexandru Bologa owns a PhD in Marine Biology at C.I. Parhon University in Bucharest, in 1980, with the thesis entitled *Photosynthetic Productivity of Marine Macrophyte Benthic Algae*. (AOŞR 2016).

He was Associate Professor at "Ovidius" University, Constanţa (1993–1996). Since 1992, he is Scientific Researcher I, responsible redactor of the journal *Cercetări marine – Recherches marines* (since 1990), a member in the redaction committees of the journals *Noesis* (Romanian Academy) and *Ocean Yearbook* (International Oceanic Institute). Currently he is Scientific Director of the Romanian Institute of Marine Research (IRCM)/Grigore Antipa National Institute for Marine Research-Development (INCDM), since 1990. His research concerned macrobenthic marine algae, the estimation of the primary plankton production with ^{14}C method, the surveillance of natural and artificial radioactivity in abiotic and biotic components of the marine environment, experiments in marine radioecology field (transfer coefficients, factors of concentration), studies of science history. Researcher Alexandru Bologa authored books *Black Sea Bibliography: 1974–1994*, GEF & BSEP, 1, UN Publ. New York, USA 364 pp., 1995 (co-author); *Environmental Degradation of the Black Sea: Challenges and Remedies*, Kluwer Acad. Publ., Dordrecht/Boston/London, 402 pp., 1999 (redaction); *Productivitatea primară marină*, Bucharest, Ed. Ştiinţifică şi Enciclopedică, 1987; *Tratat de Algologie*, Bucharest, Ed. Academiei RSR, 1976, 1977, 1979 (co-author). Among the scientific studies published we are mentioning "Planktonic primary productivity of the Romanian surface waters (Black Sea) in 1979" (*Oceanologica Acta*, 1981); "Annual cycle of planktonic primary productivity off the Romanian Black Sea coast" (*Mar. Ecol. – Progress Ser.*, 1984); "A checklist of the benthic marine algae (except the Diatoms) along the Romanian shore of the Black Sea" (*Oebalia*, 1991); "Radioecological research of the Black Sea: Report from Romania" (*IAEA Bulletin*, 1994); "A comparison of dates from Cs-137 and Po- 210 in marine food: A major international study" (*J. Environ. Radioactivity*, 1997); "Present trends in the Black Sea ecosystem and its biodiversity" (*J. Environ. Prot. Ecol.*, 2000); "Improvement of Romanian marine coastal water quality by urban sewage treatment" (*J. Coastal Res.*, 2005); "Surface and mid-water sources of organic carbon by photoautotrophic and chemoautotrophic production in the Black Sea" (*Deep-Sea Res. II*, 2006); "Cs-137 baseline levels in the Mediterranean and Black Sea: A cross-basin survey of the CIESM Mediterranean Mussel Watch Programme" (*Mar. Poll. Bull.*, 2008). (AOŞR, The Academy of Romanian Scientists, 2016).

Researcher Alexandru Bologa is a Plenary Member of the Academy of Romanian Scientists (1981-present), a national delegate to the International Commission for the Scientific Exploration of the Mediterranean Sea (CIESM), 1994-prezent, a Member of the European Society of Radiobiology (SER), 1985-prezent, Member of the International Phycology Society (1994–2005), Director of the Black Sea Operational Centre of the International Oceanic Institute (IOI), 1996–2004, a national coordinator of the Regional Committee for the Black Sea of the IOC, 1996-prezent, a Member of the International Radioecology Union (UIR),1996-prezent, a Member of the Black Sea University Foundation, 1996-present, a national representative of the International Union for the History and Philosophy of Science (IUHRS)/Oceanography Commission (OC), 1998-present, a Member in the Consulting Council for Research of the American Biographic Institute,1999-present, a Member of the International Union of Eco-Ethics, 2002-present and a Member of the Working

Group for Environment Protection of the Organization for Economic Cooperation at the Black Sea (2005-present). (AOŞR 2016).

Among the main contributions to the development of science, Researcher Alexandru Bologa introduced for the first time in Romania the estimation of the plankton primary production using the C-14 method (Geiger Muller, liquid scintillators) with applications in marine research (North-West shore of the Black Sea) and in limnology research (concerning especially Sinoe, Siutghiol and Bicaz lakes) during 1974–1984. (AOŞR 2016).

3.3 Conclusion

Dobruja is home of various spiritual realities, cultures and ethnic groups. This is a realm of intercultural, inter-ethnic and inter-religious dialogue, a rich spiritual realm of various reigious cults, churches and monasteries and the realm which gave Romania, Europe and the world many important scientific, cultural and spiritual personalities. However, the same way as a traveller cannot see everything in a first visit, a researcher cannot exhaust a topic in a first study. In this Chapter, we have only brought homage to the spiritual and cultural complexity of this special European areal, Dobruja, reflected in the cultural and spiritual remains that are mapping the transformations of the cultural eternity inspired by the Black Sea.

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Chapter 4
About "Publius Ovidius Naso" († 17 p. Chr. n.) and His Poems Written in the "Getae" Language

Nicolae V. Dură

Abstract At Tomis, the capital of "Scythia Minor" (Roman province) – where Ovid was exiled by Emperor Augustus in 8 p. Chr. – the roman poet wrote also "getic verses", i.e. in the language of the Getae, one of the northern tribes of Thraciens, the forefathers of Romanians.

Among others, in his poems written in the "Getae" language, Ovid confesses that he had adopted himself to the Tomitan environment, recte to the getic culture and civilization, due also to the fact that the language of the proto-romanians (the tracian-geto-dacians) was not so different from Latin, his native language. The linguists' latest research otherwise confirms that the "Getic" language had a lexical fund very similar to that of the language spoken by the Etruscans from Latium, which allowed Ovid to learn the "Getic" language so fast. Nowadays, such a similarity is revealed by the two neo-Latin languages, Romanian and Italian.

Keywords Latin language • Getic language • The first Latin poet of "Getae" • The Tomitan civilization and culture

4.1 Introductory Regard

In 8 p. Chr. n., Ovid was exiled – by Emperor Augustus's order – at Tomis, the capital of Scythia Minor, which had became a Roman province in 27 a. Chr. n.

Three languages were spoken in the geographic area of Scythia Minor, namely the inhabitants' language (the Thracian-Geto-Dacians'), Latin (the government language) and Greek, a kind of "*lingua franca*" of that time, used not only by the scholars of that time (philosophers, writers, historians, geographers, people of polytheistic religions etc.), but also by the descendants of the former colonists from Asia Minor (the Greek or the Hellenized Thracians), who usually dealt with trade.

N.V. Dură (✉)
Ovidius University of Constanta, Academy of Romanian Scientists, Constanta, Romania
e-mail: nicolaedidimos@yahoo.com

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What did Ovid find at Tomis, a city founded in the sixth century a. Chr. n. by the settlers who had come from Asia Minor on the site of the Thracian-Geto-Dacians' Neolithic settlement?! What impression did he make on this city-state, where the Geto-Dacian speakers (the natives, both Greek and Latin speakers, the latter being the former's ephemeral masters) were also fighting in their ideas, not only in swords and scimitars?! How did Ovid spend the last years of his life away from his native city, i.e. the eternal Rome, and from his loved ones? What relations did the poet of Rome have with the natives (the Geto-Dacians')? What did he do for them and how was he rewarded by them? What significance did his *Elegies* have for the history of today's Romanian Dobrogea? Here are a few questions that we will answer – at least briefly – based on a hermeneutical analysis of several representative and eloquent texts from his work, especially from "*Tristia*" (five volumes) and "*Epistulae ex Ponto*" (four volumes), which poet Ovid wrote at Tomis, in his express desire to obtain the revocation of the edict of exile, explaining – primarily – the harsh conditions of the life among the Tomitae, on the western Black Sea shore, i.e. among "Thracians" from the north of the Danube, called "Getae" by the Romans and "Dacians" by the Greeks, although they were one and the same people.

Before proceeding to the hermeneutical analysis of some excerpts on the so-called adversity that Ovid endured during his exile in "Scythia Minor" (today's Romanian Dobrogea), we would like to mention that – before his arrival to the Getae's homeland, i.e. the Proto-Romanians, – Ovid proved to be an adept of the ethnophyletism propagated by the philosophical schools born in the Greek polis from the seventh to fifth centuries a. Chr. n. The ethnophyletism made a clear distinction between "Greeks" and "barbarians", i.e. those who were "foreigners" to the Greeks and Romans.

In vogue in the Rome of his times, these schools made the same discriminating distinction between "the Romans" and the other nations, labeled as "barbarians", though – in the Greek speaking world – the stoic philosophy had propagated a concept "*avant la lettre*" about the mankind's universalist nature, hence its solidary and humanist origins. It is no wonder that, among its followers, the Stoicism would enroll the historian and Greek philosopher Polybios of Megalopolis (c. 200–120 a. Chr. n.), the Rabbi and philosopher Paul of Tarsus, "Apostle of the Gentiles" – who turned out to be familiar not only with his native language, i.e. Hebrew, but also with Greek and Latin –, the orator, philosopher and politician Marcus Tullius Cicero (106–43 a. Chr. n.) etc.

At Rome, Ovid was not acquainted with the Stoics' doctrine, according to which people are the same, regardless of their ethnicity, skin color, religious faith etc. Moreover, he was not acquainted with the Christian teaching of apostolic origin, which stated that there were no slaves, no freemen, no Greeks, no Romans etc., but that we all are one (cf. Gal. 3, 28), i.e. we are all from the same family of the human race, created by God. Therefore, he also continued to distinguish the Romans and the Greeks from the "barbarians", i.e. from other nations. However, at Tomis – among the Geto-Dacians' natives and the Greek speakers originating from the former colonists of Asia Minor, Greeks or Hellenized Thracians, who had been inhabiting the city since the late sixth century a. Chr. n. – Ovid could become acquainted not only with the faith and customs of the Thracians from Scythia Minor (Romanian Dobrogea), but also with the ideas of the Greek speaking philosophers, thus including those propagated by the Stoics.

Indeed, at Tomis, Ovid proved to be a humanist interested in *kalokagathia* (beautiful and good), which was disseminated by ancient philosophers; the Roman poet incarnated these values – first of all – in his verses, in his *Ars poetica*, that he actually saw as matchless and, *ipso facto*, destined to eternity.

As already stated, Ovid had not been acquainted with the Stoic conception of "man" and "humanity" when he arrived at Tomis (where he would speak and write poems in the local language of "Scythia Minor", i.e. the language of the Geto-Dacians and of the Sarmatians, Thracian tribes, – being otherwise inspired even by one of the daughters of these tribes, who served as his muse, as confessed by the poet himself). This is attested by the fact that, subsequent to his acquaintance and familiarization with the Tomitan civilization and culture, Ovid paid due attention to the Gentiles that were labeled as "barbaric" only because they did not speak Greek and Latin, and, *ipso facto*, because their population was not educated in line with the Greco-Roman culture and civilization, but in line with one that had been overtaken in terms of time and brilliance, i.e. the Thracian culture and civilization.

4.2 Ovid's Poems Written in Getic Language, a Real Documentary Source for a Better Knowledge of the Tomitan Civilization and Culture

Referring to the contribution that the informations provided by Ovid's *Elegies* would have had to a better knowledge of the Tomitan civilization and culture, some specialized Romanian historians state that these were assessed "differently by modern researchers" (Vulpe 2010). In some opinions, the only reliable historical facts evoked in his poems and confirmed by other sources are the Roman fights held in order to conquer Aegysus (Tulcea) – before 12 p. Chr. n. – and to recapture Troesmis (Igliţa, Turcoaia, Tulcea county) by 15 p. Chr. n. According to those historians, the rest of the informations consist of descriptions (exaggerated in a negative sense) of the climate, of the frequent invasions over the Danube, of the barbarians' habits, including the Getae, and of the vegetation ("absence" of the vine). Moreover, they specify that both the data on the climate and those on the vegetation are focused on common places, evoking some conditions that were unbearable to a Roman accustomed to the luxurious life from Rome; additionally, the landscape imagined by the poet was more appropriate to the Northern Pontic steppes than to Dobrogea (Vulpe 2010).

Nevertheless, beyond the exaggerations and incongruities that appear in Ovid's *Elegies* – some of them being inherent to his aim, i.e. to obtain the Emperor's clemency, and, *ipso facto*, to revoke the Edict of exile – it is noteworthy that they can be used as "historical source". This was done both by Romanian and foreign historians, although some of them have questioned or doubted the veracity of Ovid's descriptions (Syme 1978).

Among other things, in "*Tristia*" Ovid confessed that in the lands where he had been exiled, i.e. the Roman province of "Scythia Minor" (Dobrogea), there lived the northern tribes of Thracians, namely the Getae and the Scythians, but that – hearing them speaking – he found that he could write only "Getic verses" (Wheeler 1939), i.e. only in the language of the Getae.

Why did not Ovid write "verses" in the Scythians' language? The philologists' researches – from the country and abroad – come to confirm that the Getic language was – in terms of the lexical fund – similar to Latin.

For example, L. I. Cueşdean tells us that the Romanian language "does not originate from Rome but from its Getic roots, present in stem morphemes . . .", and that "the vocabulary of different Latin dialects spoken by the Getae" was unified "in one literary language, Latin", by "the Latin teachers from the schools in Rome. . ." (Cueşdean 2012).

As such, Geto-Dacians did not have to learn the Latin imposed by Emperor Trajan and by the Roman troops – who had conquered them "*manu military*" in 106 p. Chr. n. They continued to speak the language of their ancestors, i.e. the Thracian-Geto-Dacian language, that – over time – received some influences not only from the Latin spoken in "*Latium*", but also from the Greek and the Slavic languages, i.e. the languages of the tribes that had to cohabit for centuries to come.

Due to the relatedness of the two languages, namely the Latin and the Getic (the Geto-Dacian language) languages, not only did Ovid learn to speak the Geto-Dacians' language, but he also wrote poems in it – in ancient meter – even in his early years of exile, at Tomis, where he lived for about 11 years. Nevertheless, here is what Ovid himself tells us in this regard:

"*. . . Nec te mirari, si sint vitiosa, decebit carmina, quae faciam paene poëta Getes . . . et Getico scripsi sermone libellum, / structaque sunt nostris barbara verba modis: et placui (gratare mihi) coepique poëtae / inter inhumanos nomen habere Getas*" (Nor should you wonder if my verse prove faulty, for I am almost a Getic poet . . . I have written a poem in the Getic tongue, setting barbarian words to our measures: I even found favour – congratulate me! – and began to achieve among the uncivilized Getae the name of poet) (*Pontic Epistles* IV, 13, 19–20) (Wheeler 1939). In other words, the verses of this "booklet" – written in the language of the Tomitae, i.e. the Geto-Dacians – were displayed in the Latin "meter", having thus the rhyme and the rhythm of the classical Latin poetry.

Was the creation of that "*libellus*" (Cf. *Tristia*, V, 7, 59–60) (booklet, opusculum) of poems – which helped Ovid acquire the name of poet among "*inhumanos Getias*" (inhuman Getae) – triggered by the inspiration of that "foreign muse" (Pont. IV, Epist. XIII), to which the poet himself made express reference?! If we were to believe his words, we could admit that this "foreign Muse" – that made and helped him learn the Getic language and write poems in it – was not an ideational-poetic one; on the contrary, she was one of the daughters of these "inhuman Getae" (sic), who charmed him both by the beauty of her body and by her clever mind. This Getic daughter might have had a noble origin, even a royal one, and she might have talked with Ovid in his native tongue, i.e. Latin, which was in fact akin to the Geto-Dacian language, and, in general, with the Thracian language, much more than are – nowadays – Italian and Romanian.

A Latin historian from the sixth century, i.e. the Goth Iordanes, – who, in his *Getica*, intentionally confused the Goths with the Getae – wrote that they "*grecis poene consimiles*" (were almost equal to the Greeks) in terms of culture and civilization (*Getica*, 23).

Although Ovid judged and rated the Getae and the Sarmatians only through the agency of the customs, mores and lifestyle of his native city, i.e. Rome, the same poet held to thank them publicly for their hospitality by the means of his verses written in the "Getic tongue". He had to learn it in order to communicate with the locals, i.e. with the northern Thracian tribes, and – according to his own testimony – he forgot his native language, and introduced words from their language even in his poems written in Latin. "*Ille ego Romanus vates, ignoscite, Musae/ Sarmatico cogor plurima more loqui. En pudet et fateor, iam desuetudine longa / vix subeunt ipsi verba Latina mihi. Nec dubito quin sint et in hoc non pauca libello barbara: non hominis culpa, sed ista loci*" (*Tristia*, V, 7, 55–60) (Wheeler 1939) (I'm the Roman bard-pardon, ye Muses! – am forced to utter most things in Sarmatian fashion. Lo! I am ashamed to confess it; now from long disuse Latin words with difficulty occur even to me!).

For such verses, poet Ovid received from the Geto-Dacians a "*velata corona*" (crown of laurels), imposed by the "*publicus favor*" (the favour of the public) of Tomis (cf. Pont. IV, Epist. XIII); on this occasion he recited some special verses dedicated to this unique event both from his life and from Tomitae' lives (Dură 2011).

What was Ovid's perception of the Tomitae, among whom he wrote his work? According to the poet, in "*...Tomitane regionis*" (the land of the Tomitae) there was a "mixed" population made up of "*Graecosque Getasque*" (Wheeler 1939) (Greeks and Getae), who, of course, had their own history, literature, poets etc.

In Ovid's perception, the language of the Tomitae, i.e. the native Getae, had – according to the poet's confession – a decisive linguistic impact on his book, "*Tristia*", because it had been infested by "*non paca barbara*" (by not a few barbarisms). But here is what poet Ovid tells us in his *Tristia*: "*... Nec dubito quin sint et in hoc non panca libello barbara: non hominis culpa, sed ista loci*" (Wheeler 1939) (And I doubt not there are even in this book not a few barbarisms, not the fault of the man (of the author, n.n.), but of the place).

The poet himself confesses, explicitly, in the verses written in the Getic language, that he had adapted himself to the Tomitan environment, *recte* to the Getic culture and civilization – of Thracian origin, that had been ruling in Dobrogea for over a millennium a. Chr. n. Moreover, he read his verses in the public meetings of the Geto-Dacians, who proved to be sensitive and receptive to his poetic message, although their bags (which they were carrying) were full of arrows. "*Haec ubi non patria perlegi scripta Camena,/ Venit et ad digitos ultima charta meos;/ et caput et plenas omnes movere pharetras / Et longum Getico murmur in ore fuit*" (When I read all this, written not in the language of my native Muse, and the last page felt to touch of my fingers, all moved their heads and their full quivers, and there was a long murmur on the lips of the Getae) (Wheeler 1939) (*Pontic Epistles* IV, Epistles XIII).

Therefore, the great poet Ovid abundantly attested that not only did the Getae from Tomis have a poetic sensibility, but they were also endowed with the natural habit in cultivating poetry. Ovid wrote verses in their language, being determined just by this peremptory reality.

A Romanian scholar from the nineteenth century justifiably wondered: "What did Ovid's poems become? How much light did they shed on Dacian history and language, on everything related to our Dacia? They are lost forever and only the Latin writings of this illustrious author reveal the fact that they existed" (Papadopol-Calimah 2007).

Indeed, the existence of these verses written by Ovid in the language of the Romanian ancestors would have represented a peremptory testimony of the Geto-Dacian language and culture from Scythia Minor (Dură 2006). Here, the Proto-Romanians' Apostle, i.e. St. Andrew, martyred in Patras (Greece) in the year 60 p. Chr., brought Christ's light. Here, the famous "Scythian monks" from the fifth-sixth centuries p. Chr. n. (founders of the European medieval culture, whose theological, historical, philosophical works etc. – retained in *Patrologia Orientalis* – includes several volumes) were born, studied and carried out their activities.

Or, in Romanian specialized literature, all that is known about these exceptional scholars of Proto-Romanian culture is due largely to *Patrologia* (Greek and Latin), edited by J. D. Migne, because *Patrologia Orientalis* remained only at the reach of some specialized researchers. However, we hope that, one day, we will be able to find that the Textbooks and Treaties from the History of Literature, Theology, History, Philosophy, Patrology etc. will also expressly refer to the texts published in *Patrologia Orientalis*. Only in this way the work of the famous scholars known to Rome since "*illo tempore*" as the "Scythian monks" (Dură 2003, 2004, 2009), i.e. from Scythia Minor (today's Romanian Dobrogea, and their homeland in times past) – where some of the founders of the European medieval culture, *recte* the erudite scholars John Cassian († 435) (Mititelu 2011, 2012; Dură 2010a) and Dionysius Exiguus († 545) (Dură 1989, 1993) also lived, studied and wrote – will be better known both in their native homeland and in Europe.

4.3 The Latin and the Getic Languages and Their Common Linguistic Trunk

Among others, the linguists' latest research confirms the fact that the "Getic" language had a lexical fund very similar to that of the language spoken by the Etruscans from Latium, which allowed Ovid to learn the "Getic" language so fast. Nowadays, such a similarity is revealed by the two neo-Latin languages, Romanian and Italian.

In "*Tristia*", Ovid confessed, among other things, that the muse who inspired him to write verses in "the Getic language" made him forget his own language, namely Latin. "*Dicere saepe aliquid conanti – turpe fateri – verba mihi desunt de didicique loqui. / Threïcio Scythicoque fere circumsonor ore, / et videor Geticis scribere posse modis. / Crede mihi, timeo ne sint inmixta Latinis / inque meis scriptis Pontica verba legas* ..." ("Often, when I attempt some utterance-shameful confession! – words fail me: I have unlearned my power of speech. Thracian and Scythian Tongues chatter on almost every side, and I think I would write in Getic measure. O, believe me, I fear that there may be mingled with the Latin in my writings the language of the Pontus") (Wheeler 1939).

Thus, Ovid recognized that, being forced to use daily the local language, i.e. the Getic language, it was difficult to remember the "*verba Latina*" (Latin words) that – mostly – were similar, in their lexical substance, to those of the Tomitae, i.e. the Getae. Therefore, the text of those verses would easily reveal the fact that, in terms of vocabulary, the Getic language was not so different from Latin. Of course, only this way we can explain the fact that Ovid was able to learn so quickly the local language, i.e. the language of the Proto-Romanians (the Thracian-Geto-Dacians). Moreover, this also explains his fear that "Getic verses" have slipped through his "Latin" verses, written in "*Geticis modis*", i.e. written according to the rhyme and structure of the Getic poetry, and not of the Latin one. Ovid's testimony also reveals that the Getic *ars poetica* had its own rules in terms of lyrical structure, number of accents, number of syllables per verse etc. Additionally, this reality also attests the fact that the Getae were poets by nature. In this regard, not incidentally, a great romanian poet, Vasile Alecsandri († 1890), confirmed that "the Romanian is born to be a poet".

Ovid's verses reveal that these Thracian nations – which included the Getae – were speaking a common language, i.e. the "Getic" language, which was the Thracian language of the Getic natives. This reality is confirmed by the geographer and historian Strabo from Amaseia (c. 65 a. Chr. n. c. 20 p. Chr. n.), who wrote that the Getae from the banks of the Danube were a "nation of men" speaking "the same language as the Thracians, ..." (*Geografia* VII, 3, 10).

Unfortunately, Ovid's claims were not the subject of scientific research, "*sine ira et studio*", by the philologists and historians of the ancient Proto-Romanian literature. Nevertheless, we hope that they will finally come to the attention of some leading specialists in these fields, because they can bring an important contribution in terms of the disclosure of the so-called "miracle" of the Romanian language.

On another occasion, poet Ovid complained that he was forced to speak the local language, because "*... unus in hoc nemo est populo, qui forte Latine/, quaelibet e medio reddere verba queat*" (Wheeler 1939) (there is not a single man among these people who perchance might express in Latin any common words whatsoever).

Ovid recognized that "*hic*" (here), i.e. at Tomis, he was in fact "Barbarus" (the barbarian), "*qui non intellegor ulli*" (since I am not understood by nobody), "*et rident stolidi verba Latina Getae*" (Wheeler 1939) (and the Getae laugh stupidly at Latin words). But, the fact that only after 2 or 3 years, since he had been exiled at Tomis, Ovid was already able to write poems in the local language of the Thracian tribes, i.e. the Geto-Dacians and Samatians' language, proves "à l'évidence" that the two languages, that is "the Latin" and "the Getic", had a common linguistic trunk.

This reality is in fact attested by the poet himself in "*Tristia*", where he wrote: "*Ipse mihi videor iam dedidicisse Latine/ nam didici Getice Sarmaticeque loqui*" (Wheeler 1939) (I myself, I think, have already unlearned my Latin, for I have learned how to speak Getic and Sarmatian).

Undoubtedly, Ovid's verses may be invoked as a historical testimony, also truthful in terms of the common Thracian origin of the two nations, i.e. the Getae and the Sarmatians, who, "*in illo tempore*" (at that time), formed the native populations of Pontic Dacia, *recte* of Scythia Minor. Moreover, the very logic of things forces us to accept this reality, i.e. the Thracian origin of the two peoples (the Getae and the Sarmatians), because, otherwise, it would have been impossible for Ovid to learn the two languages (the Getic and the Sarmatian languages) in less than 3 years. Of course, only the fact that these languages resembled very much to Latin (even better than Romanian resembles nowadays to Italian) granted Ovid the possibility to both learn and write poems – in such a short time period – in both native languages.

Therefore, Ovid's success to speak and write in both languages, i.e. Getic and Sarmatian, even in the early years of his exile at Tomis, is due to the fact that Latin, his native language, and the two languages that were spoken at Tomis, at that time, i.e. Getic and Sarmatian, were related, being part of the same common linguistic trunk. In fact, only this way we can explain better both the so-called "miracle" of the formation of the Romanian language and the rapid process whereby Burebista's Geto-Dacians have appropriated the conquerors' language (from Latium). Perhaps, in the near future, historians, philologists, linguists etc. will also reflect upon and debate, in full awareness, this peremptory reality.

That the Getae cultivated the Muses and that poetry was at home among the Thracian nations of "Scythia Minor" are attested by the fact that these nations had poet kings, such as getic King Cotys (Cotiso) (Suetonius, LXIII, 4) of the Odrysian, who ruled between 13 and 17 p. Chr. n., and whose poems made him famous also among the poets of other nations. One of these poets was Ovid, who wrote to him "as poet to poet", and who also begged him to ease his stay among the Getae. Here is what the Roman poet exiled at Tomis wrote – in this respect – to King Cotys of the Getae, who, in his turn, had gained a universal fame as poet: "*Ad vatem vates orantia brachia tendo, terra sit exiliis ut tua fida meis*" (Wheeler 1939) (As bard to bard I extend my arms in prayer that thy land may be loyal to me in exile).

Treasured by the Getae from Tomis because he had learned and spoke their language – in which he wrote poems – Ovid received their friendly request to remain among them. As testimony to this friendship, the Tomitae addressed him – by solemn decrees – words of appreciation and praise, and spared him – through public documents – of all taxes. Moreover, he was granted the same privileges by the neighboring Getic cities. Here is what Ovid confesses in his Pontic verses, namely that at Tomis he was privileged and that "*... Tomitae me, ..., / cupiunt hic tamen esse sui. / Nec mihi credideris: exstant decreta, quibus nos laudat, et* *immunes publica cera facit . . . / Proxima dant nobis oppida munus idem . . .*" (Wheeler 1939) (. . . the Tomitae . . . are eager to have me remain (no to depart from them). And trust not me for this: there are extant upon the wax decrees praising me and granting me immunity . . . And the neighboring towns grant me the same favor).

The Tomitae from poet Ovid's times – whom he wrote and recited verses in their language – really wanted him to stay with them, and he remained "*hic*" (here), at Tomis, where he also would die. And, after the poet's death, the Tomitae continued to recite his verses, written both in their language, i.e. "Getic" and Latin. Unfortunately, nowadays, we can no longer read or recite his verses in the language of our ancestors, that is in getic one; instead, we can read those written in his native language, Latin. After the conquest of Dacia, in 107, Latin had a defining impact on the Proto-Romanians' (the Daco-Romans) language, which we speak today (i.e. Romanian), and in which – for centuries – his verses have been uttered (also called the "language of ancient Holy Scriptures" by Alexei Mateevici, when referring to the old Romanian language).

Aware of the poetic value of his work, poet Ovid wanted to assure his readers that his verses will last for centuries. Indeed, ". . . *nullaque res maius tempore robur habet / Scripta ferunt annos: . . .*" (Wheeler 1939) (. . . nothing has a strength greater than that of time. But writing endures the years).

As regards the awareness of his poetic value, it is noteworthy that Ovid actually lived his work and expressed it without reservation. "*Iamque opus exegi: quod nec Iovis ira, nec ignes, / Nec poterit ferrum, nec edax abolere vetustas. . . . Nomenque erit indelebile nostrum*" (Ovidius 1822) (And now I have finished a work, which neither the anger of Jove, nor fire nor steel, nor the consuming teeth of time, shall be able to destroy . . . Nor shall my name ever cease to be in honor).

The poet's testimony turned out to have full coverage in reality, because – in his adoptive country, i.e. the former Scythia Minor and today's Romania – his poems, written in the Getic language, had been also perceived as an official recognition on behalf of the one of the greatest roman poets, who, – in terms of the same full confidence in the durability of his poetic work -declared categorically that his reputation will endure over the centuries: ". . . *Me tamen extincto fama superstes erit*" (Wheeler 1939) (. . . Yet when I am dead my fame shall survive).

If I were to paraphrase the Romanian poet Tudor Arghezi († 1967), only the one who left his/her name inscribed on a book remains imperishable. As regards Ovid, nowadays, we can attest that his name remained enrolled not only in the durability pantheon of Romanian poetry and culture, but also in that of the entire mankind.

The same poet of the world – but equally of the Romanian people – was indeed right when he stated that "*singula ne referam, nil non mortale tenemus, / Pectoris exceptis ingeniique bonis*" (Wheeler 1939) (in brief we possess nothing that is not mortal except the blessing of heart and mind).

4.4 Ovid and His Attitude Towards His Homeland and His Adoptive Country, "Scythia Minor" (Romanian Dobrogea of Today), Where He Felt as a "Hospito" (Guest), and Not as a "Fugatis" (Exiled)

Was Ovid a man who honored Divinity?! Here is a question to which we can answer only affirmatively. The fact that Ovid, a humanist intellectual, had never declared war to the Gods is also attested by his lyrics. On the contrary, he urged his peers to look up, towards heaven, because "*Opifex rerum*" (the Great Artificer of things) created (*fecit*) the man from a "*divino semine*" (divine principle) and endowed him with a great image (Ovidius 1822).

That a worshiper of God is, at the same time, a lover of peers is a fact revealed nearly by all the great humanists produced by the mankind along time; an exceptional one was our Tomitan, i.e. Ovid, who believed that helping one's peers is one of the finest pleasures and worldly pursuits. "*Conveniens homini est hominem servare voluptas, / Et melius nulla quaeritur arte favor*" (Wheeler 1939) (It is a fitting pleasure for man to save man; there is no better way of seeking favor). How great it would be if we hang these lines at the gate of our soul . . .!

According to Ovid, only through culture, through the practice of "Fine Arts", the human being becomes more human, he/she humanizes himself/herself, "*ingenuas dedicisse fideliter . . . artes, / Emollit mores, nec sinit esse feros*" (Wheeler 1939) (because a faithful study of the liberal Arts humanizes character and permits it not to be cruel).

His existential love for his homeland was also expressed by Ovid in pathetic verses: "*Nescioqua natale solum dulcedine cunctos / Ducit et inmemores non sinit esse sui*" (Wheeler 1939) (But what sweet charm I know not the native land draws all men nor allows them to forget her).

Naturally, these verses can be understood in the entire reverberation and amplitude of their content only by those who were forced to live away from their country for at least a decade, like poet Ovid.

Although the fate had made him a "*fugatis*" (exiled) from his "homeland" – as he himself confessed – Ovid continued to love it during his stay at "Tomis", a city, that was "*tam cara*" (so dear) to him, and where he felt like a "*hospito*" (guest) (*Pontic*, IV, 14, v. 59–60).

At Tomis, which he "loved" until the end of his earthly life († 17 p. Chr. n.), Ovid remained indeed a "*hospita*" (guest), who had never lost his hope that the emperor would forgive him, and that, one day, he would return to his homeland. Here is how the poet expressed this hope: "*Ipse licet sperare vetes, sperabimus usque; / Hoc unum fieri te prohibente potest*" (Wheeler 1939) (Though thou dost thyself forbid me to hope, I shall hope constantly; this one thing can be done in spite of thy command).

It is precisely this hope that fueled his inner combustion, helping him to overcome the new living conditions and the harsh climate, even if, at the beginning, he disliked the lands he had been exiled to. "*Sed nihil admisi, nulla est mea culpa,* *Tomitae, / Quos ego, cum loca sim vestra perosus, amo*" (Wheeler 1939) (But I have committed no crime, I am not at fault, Tomitae, for you I esteem, though I detest your land).

Nowadays, Ovid is no longer just the guest of the Tomitae, but he became one of them. Nowadays, poet Ovid is present in the Tomitan consciousness, which is confirmed both by the presence of the poet's statue in the city of Pontus Euxin – solemnly inaugurated on 18th/30th August 1887 (Lascu 1970, 1978), in the Square that bears his name – and by the fact that, since 1991, the first university from the former Roman province of Scythia Minor (today's Romanian Dobrogea) also bears his name. Moreover, not only the students and the teaching staff of this university utter the poet's name with legitimate pride, but also all the inhabitants of Tomis, former metropolis of the Roman province "Scythia Minor", currently, the capital of the Romanian province, "Dobrogea".

Among others, in homage and remembrance, at the semi-centenary of *Ovidius* University (Dură 2010b), from the city where Ovid had lived and worked, a bust of the poet was inaugurated. Moreover, on ten stone slabs, there were engraved verses from his poems, selected and translated from Latin by the author of this paper.

Poet Publius Ovidius Naso – exiled at Tomis in 8 p. Chr. n., where he lived until his death (17 p. Chr. n.) – has continued therefore to be at home, among the Tomitae of that time and of today (i.e. Constanta inhabitants, Dobrogea), and his poetry is part of the cultural and spiritual patrimony of the entire Romanian people.

Aware of this reality, this year (2017), both the citizens of Tomis and the teaching staff and the students of our "Alma Mater" – which bears his name – bring him a natural and well deserved posthumous tribute on the occasion of the anniversary of 1900 years from his passage into eternity.

4.5 Instead of Conclusions

Instead of concluding these lines dedicated to the memory of Publius Ovidius Naso († 17 p. Chr. n.), the first Latin poet who wrote poems in the Proto-Romanians' language, and, *ipso facto*, in the Romanians' language (and whose remains lay in his adoptive country, Scythia Minor, i.e. today's Romania), we urge the lovers of Latin poetry to read or to recite his verses. Their message uncovers Ovid not only as a "Roman poet", but also as one of the world's greatest poets, who was endowed with the "Muses' inspiration" in order to write poems in the Geto-Dacians' language (the Romanians' ancestors). Thus, his work of Latin expression was able to face the "passage of time" also in the Thracian-Geto-Dacian area from the Danubian-Pontic-Carpathian space.

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Chapter 5
The Global Warming and the Water Resources of the Earth

Adrian Bavaru and Rodica Bercu

Abstract This paper presents some of the climate changes that are occurring at Earth level. It highlights particularly the main temperature increases caused by the greenhouse effect. One of the consequences of the temperature increases is the melting of polar ice caps, polar glaciers and mountain glaciers that feed many streams and rivers. The result may be the rising of the sea and ocean level with catastrophic flooding and loss of an important land reservoir of drinking water, without which life is not possible.

Keywords Climate change • Temperature increases • Greenhouse effect • Melting ice caps • Floods

5.1 Introduction

The Paris Conference of December 2015 devoted to climate change stressed one undeniable thing, global warming and the danger this poses to the whole world. Recently, in early October 2016, the decisions taken in Paris have been ratified by all Member States of the EU.

According to the deal reached in Paris, the main objective is to limit global warming to a maximum of 2 °C by 2100 and this should be done by drastically reducing anthropogenic emissions of greenhouse gases, especially carbon dioxide and methane. If this is not achieved, temperatures may rise by 5 °C, as shown –

A. Bavaru (✉)
Faculty of Natural and Agricultural Sciences, "Ovidius" University of Constantza, Constantza, Romania

Academy of Romanian Scientists, Bucharest, Romania

University Ovidius of Constanţa, Constanţa, Romania
e-mail: bavaruelena@yahoo.com

R. Bercu
Faculty of Natural and Agricultural Sciences, "Ovidius" University of Constantza, Constantza, Romania

University Ovidius of Constanţa, Constanţa, Romania
e-mail: prof.rodicabercu@gmail.com

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since 2009 – by a team of researchers from the Massachusetts Institute of Technology, which will be a disaster for life on Earth (Brown 2011b). A group of scientists was therefore constituted and, by 2018, they must bring concrete proposals for all countries so that temperatures do not rise more than 1.5 °C.

5.2 Discussion

In order to combat global warming the appropriate measures must be analyzed. One the one hand, there is a need to assess the evolution of climate in the near and distant future and, on the other hand, there is a need for the analysis of the proposed measures (Houghton et al. 1997). In order to do these things, different climate models have been developed and they were accepted by the scientific community and considered relevant by the Intergovernmental Panel on Climate Change (IPCC), through which the evolution of temperatures throughout the twentieth century could be simulated. Using such models it was estimated that the global climate will grow hot by 1.1–6.4 °C over the twenty-first century (Houghton et al. 1997). Such a model is HadCM3 (Hadley Centre Coupled Model, version 3), used for the third Report of the IPCC assessment (Collins et al. 2001; Houghton et al. 2001) (Fig. 5.1).

One of the main consequences of global climate warming is the reduction of freshwater, given that world population is still increasing, the estimations indicating

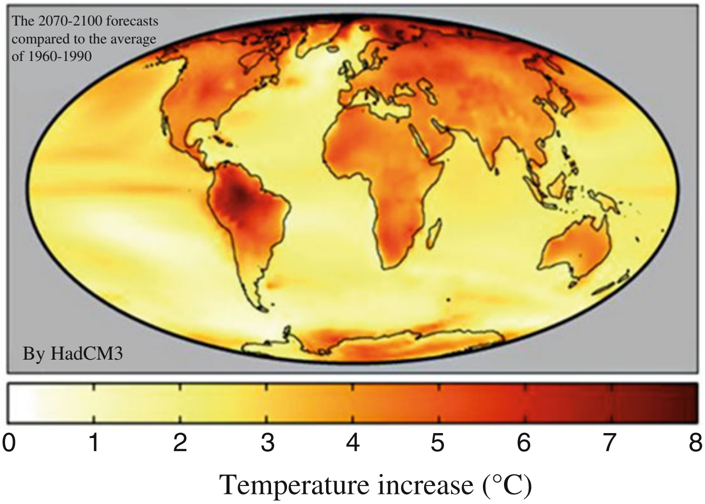

Fig. 5.1 Map indicating the geographical distribution of warming forecasts in the twenty-first century, based on the HadCM3 climate model involving current scenarios concerning the economic growth and greenhouse gas emissions. In this figure, the average global warming corresponds to approx. 3.0 °C (Web 1)

nine billion people by 2100 (if not earlier). All these people needs a growing amount of food and water as well.

For instance, in terms of water, given the population growth, the researchers from UNESCO and the UN believe that within only 20 years mankind's need for water will double. The individual water consumption has an impressive increase: from 15–20 l/day in the Middle Ages to over 600 l/day per person today (of course, there are considerable differences between countries and geographic areas).

The World Health Organization (WHO) is making a recommendation: to consume approximatively 150 l of water/day per person. In these circumstances, this recommendation remains a challenge for many countries.

The specialists believe that the Earth would have sufficient resources, if they were properly used. Nowadays, the consumption is approximately 14% of the existing resources, and a reduction is desired in the future. Lester Russell Brown (2006) points out that water consumption has tripled in the last 50 years so a reduction of this is essential.

Four fifths of our planet – called "The Blue Planet" – is covered by water, the total amount of water being 1.4 billion km^3. Of this amount, sea water is 1.362 billion km^3 i.e. approx. 97.3%, while the remaining 0.038 billion km^3 (2.7%) is freshwater. The largest freshwater reserve is located in the polar caps and glaciers, estimated at approximatively 77.2% of all fresh water. According to other specialists, glaciers occupy only 11% of the earth's surface but contain 3/4 of the drinking water. And thus, we reach one of the main consequences of this phenomenon, of global warming, namely the melting of polar ice caps and glaciers, which are, as we said, the largest freshwater reserve.

Lester Russell Brown (2011b) mentions a study developed by the Arctic Climate Impact Assessment (ACIA) in 2005 and titled "Impacts of a Worming Arctic", in which it is demonstrated that the Arctic is getting warm twice as fast as the rest of the planet. Over the past decades in Alaska, western Canada and the north-western part of Russia, winter temperatures have increased by 3–4 °C, the conclusion being that this area is experiencing one of the most rapid and severe climate change, representing in fact "a picture of what is happening to our planet." Here, in the Arctic, life has and will increasingly suffer more. Arctic animals, especially polar bears, are in great distress, lack of food will make them cannibals, and very many of them – the estimates say about two-thirds – will disappear by 2050. Lester Russell Brown (2011b) reminds us, in one of his last books, that research made by the National Snow and Ice data Center (NSIDC) between 1974 and 2006 showed that the melting ice in the Arctic Ocean accelerated by 9.1% every decade, and a record melting occurred in 2007 which decreased the surface of the Arctic ice by 20% compared to 2005.

It is known that about 70% of the sunlight that reaches the Arctic ice is reflected back and only 30% is absorbed. If the ice disappears – more dark water color – the reflected light will be only 6% while 94% of it will be converted into heat, contributing to an accelerated melting of the ice.

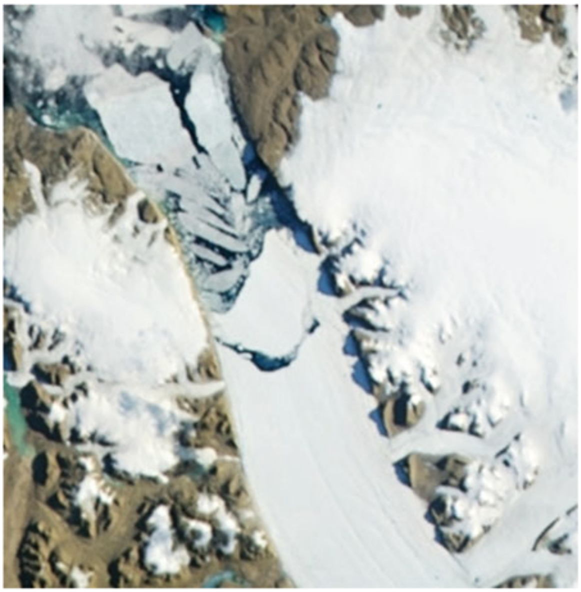

Fig. 5.2 The fatal events of the Petermann glacier (Greenland). Image taken from NASA's Aqua satellite. Author NASA, July 16, 2012 (Web 2)

Still sadder is the fact that the Arctic ice will no longer be restored over the next winters, its thinning continuing year after year and questioning thus the future of the Arctic ice cap.

Lester Russell Brown (2011b) again shows that the same researchers from the National Snow and Ice Data Center (NSIDC) believe that we are witnessing a shortening of the Arctic winter and, in the future, the Arctic Ocean could be free of ice in the summer, facilitating thus navigation.

The ice layer in Greenland is in the same situation. A study of the University of Colorado (USA) showed that within 2 years (2004–2006) Greenland lost its ice 2.5 times faster and this will continue in the future if the warming continues, while the draining of the glaciers will intensify (Brown 2011b). In our country, the mass-media reported in the summer of 2008 that a large piece of the Petermann Glacier in northern Greenland, measuring 11 nautical miles, detached and slid into the sea (Fig. 5.2). Such processes have continued every summer and will continue in the future, more intense if temperatures keep rising.

The satellite observations of the researchers from the European Space Agency (ESA) and the studies conducted by specialists from the National Snow and Ice Data Center (NSIDC) and those of the University of Colorado (USA) (Fowler et al. 2004; Maslanik et al. 2007, 2011) show that between 1988 and 2005, the average age of the Arctic ice decreased from 6 to 3 years due to the accelerated climate warming in this region, approx. 2.5 °C (instead of 0.7 °C, the planet average). Due to the temperature increase, the average glacier thickness decreased by 40% between 1993 and 1997 compared to the period 1958 to 1976. It was also found that in 2007 there was a decrease in the Arctic floating ice surface by 20% in a single year, as a result of the acceleration of melting glaciers, the process increasing alarmingly as well between 2000 and 2011 (Figs. 5.3a, b and 5.4a–c).

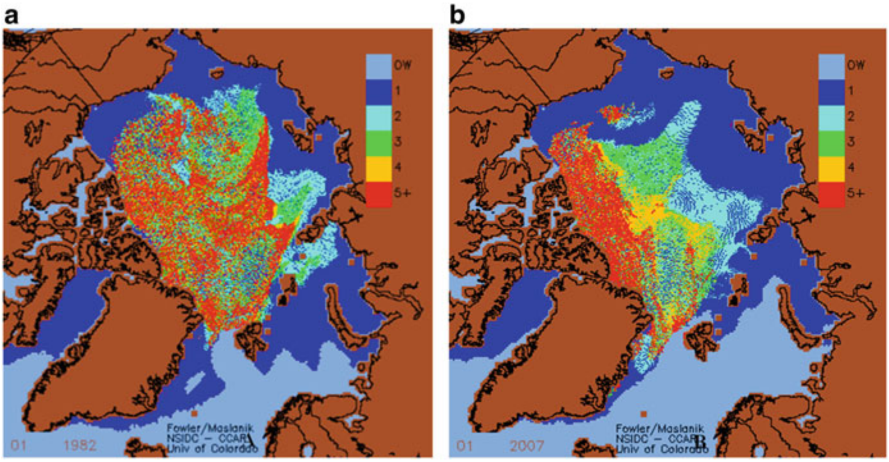

Fig. 5.3 The decreasing of Arctic ice thickness between 1982 (**a**) and 2007 (**b**) (Web 3)

In Antarctica – the opposite pole – similar things are happening. Here, like in the Arctic, studies have shown the same occurrence: temperatures increases in recent years by approximately 3 °C compared to the temperature of 30–40 years ago.

More research shows that the Antarctic ice sheet – 2.5 km thick – with an area 1.5 times larger than the US, began to melt too (Brown 2011a). Since 1995, reports have started of huge pieces of ice detaching and sliding into the sea due to temperature increases. We will mention only one example among many others, made known by the Romanian mass-media: in 2002 NASA witnessed the moment a piece of ice the size of Manhattan (New York) detached and broke.

But all these breaks and fallings of huge blocks of ice into the sea, in addition to the thinning of the Arctic and Antarctic ice, lead to a reduction of the world's drinking water and, inevitably, to an increase of the seas and oceans level, causing catastrophic floods (Fig. 5.5).

In his book *Plan B 4.0. General Mobilization to Save Civilization*, Lester Russell Brown (2011b) mentions a study made by a team from the Institute for Arctic and Alpine Researches, University of Colorado (USA), accomplished 8 years ago (2008). According to this study, glaciers melting will lead to the rising of the seas and oceans by 0.8 cm^{-2} m by 2100. Also, the reports of the International Panel on Climate Change (IPPC) indicate ocean levels increased by 0.1–0.2 m in the twentieth century (Fig. 5.6). These reports estimate a rise of the sea by 0.18–0.59 m by the end of the twenty-first century and 2 m by the end of the twenty-third century if the current rate of temperatures rising is maintained. Some observers believe that if the trend of temperatures rising continues, the sea ice will be completely melted by 2030 or even earlier. But there are other studies that estimate the water levels will rise much more. Researchers at Harvard and Princeton University have published the results of their studies and believe that these increases will vary between 4 and 6 m; which would be a real catastrophe.

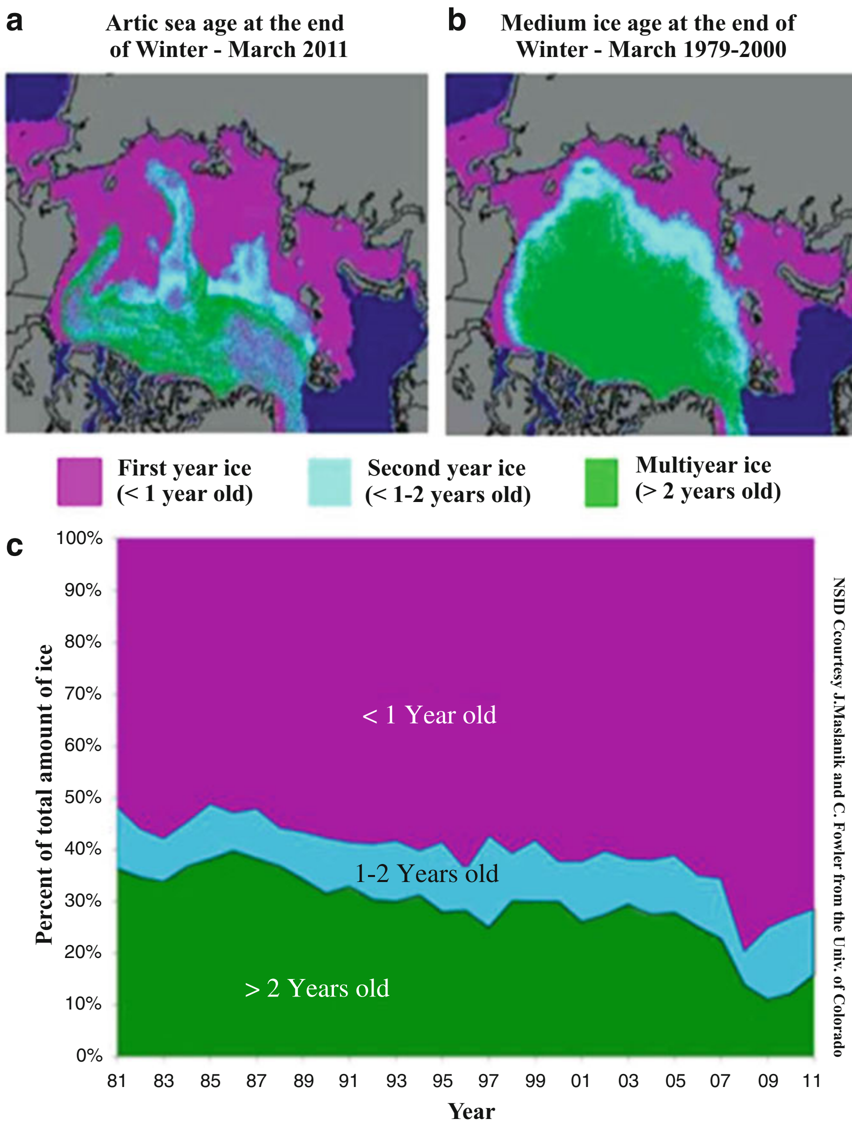

Fig. 5.4 Images showing the Arctic glaciers age in the third week of March 2011 compared to their average age during the reference period of the years 1979–2000 (**a**, **b**). Images taken by NSIDC (by J. Maslanik and C. Fowler University of Colorado). The glaciers age as a percentage of the total Arctic ice (**c**) (Web 4)

However, the estimates may not be accurate because they depend on the emissions of greenhouse gases.

If these forecasts come true, huge areas will be flooded, as well as numerous islands in the Oceanian, Maldives etc. Many cities on the seashore will be in serious

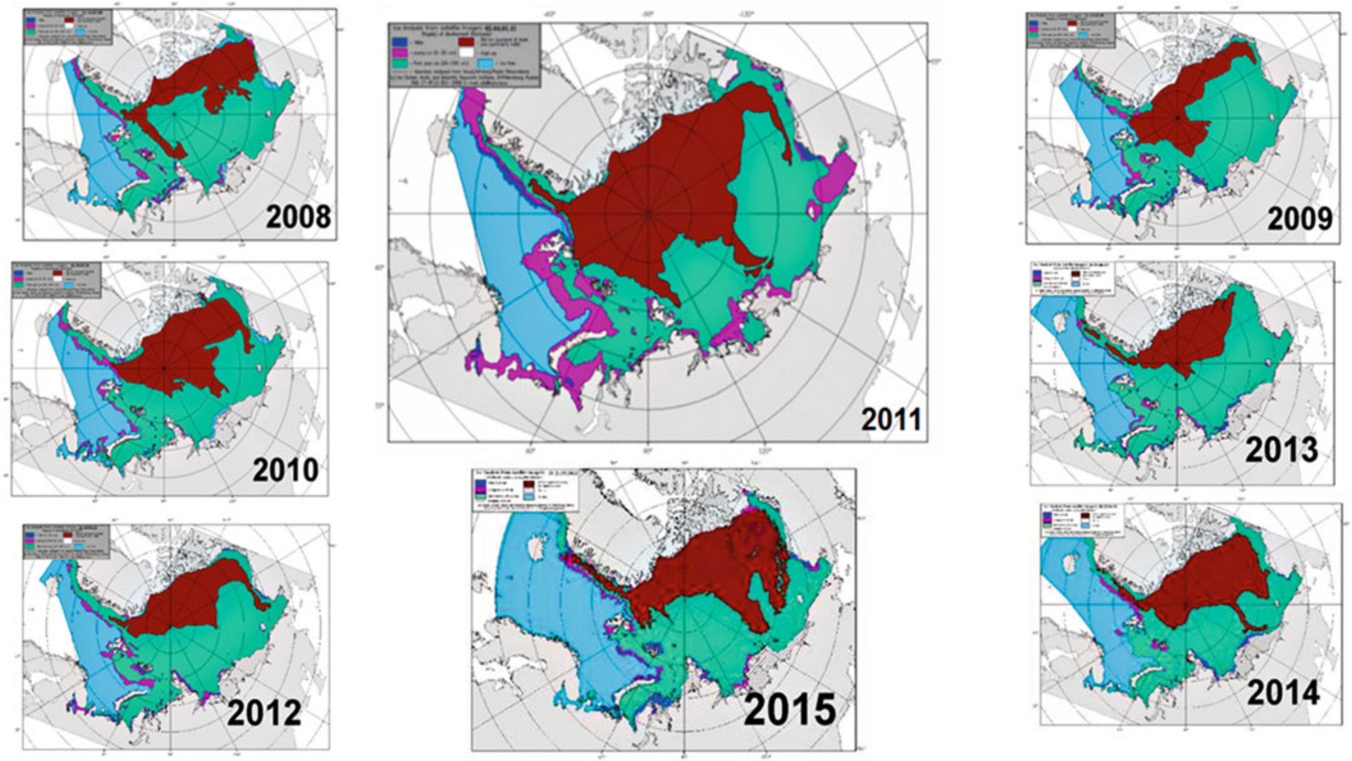

Fig. 5.5 Map representing the analysis of the glaciers realized by The Arctic and Antarctic Research Institute (AARI) from Sankt Petersburg (Russia), in 2011–2015 compared to 2008–2010. Legend of figure: *light blue* shows where the open sea is, *dark blue* is for water covered with very thin ice, *pink* is for young ice between 0–30 cm *thick*, *green* is for first-year ice with a thickness of 30–200 cm and *white* for the rapid melting of ice. The *brown color* is for old ice that survived at least one melting season, and it is this that interests us most, while white is the fast ice melting (Web 5, 6)

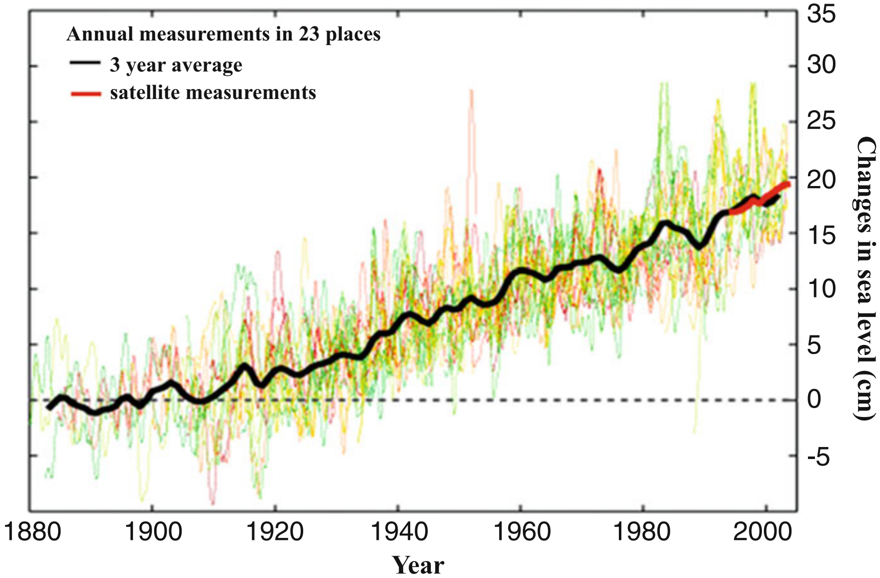

Fig. 5.6 Increasing of the sea levels in the twentieth century (Web 1)

trouble: New York, Shanghai, New Orleans, the Netherlands with cities like Rotterdam and Amsterdam. Bangladesh will lose 18% of its territory, a country which is an important agricultural area. The same will occur in the case of the Ganges and the Mekong delta, as well as other agricultural areas important for the cultivation of rice (Bavaru and Bercu 2014; Brown 2011a; Mâşu 2014).

Numerous glaciers on mountain ranges will suffer the same process – will melt – under the action of high temperatures, with the same serious consequences. The Glacier Monitoring Service of the Zurich University shows that in the last 18 years the alpine glaciers have reduced their volume continuously. They are melting twice as much now than a decade ago. In many regions of the world the phenomenon of mountain glaciers melting is extremely dangerous because it affects people's food security.

There are numerous such extremely eloquent examples in the specialized literature. Thus, in India, the giant Himalayan Gangotri glacier restricts its volume alarmingly every year and it may disappear by 2035. Its annual melting ensures 70% of the Ganges River flow, a river that is the main source of irrigation and drinking water for approximatively 400 million people in this river basin (Brown 2011a).

For China things are even worse. One of the most famous Chinese glaciologist, Yao Tandong, believes that if temperatures continue to rise, the Tibetan glaciers which feed the two great rivers of China, the Yellow River and the Yangtze, two thirds of these glaciers will disappear by 2050. And do not forget that these two great rivers are feeding hundreds of millions of people. Approximately 369 million people live in the Yangtze River basin and 147 million in the yellow River basin. About half of China's rice production is cultivated in the two river basins (Bavaru and Bercu 2014).

In the USA things are also not much better and will continue to decay. In the West of Montana State there is a small reserve called "Glacier National Park". In this park there are approximately 100 glaciers protected by law. At the last evaluation done in 2009, there were 27 glaciers left and after 1 year, in 2010, two others disappeared. It is estimated that in a few years (by 2020) all of them will disappear (Brown 2011a).

South America is also in the same situation, as approximately 80% of its glaciers could disappear by the end of the next decade, seriously affecting the farming of some countries such as Peru or Ecuador (Brown 2011b). Let us mention that Lima, the capital of Peru, a town which currently has over eight million people get their drinking water from rivers that come from the highlands of the Andes mountains, fed by melting glaciers. If they disappear what will happen to this city whose population is continuously growing?

5.3 Conclusion

As the planet warms up, the Earth icecaps and glaciers will melt and we will witness a catastrophic rise of the sea and ocean water levels.

In addition, the melting of the mass of ice and its mixing with marine waters will slowly deplete our drinking water supply that the polar caps and mountain glaciers have always offered us and that we will increasingly need. Let's remember one known thing: life is not possible without water. Life was born in water and will disappear without it.

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Part II
Geology, Geophysics and Sedimentology

Chapter 6
New Insights into the Black Sea Basin, in the Light of the Reprocessing of Vintage Regional Seismic Data

Ioan Munteanu, Paolo Diviacco, Chiara Sauli, Corneliu Dinu, Mihai Burcă, Nicolae Panin, and Giuseppe Brancatelli

Abstract Any petroleum exploration or regional model construction need a detailed understanding of the geologic evolution of the basin under consideration. This is possible only through a careful regional scale interpretation of the data available. The prolongation of any geological model from a relatively well to a less constrained area is always challenging. This is the case of the Western Black Sea Basin where the stratigraphic correlation from the shelf to deep water is not straightforward. So far this was in part due to the fact that the backbone of any regional interpretation in the Black Sea have been the OGS and DSS lines acquired in 70s that were available as paper sections only. The acquisition and publication of the new regional industry lines, driven by the new deep water hydrocarbon exploration, eased and improved the geological interpretation of this area.

In the light of the results emerging from the availability of the new data, a revision of the vintage data was considered advisable. It is known, in fact, that the reprocessing of vintage seismic data that takes advantage of new and modern processing techniques can be a useful tool to unlock the potential of such data. This is the case of the OGS seismic lines acquired in the Black Sea Basin during the 1975 campaign. The reprocessed lines have been integrated with published regional

I. Munteanu (✉)
Repsol Exploration, Mendez Alvaro 44, 28045 Madrid, Spain
e-mail: ioan.munteanu@gmail.com

P. Diviacco • C. Sauli • M. Burcă • G. Brancatelli
Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Borgo grotto Gigante 42/c, 34010 Sgonico, Trieste, Italy
e-mail: pdiviacco@inogs.it

C. Dinu
Faculty of Geology and Geophysics, University of Bucharest, 6 T. Vuia St., 020956 Bucharest, Romania

N. Panin
National Institute of Marine Geology and Geoecology, 23–25 D. Onciu St., 024053 Bucharest, Romania

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seismic and well data resulting in a coherent geological model correlating the Western Black Sea margins crossing the deep water part of the basin.

6.1 Introduction

Regional basin scale interpretation aiming at the understanding of geological evolution is an important step in petroleum exploration and in the construction of a regional geological model. The prolongation of the geological model from areas where it is relatively well constrained to those where it is less constrained can be problematic. This is the case of the Western Black Sea Basin where the correlation from the shelf to deep water is not straightforward.

The backbone of any regional basin scale interpretation of the Black Sea Basin have been for a long period of time the OGS and DSS lines acquired in the late 70s and published during the 80s in the two monographies of the Black Sea (Fig. 6.1, Finetti et al. 1988; Tugolesov et al. 1985). Since that moment, important steps have been made in the research and understanding of the Black Sea Basin architecture and evolution, from both the academic and industry side. The industry, to unlock the hydrocarbon potentials, have been mainly concentrated on the shallow water shelf areas where a large amount of seismic data has been acquired and where a significant number of wells have been drilled.

On the academic side the efforts have been focused on two main issues, and namely:

1. The architecture and evolution of the Mio-Quaternary sequence. This had an important moment in the drilling of DSDP 380 and 381 (Hsü and Giovanoli 1979) which launched the controversy over the existence of Messinian Salinity Crisis in the Black Sea. And another important moment in the multinational academic collaboration resulted in the acquisition of high resolution seismic lines and gravity cores, like the ASSAMBLAGE, BLASSON, and other national campaigns (Dondurur et al. 2013; Gillet et al. 2007; Konerding 2008; Lericolais et al. 2013).
2. The join collaborative work between the Academia and the Industry, resulting in publication of numerous data and most important the well results from the shelf area, such as in the popular AAPG Memoire 68 (Robinson 1997, Ed.). The academic-industry collaboration continued during the past decade bringing significant contributions in the understanding of the Black Sea tectonic evolution with significant amount of new publications.

A new impulse in the research of the Black Sea Basin have been given by the deep water hydrocarbon exploration with the discovery of Domino gas field in 2012 Offshore Romania (Şen 2013; Tari et al. 2009). The most noticeable outcome of the ongoing industry academic collaboration is without doubts the publication of the new regional data set acquired in 2011 by ION conducted in affiliation with

Geology Without Limits and Soyuzmorgeo in the Black Sea Scientific Exploration Program (Graham et al. 2013; Nikishin et al. 2015a, b).

In this perspective it was highlighted that reprocessing the vintage OGS seismic data using up-to-date methods could increase the image quality and interpretability of the existing data sets (Fig. 6.2). Funding for reprocessing was provided also by CGG GeoSpec. The reprocessed data set have been then integrated with the existing published sections and wells resulting in a regional geological interpretation across the Western Black Sea Basin with the prolongation of geological data from the well-studied North Western Romanian-Bulgarian shelf to less constrained deep water basin and Turkish shelf area.

6.1.1 Inferences Over the Black Sea Basin Evolution

The roll-back associated with the N-ward subduction of Neotethys under the Rhodope–Pontides Arc opened the Western Black Sea back-arc basin during (Adamia et al. 1977; Dinu et al. 2005; Görür 1988; Letouzey et al. 1977; Zonenshain and Le Pichon 1986) latest Cretaceous–Middle Eocene times (Fig. 6.3, Munteanu et al. 2011; Robinson et al. 1995). This extensional stage resulted in the formation of two oceanic crust overlain by an up to 15 km thick sedimentary sequence in their centre (Neprochnov et al. 1970; Shillington et al. 2008; Graham et al. 2013; Nikishin et al. 2015a). Shortly after this extensional period, as a result of the Pontides/Taurides continental collision, inversion of both sub-basins started with the Late Middle Eocene times (Dinu et al. 2005; Finetti et al. 1988; Hippolyte et al. 2015; Khriachtchevskaia et al. 2010; Okay et al. 1994; Sinclair et al. 1997; Yilmaz et al. 1997). The far-field transmission of contractional deformation from the Balkan-Pontides Indentor to the Romanian-Ukrainian Offshore resulted in the inversion of pre-existing extensional structures and the formation of a North-vergent thick-skinned thrust system in the Western Black Sea (Figs. 6.1 and 6.3, Munteanu et al. 2011). The Late Eocene-Pliocene compressional structures changes polarity along the basin strike, from north-vergent in the west to south-vergent in the east, as inferred by observations and analogue modelling studies (e.g., Munteanu et al. 2011, 2013). Hence the S-ward indentation of Crimea and Caucasus created an S-vergent thick-skinned thrust system in the Eastern Black Sea (Finetti et al. 1988; Nikishin et al. 2015a, b). A large transfer zone including the Odessa–West Crimea fault and Mid–Black Sea High accommodates the overall contractional polarity change during Late Eocene–Pliocene times (Finetti et al. 1988; Starostenko et al. 2015). The measured total amount of shortening recorded across the entire Black Sea domain is in the order of ~30–40 km (e.g., Munteanu et al. 2011 and reference therein).

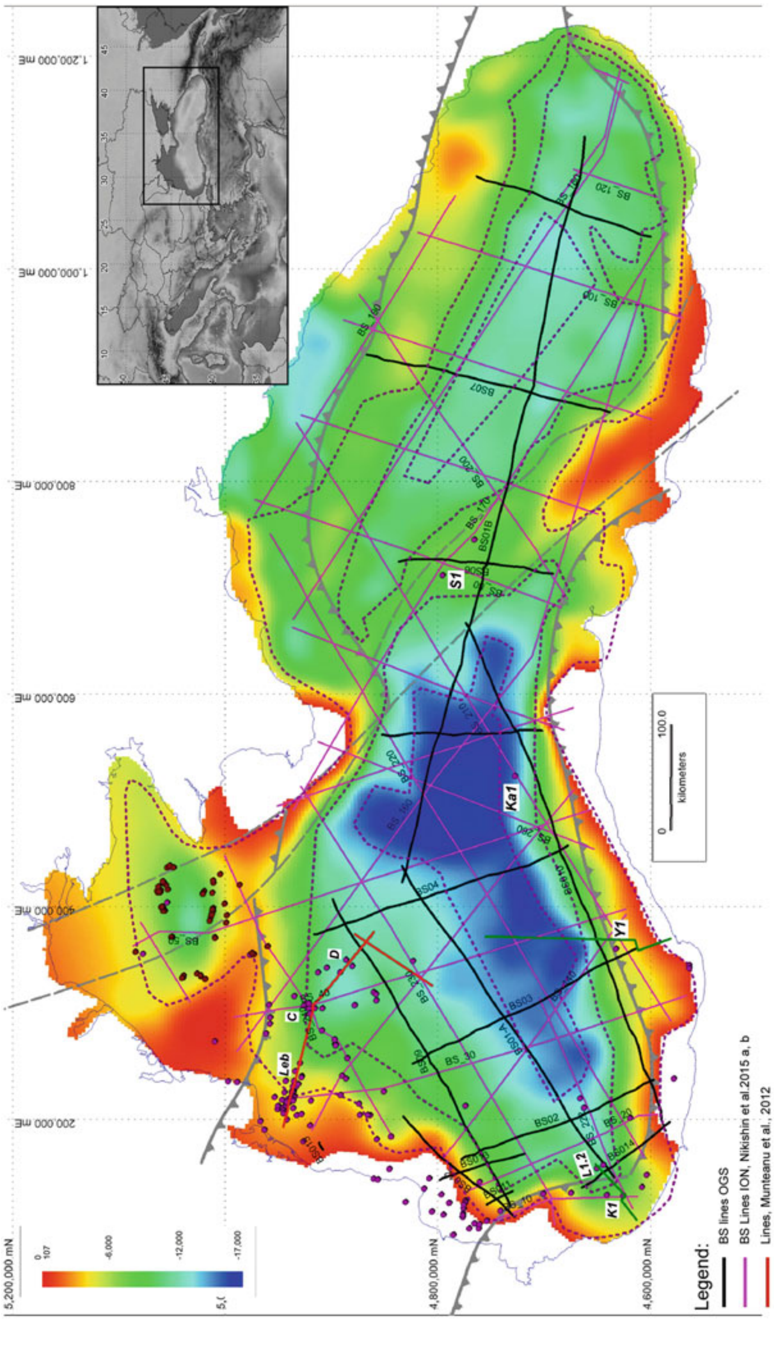

Fig. 6.1 Map illustrating the localization of the interpreted regional lines and wells used in this study. Background represents the depth of crystalline basement after Nikishin et al. (2015a) from which we also take the limits of different crustal types. The main Eocene-Pliocene thrust front of the inversion areas, after (Munteanu et al. 2011). *Inset* with the localization of the Black Sea Basin in the Europe-Africa contact zone; in background the DEM (after SRTM), the *dark grey* represents the higher elevation. The wells name abbreviation stands for: *C* Cobalcescu wells, *K1* Karadeniz-1, *Ka1* Kastamonu 1, *Leb* Lebada wells, *L1.2* Limankoy 1 and 2, *S1* Sinop 1, *Y1* Yasssihoyuk-1

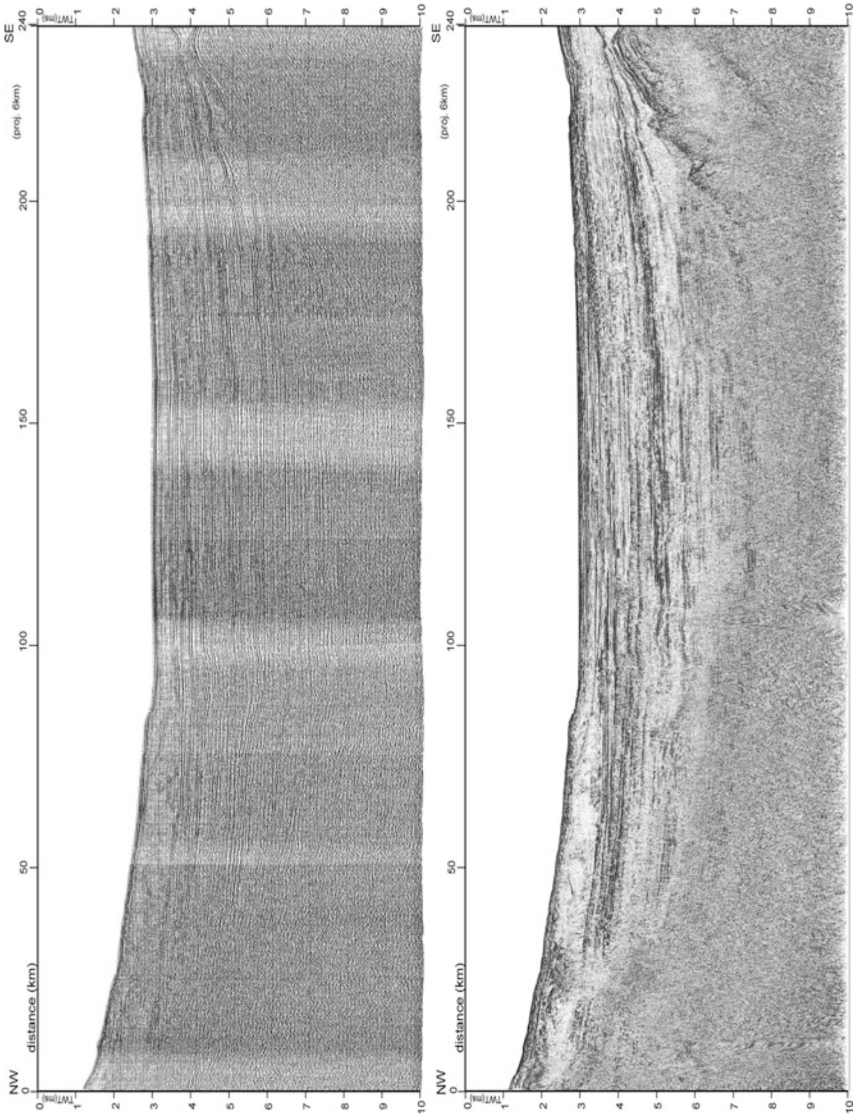

Fig. 6.2 Comparison between original 1975 processing, *upper panel*, and the new modern processing approach, *lower panel*, of line BS03. The original line was scanned from the paper print, while the *lower panel* one is exported from the interpretation software. See Fig. 6.1 for localization

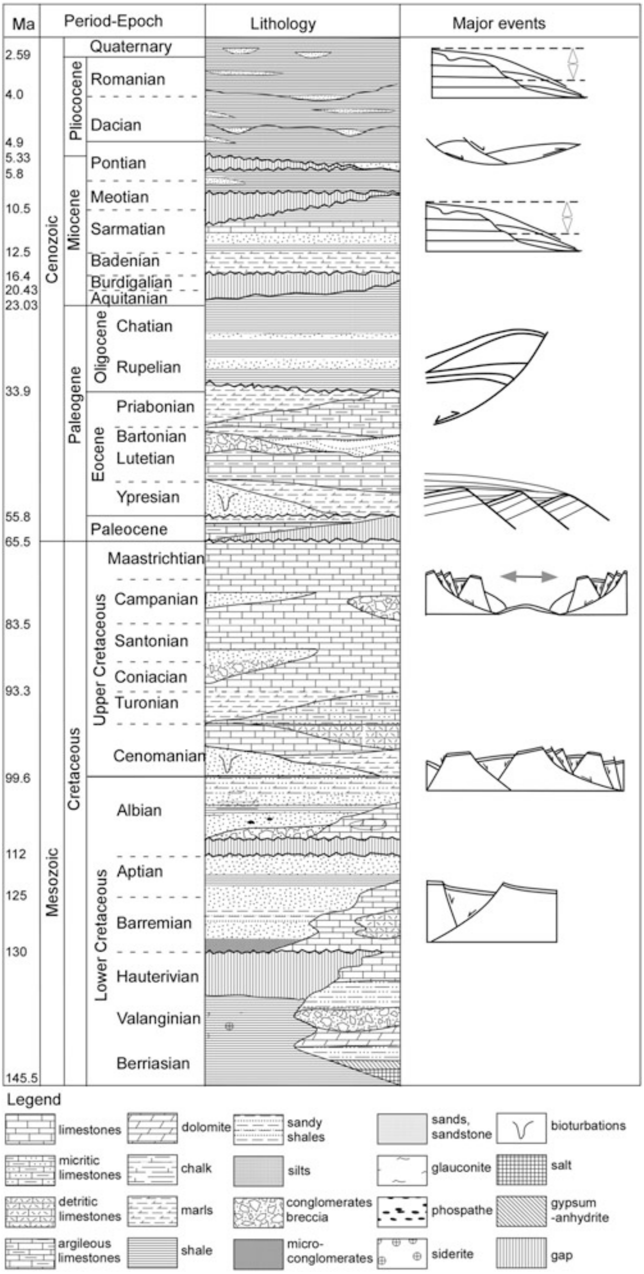

Fig. 6.3 Tectono-stratigraphic chart of the Western Black Sea part situated in the offshore Romania (compiled from Baleanu et al. 1995; Dinu et al. 2005; Munteanu et al. 2011; Tambrea et al. 2002a). The tectonic events are derived from the study of Munteanu et al. 2011

6.2 Seismic Dataset

6.2.1 Vintage Data Challenges

The term “Vintage Data” denotes essentially data that were acquired before the eighties/nineties, with technologies and protocols that today are not used anymore. This introduces a wide range of issues that cannot be solved easily because the seismic data are currently processed cannot handle them directly (Diviacco et al. 2015; Diviacco and Busato 2012; Diviacco 2012). Mostly this is due to the fact that a lot of information is not available and has to be reconstructed manually. At the same time, vintage data have several limitations in the resolution of data, in particular spatial resolution.

Positioning itself, sometime, can be a problem, because satellite positioning was generally not available at that time.

Media recovery can be a serious problem as well. In fact tapes like old digital 9 track tapes can suffer from what is generally called “sticky shed syndrome”, where humidity triggers a process of hydrolysis that results in an adhesive build up that makes the tape almost impossible to play. Recovering data from old media can, therefore, be difficult and risky whenever only one copy of the tape is available, as possible deterioration of the media during the process of reading can lead to a definitive loss of the data.

When it is not a matter of the tape itself, it can be a matter of the tape reader. These devices, in fact, tend to become obsolete very quickly and spare parts are difficult to find.

Specific care is needed when only paper seismic sections are available. In this case it is possible to use the process described by Miles et al. (2007) and Diviacco et al. (2015), where paper sections are scanned and the images are converted into actual seismic data estimating the value of each sample in the traces through a statistical analysis of the image grid in the vicinity of the sample. When tape reading is problematic and several records are not available, seismic data reconstructed from paper sections can be added to fill the gaps.

Geo-referencing vintage data often results in the need to digitize paper positioning maps.

Of course, all this is a time consuming process that involves specific economic investments. When these latter are not available, there can be serious limitations on the possible exploitation of such data to develop new ideas.

Notwithstanding all these issues, vintage data have potentialities that recently acquired data often cannot offer. For example, vintage data were often acquired in a different geopolitical situation so that they can have a regional coverage that could be difficult to obtain now. In addition, often, seismic sources used at that time were much more powerful, gaining deeper penetration. This cannot be easily obtained today for environmental reasons.

6.2.2 The OGS-BS (Black Sea) Dataset

The multichannel seismic lines were collected by OGS with the research vessel Marsili in 1975.

During the surveys, 3702 km of 6–12-fold MCS data were acquired, along 18 lines. Survey equipment and parameters utilized during the survey are summarized in Table 6.1. MCS data were recorded 6–12-fold using a 2400 m streamer and a Flexotir source, with a record length of 10 s, as detailed in Table 6.1.

These low fold multichannel seismic lines were available as paper stacked sections and tiff digital images and they were reprocessed with the commercial processing packet Paradigm FOCUS to enhance the coherency and lateral continuity and the high frequency content. In addition, more recent processing techniques, such as the Surface-related multiple elimination (SRME) (Verschuur et al. 1992) or the Kirchhoff PSTM (Alkhalifah 2006), were applied to these low fold data (6 or 12-fold) to better attenuate the multiples and to migrate morphological and tectonics features and reconstruct their real geometries.

All lines underwent despiking and bad traces/shots editing. Denoise processing techniques were applied (1) on shots (Linear noise attenuation, SRME, WBDecon), (2) on CMP gathers, using the Radon transform (Foster and Mosher 1992) and (3) on common offset planes.

Surface related multiple elimination (SRME) – matching in shot and common trace (dependant on water depth), Predictive Water Bottom Decon (300 ms Operator Length/Gapped to water depth) and Parabolic Radon domain subtraction were the main used demultiple techniques. Testing for the best parameters choice were completed.

Data were gained (T squared scaling) and deconvolved (TX Multichannel Decon, 120 ms Operator length/24 ms Gap, 6 Channel, 2 windows), and velocity analyses were performed every 4/8 km to pick the migration field.

Data were prepared for Kirchhoff Pre-stack Time Migration (PSTM) by regularisation of the offsets and differential NMO application. Kirchhoff pre stack time migration, using a 4 km half aperture, was performed a second time

Table 6.1 Survey parameters and equipment used aboard the *MV (R/V) Marsili* during the survey

Recording system	DFS V
Record filters	LOW-CUT:8Hz
	HIGH-CUT:62Hz
Streamer length	2400 m
Streamer offset	300 m
No. channels	48
Streamer depth	10 m
Group length	50 m
Source	Flexotir
Source depth	14 m
SP interval	200 m
CDP interval	25 m

using an updated migration velocity field derived from the residual move out migration melocity analysis, located at 4/8 km intervals.

FX Deconvolution, Time Variant Bandpass Filter and scaling/equalisation were applied as post stack processing.

6.2.3 Additional Processing Needed in Specific Areas

The modern seismic processing sequence is not designed for old data characterized by low fold coverage and therefore some important enhancement steps may fail. In particular, low fold data are under-sampled in space causing aliasing problems. In our sequence these problems can affect the SRME and the pre-stack time migration. To mitigate the effects of data sampling aliasing Verschuur et al. (1992) suggested a data interpolation before SRME multiple attenuation. On the other hand Yilmaz (2001) proposed the same expedient also for the aliasing problems in the migration process.

According with these advices we implemented a sequence which includes an interpolation step before the SRME process increasing fold coverage from 12 to 24. The final results show sections of better quality and resolution compared to the old ones (see Fig. 6.2 for a comparison between original and re-processed stacked data). This particular sequence was applied only on some lines that were mostly affected by aliasing problems (such as BS004 and BS012).

6.3 Basin Scale Interpretation in the Western Black Sea

The regional Western Black Sea Basin (WBS) interpretation have been performed using as a backbone the OGS reprocessed lines incorporated in a large dataset of published seismic and geological cross-sections (Fig. 6.1). The age calibration have been done using the available published well data, where it was possible, or using the seismic sequence stratigraphy principle as long offset basin scale correlation (Posamentier and Walker 2006; Vail et al. 1977; Van Wagoner et al. 1988). The seismic interpretation was done using the IHS Kingdome software, with the GIS data base being compiled in QGIS software.

6.3.1 Age Assignment and Interpretation

Age assignment of the main horizons and sequences is one of the most important stage in any seismic interpretation while making the link between wells (punctual data) and seismics (regional data). In frontier basins, such as the Black Sea Basin with limited amount of data, this is even more challenging, especially in long offset correlation from shelf areas to the deep sea part of the basin. In our age assignment of the main interpreted horizons and seismic sequences we have taken the advantage of the petroleum exploration wells drilled in numerous part of the Black Sea shelf area (Fig. 6.1) and recently in the deep part of the basin by a few frontier exploration wells targeting the Mio-Pliocene biogenic gas play or the deep Paleogene plays (see also Bega and Ionescu 2009; Georgiev 2012; Tari et al. 2009). The results of these new wells are partially disclosed such as those drilled offshore Turkey, like Sinop-1, Yassihoyuk-1 and Kastamonu-1 wells (Aydemir and Demirer 2013; Korucu et al. 2013; Şen 2013; Tari et al. 2011) and are facilitating in part the correlation of the sequences encounter on the shelf with their deep water equivalents. Of course the calibration is still punctual, the wells being drilled on the uplifted areas (Fig. 6.1), and it will be probably revised with the results of other wells being gradually disclosed or of future drilling.

Notwithstanding this, the combination of existing wells and regional seismic data provide a good age constrain along the WBS for the sequences above the Base Oligocene, which we call in our study the main unconformity, and a more challenging one for the sequences below and above the WBS basin basement, oceanic or continental in origin (Fig. 6.1). The above mentioned issues are related in part with the numerous basin scale unconformities, such as the Messinian, Serravallian, Base Oligocene, Intra Eocene, Base Eocene and Paleocene (see also, Dinu et al. 2005; Finetti et al. 1988; Robinson et al. 1995; Sinclair et al. 1997) that are effecting the basin margins; and in part of the difficulty in assessing the age and geometry of the oceanic crust in the WBS, with the inferred age ranging from Middle Cretaceous to Upper Cretaceous or Paleocene (Belousov et al. 1988; Galushkin et al. 2007; Golmshtok et al. 1992; Munteanu et al. 2013; Nikishin et al. 2015b; Spadini et al. 1996).

As we have mentioned above the main unconformity splits our age correlation into two main units (Figs. 6.3 and 6.4). The age of the main unconformity is better constrained by the wells drilled offshore Romania and Bulgaria that had encountered Oligocene deposits on top of older series from the basement to Mesozoic with the youngest one being Upper Eocene in age, hence the unconformity marks the base of Oligocene deposits (Dinu et al. 2005; Georgiev 2012; Ionescu 1999; Robinson et al. 1995; Tambrea et al. 2002b). The age of the prograding sequence observed offshore Turkey is still problematic (Fig. 6.7 BS03). In our interpretation we include it within the Oligocene sequence representing most probably early lowstand deposits, which makes our interpretation different from those of Nikishin et al. (2015a). We base our interpretation on the observation that the Upper Eocene shallow water carbonatic deposits drilled onshore Romania have a HST prograding geometry with a clear erosional upper limit on which the Oligocene deposits are gradually onlaping (Ionescu 1999; Tambrea et al. 2002a, b). Another observation is that the Yassihoyuk-1 well (Fig. 6.7 BS03 line) drilled Middle Eocene shallow water carbonates below the main unconformity which suggest that if there were any Upper Eocene deposit they have been removed and transported in the deep sea part during Early Oligocene times (Aydemir and Demirer 2013; Korucu et al. 2013).

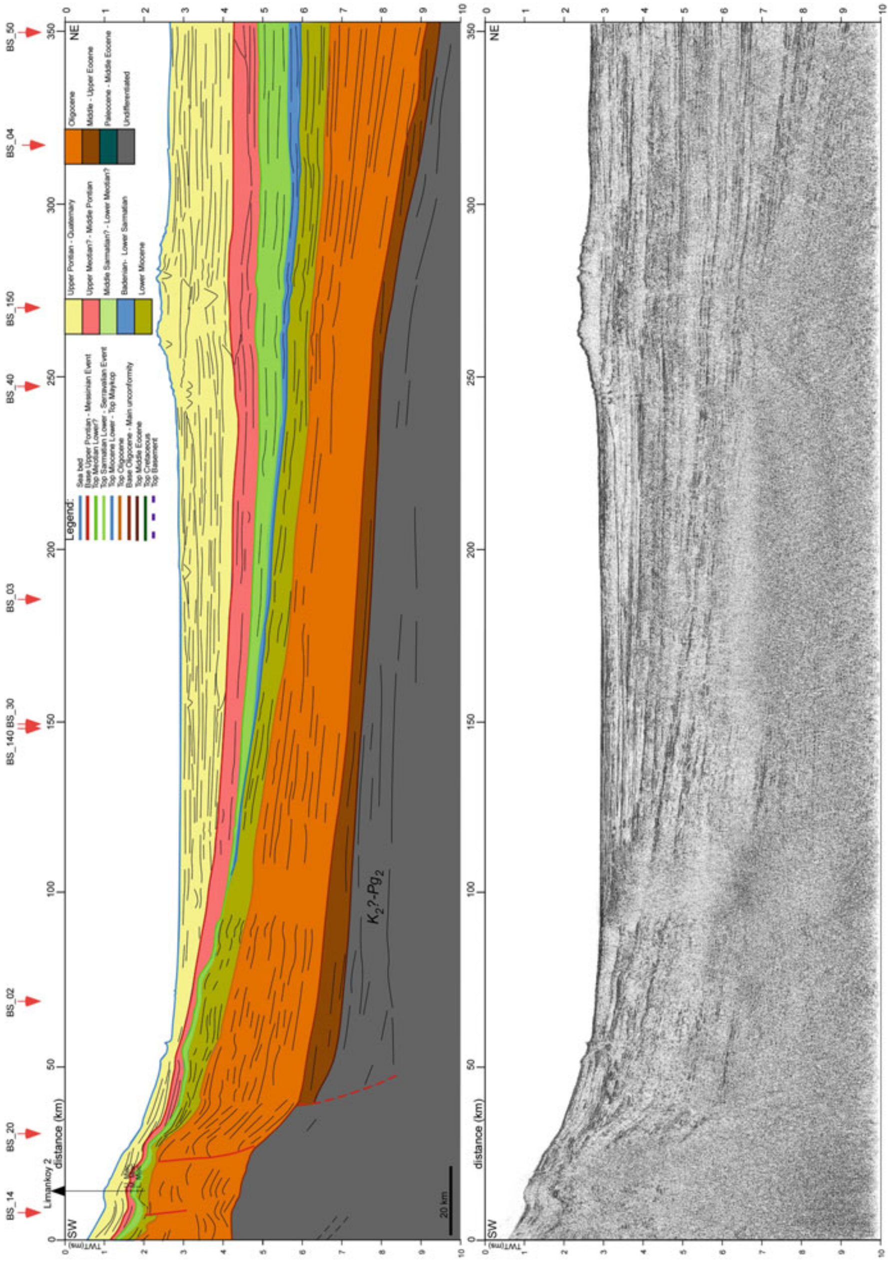

Fig. 6.4 Line drawing and interpretation of BS01A seismic lines across the WBS basin. The line ties with the Limankoy 2 well. Uninterpreted line in *lower panel*. For localization see Fig. 6.1

The Lower Miocene deposits have been proven by the wells on the Bulgarian and Turkey shelf like the Limankoy-1 (Fig. 6.4), while they were not encountered on the Romanian Shelf, and the Oligocene deposits are unconformable overlaid by the Middle Miocene deposits (Fig. 6.8, see also Dinu et al. 2005). The Middle Miocene, Badenian – Lower Sarmatian in local Paratethys scale (Fig. 6.3) has a reduced thickness as proven by the well drilled on the shelf, and contains another important basin scale unconformity, of Middle – Upper Sarmatian age, also known as Serravalian Event which represents the base for the next sequence (see also Menlikli et al. 2009). The next sequence has a reduced thickness on the basin margin as it is constrained between two major regional unconformities, Serravallian and Messinian at the base and top respectively. The Upper Sarmatian – Meotian age of this sequence is attributed on the base of the Limankoy 1 and 2 wells (Figs. 6.1 and 6.4) and Yassihoyuk-1 (Figs. 6.1 and 6.7) on the Turkish margin (Menlikli et al. 2009; Robinson et al. 1995; Şen 2013), while on the Romanian margin it is generally missing (Dinu et al. 2003, 2005) with the exception of one of the Cobalescu well which seemingly drilled the Upper Sarmatian deposits below the Lower Pontian ones (Floroiu et al. 2010; Schleder et al. 2016). The presence of this sequence in the ODP site 380 have been suggested by the Vasiliev et al. (Vasiliev et al. 2015).

The Messinian Event defines the Miocene-Pliocene limit and is the base for our last sequence, Pliocene – Quaternary (Figs. 6.3 and 6.4). This event has been initially described in the deep water settings by the ODP 380 and 381 legs (Ross et al. 1978). Its precise age and the magnitude of the sea level drop is still a matter of debate, spanning values such as 1600 m (Hsü and Giovanoli 1979), 1300–1700 m (Munteanu et al. 2012), 500–600 m (Schleder et al. 2016), 100 m (Tari et al. 2015, 2016) or 50–100 m (Krijgsman et al. 2010). The precise age of this event is not easy to establish since a large erosion, due to slope failure and gravitational sliding, has been associated with it on the shelf area, where most of the wells have been drilled, proving the Midlle Pontian gap (Gillet et al. 2007; Munteanu et al. 2012; Tambrea 2007), while the only largely studied deep-water wells remain the ODP 380 and 381 sites which are on continuous re-evaluation and scrutiny (Suc et al. 2015; Tari et al. 2016; Vasiliev et al. 2015). Based on our experience of the Romanian shelf, we have correlated this event with the Middle Pontian gap that is recorded in the wells, where the Upper Pontian overlies Lower Pontian or older deposits (Dinu et al. 2002; Tambrea 2007). On the Romanian-Bulgarian margin we picked the MSC Event unconformity, at the base of the strong amplitude reflectors representing the Upper Pontian deep sea fans (Figs. 6.4–6.9). We had to make this decision because of the relatively low resolution of the lines in this area and hence the ambiguity in picking the base of the mass transport complexes (MTC) of Middle Pontian age, representing the early lowstand deposits associated with slope failure as in Munteanu et al. (Munteanu et al. 2012) which would support the role of the MTC as the base of Pliocene sequence.

The age of the deposits below the main unconformity are seemingly Middle Eocene- Cretaceous in age resting directly above oceanic or thinned continental crust (see also Nikishin et al. 2015a). The precise age of these deposits will be

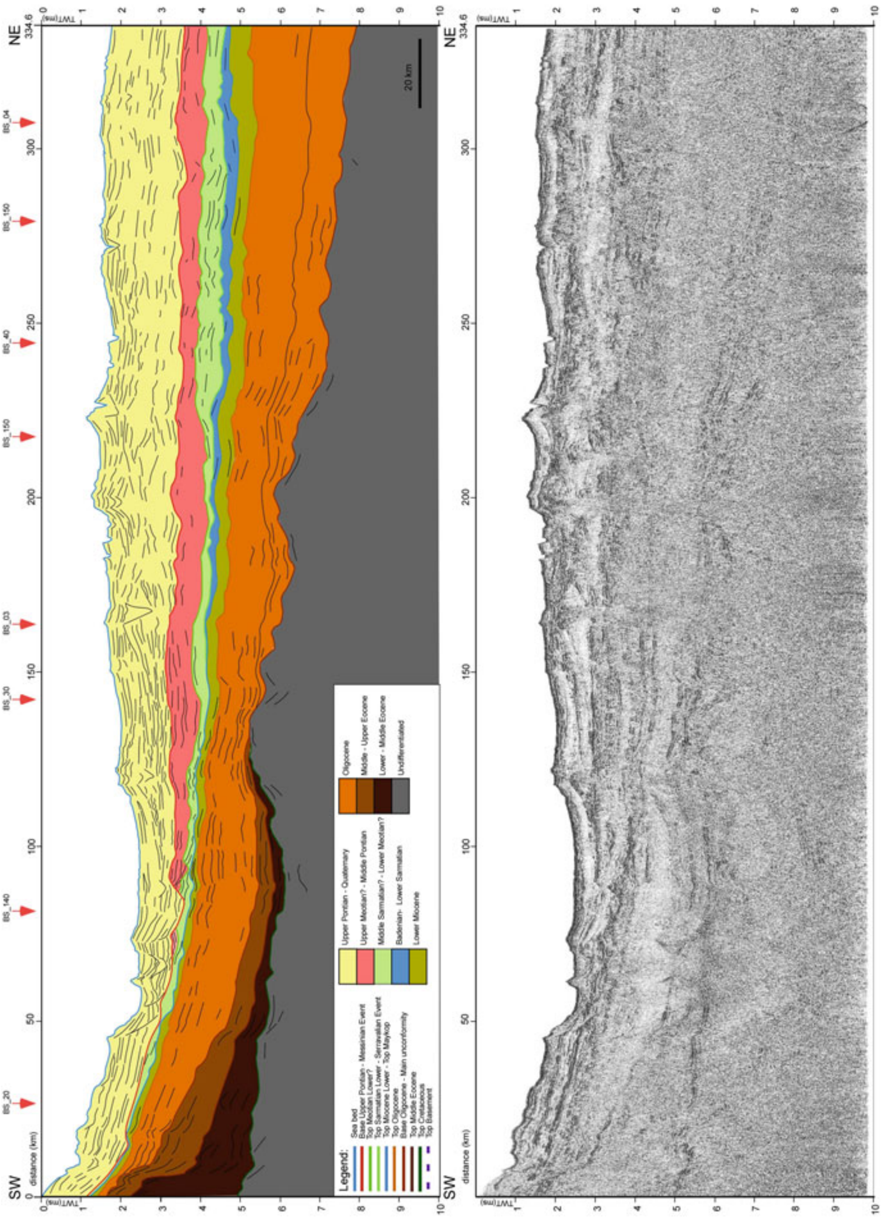

Fig. 6.5 Line drawing and interpretation of BS09 seismic line across the WBS basin. The lines goes from the Balkanides front in the south towards central part of the basin. Uninterpreted line in *lower panel*. Localization in Fig. 6.1

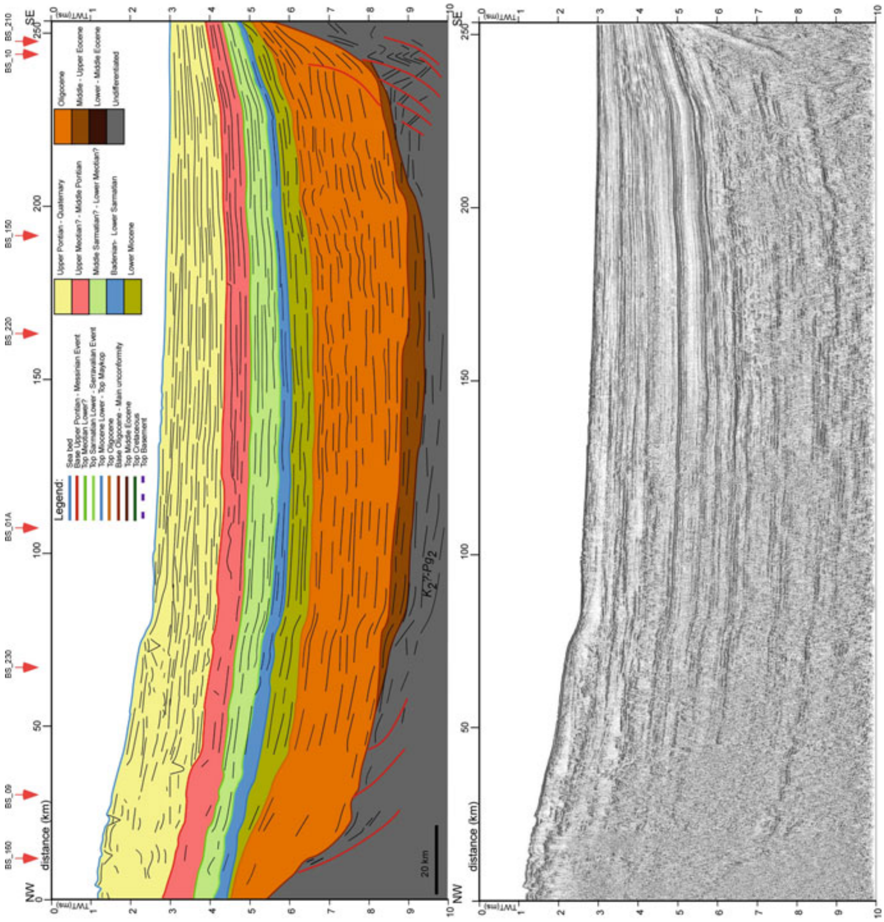

Fig. 6.6 Line drawing and interpretation of BS04 seismic line across the WBS basin. Uninterpreted line in *lower panel*. For localization see Fig. 6.1

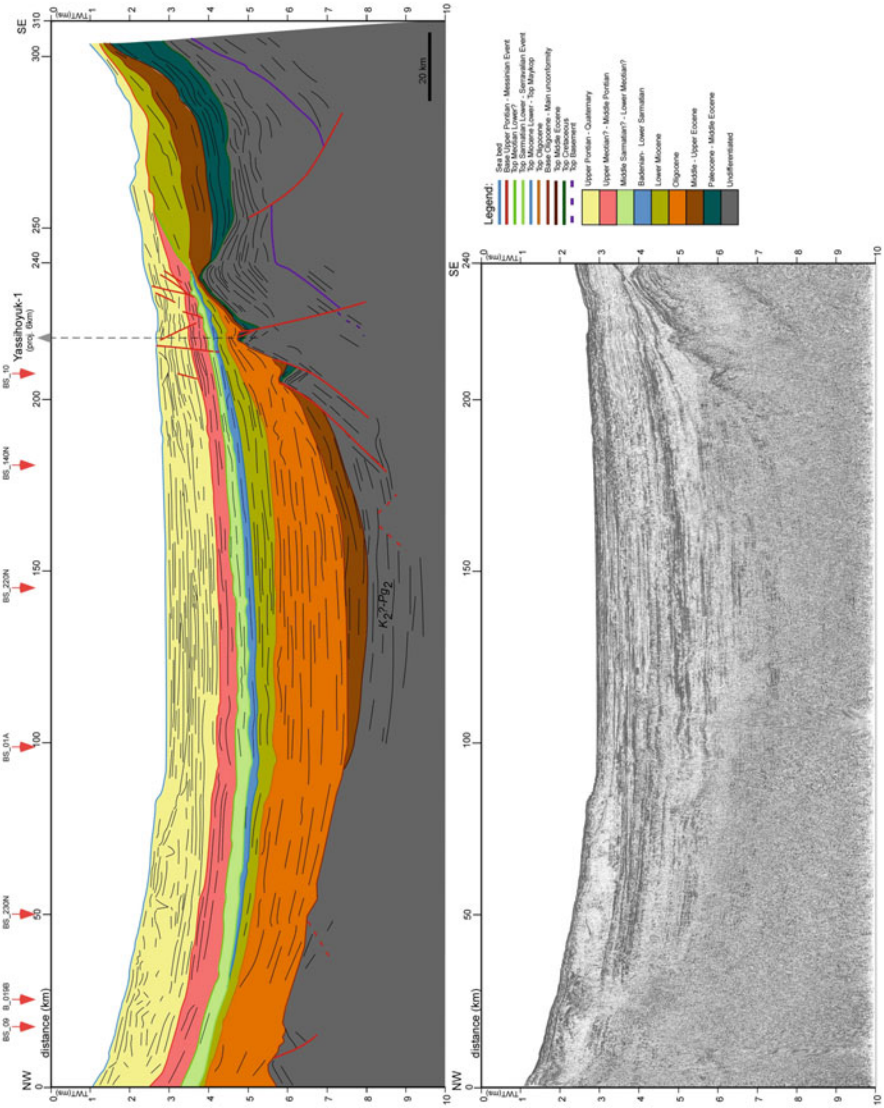

Fig. 6.7 Line drawing and interpretation of the composite seismic line across the WBS basin, *upper pannel*. The line is compose of BS03 with the southern part completed from Fig. 6.2a of (Menlikli et al. 2009) (note that the Yasssihoyuk-1 well is projected on the line. Uninterpreted line in *lower panel*. For localization see Fig. 6.1)

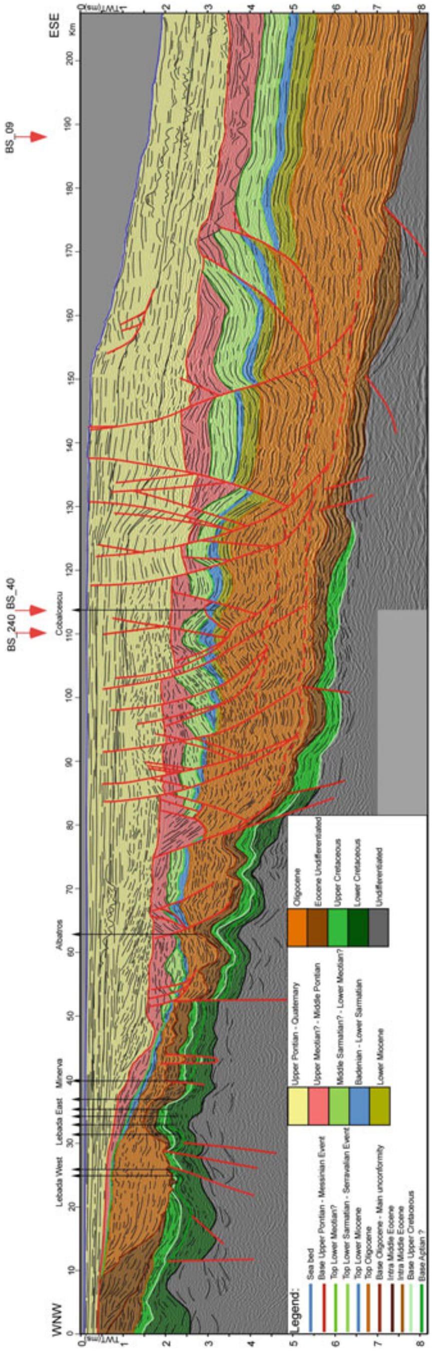

Fig. 6.8 Interpreted composite seismic line linking the Romanian shelf with the deep sea part of the WBS basin, adapted and redrawn from (Bega and Ionescu 2009; Matenco et al. 2016, 2012)

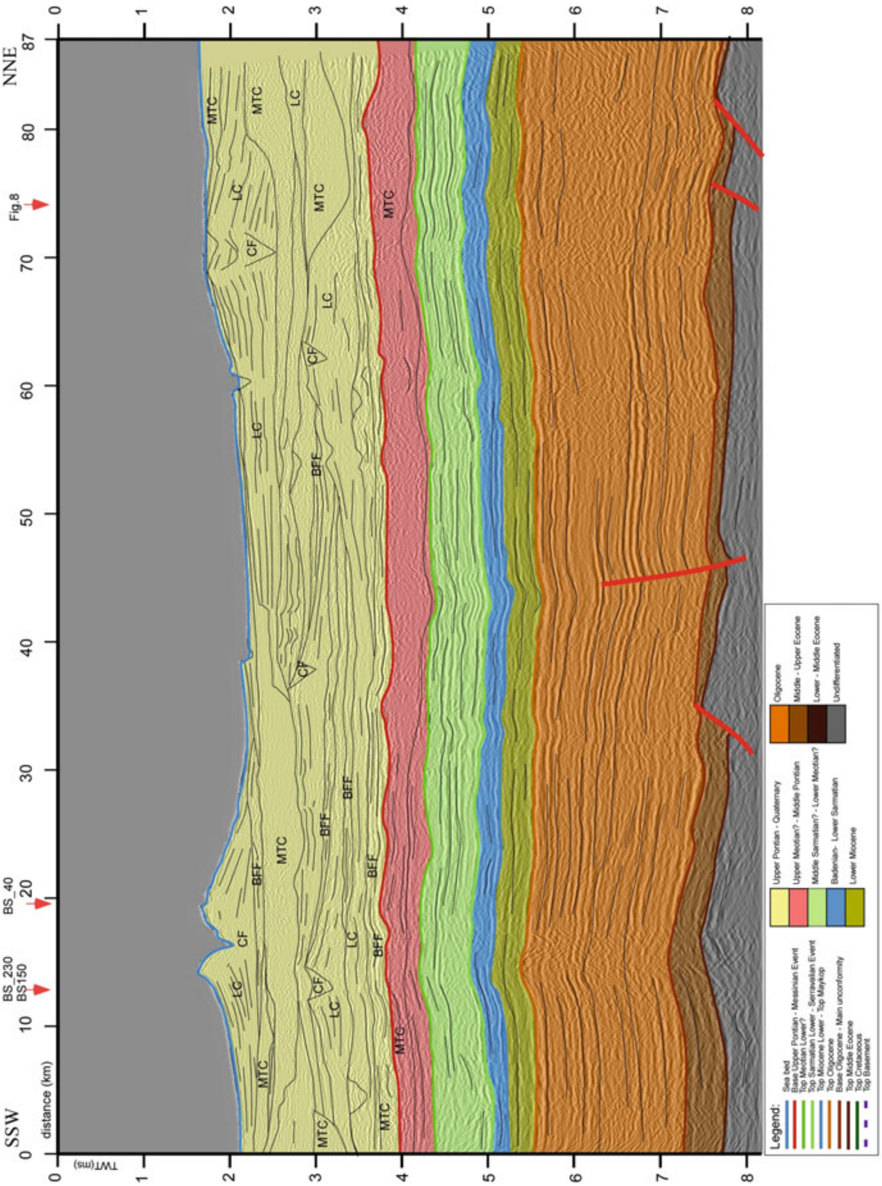

Fig. 6.9 Interpreted seismic line across the Danube deep sea system, line reinterpreted and extended after (Munteanu et al. 2012). *CF* Channel Fill, *LC* Leveed Channel System, *BFF* Basin floor fans, *MTC* Mass transport complex. The nomenclature is following (Posamentier and Walker 2006)

difficult to constrain since they are only indirectly calibrated and the age of the oceanic crust, which might constrain their base, is still under debate, ranging from Lower Cretaceous to Upper Cretaceous (Cloetingh et al. 2003; Galushkin et al. 2007; Nikishin et al. 2015b; Robinson et al. 1995) or even younger, possibly Paleocene (Munteanu et al. 2013).

6.3.2 *Geological Interpretation of the Seismic Lines*

The first interpreted OGS line, BS01A (Fig. 6.4) goes from the Turkey margin towards the Crimean margin crossing the deep sea part of the WBS (Fig. 6.1). The line is directly calibrated with Limankoy-2 well, Limankoy-1 and Karadeniz-1 wells, through the BS014 seismic line and the line in Fig. 6.2 of Menlikli et al. (2009). A more regional calibration can be done using the BS03 and BS04 (Figs. 6.6 and 6.7) and the ION-GXT lines published in Nikishin et al. 2015a, b (Fig. 6.1). In the southern part of the line one can see the complex structures of the front part of the Pontides Orogen, represented here by the thrusting and folding of Oligocene-Pliocene with the thrust decollement at the base of Oligocene (Fig. 6.4).

The overall NE-ward orientated wedge shape geometry of the sedimentary cover is clear in almost all the geological formations (Fig. 6.4). Differently, the oldest sequences, Upper Cretaceous-Eocene wedge, are thinning NE-ward from the continent towards the oceanic deep sea basin (Fig. 6.4). The next sequences, Upper Eocene-Lower Miocene in age, covering this unit have a more uniform thickness, although small increases in thickness can be observed towards the edges (Fig. 6.4). Starting with the Middle Miocene (e.g. Badenian-Sarmatian) all the sequences are thinning out SW-ward resembling a NE-ward orientated wedge shape geometry. The uppermost unit, Pliocene-Quaternary in age, has the most dramatic increase in thickness (Fig. 6.4).

The overall internal geometry of the sequences is defined by the parallel to sub-parallel continuous reflectors, with the exception of the Upper Meotian-Middle Pontian which locally has a chaotic facies, and with the Pliocene-Quaternary one that has a more complex geometry with chaotic to parallel and even divergent reflectors.

The northernmost second interpreted line, BS09 (Fig. 6.5), parallel with the previous one, crosses the present day shelf – slope to deep-water transition of the Bulgarian-Romanian margin, overlapping with the transition from continental to stretched-continental crust (Fig. 6.1). The oldest interpreted sequences which are of Eocene age, are gradually thinning NE-ward, in contrast with the other sequences that have the SW-ward trend (Fig. 6.1). Although not interpreted in the Northern part of our section, the Upper Eocene could be locally present in depocenters such as the one in Fig. 6.8.

Compared with the previous line the sequences boundaries have a clear unconformity character defined by their rough topography (Fig. 6.5). This character is more evident for the Base Oligocene unconformity where parallel reflectors are onlapping on a paleo-relief surface.

Similar to the previous line the Oligocene – Quaternary sequences have the same wedge shapes and thicken in a NE-ward direction. The largest variations are observed in the case of the Oligocene deposits with increased thickness in the local depocenters (e.g. Kamchya and Histria Depressions), and in the case of the Middle Miocene- Middle Pontian which are thinning and disappear towards the Bulgarian shelf (Fig. 6.5). The internal geometry of Oligocene sequences is changing upwards from draping parallel sub-parallel reflectors to a more parallel continuous configuration. In the case of the other sequences we can notice large variations from parallel, sub-parallel to chaotic seismic facies. Like in the previous lines some divergent facies can also be observed in the Pliocene-Quaternary sequences.

The first dip oriented line BS04 (Fig. 6.6) on the present day shelf crosses the deeper part of the WBS basin from the Romanian slope in the NW to Turkey deep water parts (Fig. 6.1). From a tectonic point of view the line connects the northern and southern continental margins separated by the oceanic domain (Fig. 6.1). The presence of the first two interpreted sequences with reduced thickness is limited to the central part of the section which corresponds to the oceanic domain and locally to the stretch-continental crust (Fig. 6.6). Starting with the Oligocene the sequences have relatively constant thickness and extend on the entire section with a lens shape thinning at both edges.

The internal architecture of the sequences is given by the parallel to sub-parallel reflectors moderate to high continuity, except the youngest two sequences that in the NW part are defined by chaotic facies or divergent wedge shape. Noticeable the Oligocene and Lower Miocene deposits exibit clear onlap terminations.

We have included the last present OGS line, BS03 (Fig. 6.7) in a composite line, in order to have a better constrain on the age calibration and general architecture of the basin margin. The southern part have been completed with the seismic line publish by Menlikli et al. (2009).

The line goes parallel to the BS04 but it is located in a more southern position (Fig. 6.1). Both lines are showing similar features of the sequences development with the noticeable difference in the thickness which is reduced.

Almost all the sequences are gradual thinning and disappearing towards the Southern Turkish margin. The only exception is the Lower Miocene which has an increased thickness south of the uplifted structure defining a prograding wedge shape geometry. The uplifted structure separates two sub-basins with different basin infill, Eocene vs. Eocene-Oligocene in age. Above this structural high the shallow sequences are affected by the normal faults which terminates in the Upper Miocene deposits and are reaching the sea bottom.

The two lines offshore Romania have been integrated in this study for the calibration of the age of WBS basin sedimentary cover (Figs. 6.8 and 6.9). The composite line in Fig. 6.8 shows the architecture of the NW basin continental margin with the overall basin-ward prograding and growing of the WBS basin sedimentary cover starting with Eocene deposits which define a clear prograding wedge. Another interesting observation is the presence of the normal gravitational faults which affects the upper part of the sedimentary pile and are connected basin wards with toe of thrusts defining a shelf collapse system.

The line in Fig. 6.9 together with the previous lines details the internal architecture of the sedimentary cover of the WBS basis, with particular insights into the Pliocene-Quaternary sequence that have been described elsewhere on the previous sections (Figs. 6.4–6.7). Looking in details one can see the typical deep sea features like: mass transport complexes (MTC) characterized by chaotic facies; basin floor fans (BFF) marked by parallel high amplitude continuous reflectors; channel leveed system (LC) with their characteristic divergent wedge reflectors pattern and transparent facies and the channel fill (CF) marked by the chaotic high amplitude reflectors.

6.4 Discussions and Conclusions

The first order feature that characterizes all the seismic lines is the increased thickness towards the basin centre, this is clearly related with the basin subsidence history. Based on this we can split the basin evolution into four main stages. During the first one, before the Oligocene, the sedimentary sequences Upper Cretaceous?-Eocene are thinning towards the basin centre. This might have at least two main reasons: one is that the extension that started in the Lower Cretaceous continued until Eocene with the formation of the oceanic crust since uppermost Cretaceous (see also Munteanu et al. 2013); the second one might be related with the sediments supply, with the sediments being trapped in continental normal faults (tilted blocks) related sub-basins with limited amount of sediments reaching the basin centre which was starving.

The second stage starts with the Oligocene deposition and marks the beginning of deep water WBS basin, as a consequence of the thermal subsidence of the oceanic domain. This steady and gradual subsidence is also evident by the uniform Oligocene-Lower Miocene architecture and facies and their spatial distribution. The observed differences in the Oligocene thickness could be related to the deposition and filling over an inherited paleo topography relief that was tectonically controlled and created the sub-basins. The structural grain is related with the inherited geometry from extensional history of the basin and in part with the inverted structures during the Upper Eocene-Miocene times that affected the basin margins.

The third stage marks the transition from a tectonically controlled basin to mainly sea-level driven mechanism. This stage is defined by the general reduced thickness of the Middle Miocene to Upper Miocene sequences and numerous local unconformities.

The last stage starts after the major sea-level drop at the Miocene-Pliocene boundary, which created a large unconformity (MSC unconformity) with shelf collapse and formation of gravitationally related structures that affected the previous deposits including the Oligocene. Some of these faults can be active in the present days, like those described on the Turkish and Romanian margins (Figs. 6.7 and 6.8). In connection with this event the Danube deep sea fan started to be developed with major sedimentary influx from the NW part of the margin.

The integrated interpretation of regional basin lines (OGS lines) with the local high resolution lines calibrated with available well data, and the existing published interpreted regional seismic lines (like IONone, see also Nikishin et al. 2015a, b) proves to be a very powerful tool in basin scale correlation which brings important contribution to the understanding of the geological evolution of the Western Black Sea basin. The reprocessing of the existing vintage lines with up-to-date technology and processing techniques brought important improvements to the seismic images and therefore increased the interpretability, allowing the correlation with modern data sets. In addition this dataset crosses political borders that might be difficult if not impossible to pass, which means it holds a particular value in analysing this basin at regional scale.

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Chapter 7
Lithodynamics of the Coastal Zone

Ruben D. Kosyan and Boris V. Divinskiy

Abstract The history of human civilization is directly linked to the social and technological state of the access to the sea, which ensured two very important aspects of the activity: trade and access to resources. On the other hand, the economic development of the shoreline depends on the protection from adverse natural processes such as storm waves or sediment motions. The development of coastal infrastructure is related not only to the current state of economy but also to its future state. The integration of accumulated knowledge led us to the creation of the lithodynamics science, which comprehensively studies the dynamics of the coastal zone. Despite the obvious successes, some problems of the coastal zone dynamics remain that require a deeper physical understanding. This Chapter describes the main problems remaining in the investigation of coastal zones and gives an analysis of poorly studied physical processes and mechanisms.

Keywords Lithodynamics • Coastal zone • Suspended sediment • Hydrogenic processes • Lithodynamic systems • Coastal zone hydrodynamics

7.1 The Role of Coastal Zones in Human Life

The coastal zone is a boundary region of the oceanic basin. It plays a special role in the dynamics of the World Ocean. The coastal zone is characterized by morphological peculiarities: shallow depths and steep slopes of the bottom topography, which determine its leading role in the dynamics of wind waves. The waves absorb enormous energy from wind and spend it generally in the coastal zone. The appearance of a number of specific hydrodynamic, lythodynamic, and morphodynamic processes follows from the wave energy dissipation. Strong and very variable currents develop here. Complex systems of intense water exchange are generated. Underwater ridges are formed and intensely move. A set of processes of coastal transformation appears. Specific peculiarity of the coastal zone is

R.D. Kosyan (✉) • B.V. Divinskiy
The Southern Branch of the P.P.Shirshov Institute of Oceanology, RAS, Prostornaya, 1g, 353467 Gelendzhik, Krasnodar, Russia
e-mail: rkosyan@hotmail.com; divin@ocean.ru

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associated with the fact that dynamic processes are interrelated, and individual processes are included into this complex in various combinations.

From the point of view of a specialist involved in the problems of the deep ocean dynamics, the coastal zone is very interesting as a study region, in which many dynamic processes, characteristic of the oceanic basin, are presented in the concentrated form. The dynamic processes occur most intensely, and usually, their observation can be technically organized more easily.

It is likely that the peculiarities of the coastal zone are most clearly distinguished in the dynamics of the bottom deposits. Fragmentary material is continuously transported from land, which is later transformed; as a result, the particles are either transformed or buried here, or transported to the other regions of the ocean. Thus, the coastal zone is a filter for the material transported from land on its way to the oceanic depths.

The practical considerations, which focus the attention of scholars and engineers on this region of the oceanic basin, are not less important. For a long time already, the coastal zone has been a region of intense economical expansion whose development rate strongly increased in the last decades; it is clear that the process will become more intense in the nearest future. Of course, the economical development spreads now to the deeper layers of the sea, which are not related to the coastal zone. However, it is clear that this zone will remain the most important part of the oceanic basin for humanity.

Investigations of the coastal zone dynamics were initiated due to the interest to sea waves among the navigators. Indeed, sea waves and especially the waves in the coastal regions of the sea are hazards to seafarers. It was necessary to protect specific regions of the coastal zone, so that the ships could approach the shore for contacting the land in any weather and hide there from the storms. Ports with protection constructions at the open shores were built in the places that did not have natural harbors.

As the ship draughts increased, the ancient seafarers faced the problem of sediment accumulation in natural harbors (for example, in the mouths of rivers). This problem became especially important during the first attempts to build ports over open shallow water coastal zones. Hence, the knowledge of the natural regime of the coastal zones became necessary as well as foreseeing the processes, which would be caused by the constructions. It is likely that already in the middle ages the works were initiated to protect the shores from destruction by the sea, which followed the first constructions of ports. As the cities, especially the port cities, increased in size and lifetime, and cost of the constructions increased, a necessity appeared to protect the basements of the sea shores. In recent years, the tonnage of ships has increased significantly, which leads to the increase in the depth and other sizes of the channels allowing the ships to approach the ports.

Excavation of mineral resources from the sea bottom is a very important problem. It is related to the problems of differentiating the loose material and deposits of particles with specific properties. Large-scale excavation of sand, shells, pebbles, and gravel for construction and other purposes is a hazard to the coastal regime and can lead to undesirable consequences. However, a specific amount of the excavation of these materials from the sea is frequently quite admissible, which is important when other sources are not available on land. Therefore, a scientific approach to the solution of the problems of the possibility, locations, and admissible amounts of such material is important.

Using of the sea as the source for food resources led to the development of special aquaculture farms in the coastal locations, which is most productive for cultivation species of marine fauna.

Solution of the problems related to the ecology of the coastal zone is impossible without the data on the hydrodynamic transport of sedimentation. Solid particles transported by water flows may become absorbers of the chemical and radiation pollution.

The role of the coastal zone in the human life and vital activity is not limited by these examples. They are given here only to illustrate the many-sided nature and importance of our interests in this part of the World Ocean. At the same time, the anthropogenic factor becomes one of the most important in the dynamics of the coastal zone. In addition, this part of the ocean is most vulnerable and sensitive to various forcing, and the problem of protecting and conservation of the environment is most pressing here. It becomes clear that the solution of the problem of the possibilities and methods of the technical expansion should be preceded by a forecast of its consequences. Such a forecast can be carried out on the basis of specific knowledge and thorough analysis of the dynamic processes in the coastal zone.

7.2 Lithodynamics of the Coastal Zone

In the last decades such terms as "lithodynamics", "lithodynamic processes", "lithodynamic research" have become more and more spread in the hydrotechnical, oceanographic, geo-morphological and geological publications. These terms define the phenomena and research of sediment transport along the Earth surface due to the exogenous factors and gravity. In the oceanographic science, these terms are the most accustomed owing to the growing interest to such researches in the ocean. Practical significance of these processes follows from the extensive human activity on the sea floor from the coastal zone to the continental slope. Special departments were organized in a number of scientific and design institutes to carry out lithodynamic research considered as one of the major problems in the study of the world ocean.

Nowadays, the Earth's landscapes are involved into the lithodynamic research. These investigations are carried out by various specialists: geologists, hydrologists, hydrotechnicians, geomorphologists, and lithologists mostly with the aim of solving particular applied or scientific problems. A number of monographs appeared which are fully or partially devoted to the lithodynamics of some landscapes deserts, fluvial valleys, sea coastal zone, mountain slopes. Until very recently, research of fluvial processes has been most successful and intense.

Vladimir Longinov was the first to formulate the goals of the new geophysical field in 1954, which he called “lithodynamics” (Longinov 1954). He believed that this term was the most successful in relation to the sense of the new science. In his “Essays” (Longinov 1973), he formulated in detail the main aspects of this oceanographic field and gave a list of the existing concepts about the ocean lithodynamics and the main goals of its future development. He emphasized that according to its content and general goals, lithodynamics can be related to the geophysical disciplines, but owing to the variety of requirements to the lithodynamic investigations, they were conducted within various scientific fields: lithology, geomorphology, dynamical geology, oceanography, hydrology of land, and many other applied sciences (Longinov 1973; Longinov and Pykhov 1981; Longinov and Kosyan 1994).

Lithodynamic problems can be divided into the general geophysical and particular applied goals related to the interests of the other Earth sciences. Lithodynamics is related to a field of geophysics, but owing to the complexity of the processes and its multidisciplinary character, these researches are carried out at the boundary of different disciplines.

V.V. Longinov divided the lithodynamic problems into engineering, geological, geomorphlogical, biological, etc. The most important in the engineering aspect are:

- Distinguishing local differential time dependencies of matter transport on the factors that determine this transport;
- Transition from one or another expression for the sediment transport as functions of the determined parameters to the expressions for variations in topography;
- Establishing correlations between the engineering properties of the formed deposits, their mobility and character of their motion;
- Distinguishing the equilibrium conditions between different forms of material accumulation.

In the biological aspect, one can distinguish the problem of instantaneous and time average local mobility of deposits (its intensity) and establishing the degree of stability of variations in the composition and character of deposits as the most important ecological factors.

Investigation of the physical, and first of all of the dynamic processes in the contact zone between the lithosphere and hydrosphere or atmosphere is the basis of the lithodynamic research. As we investigate the local dynamic regularities in this contact zone it becomes possible to know how they spread in time and surface of the lithosphere based on the lithological and geophysical studies of the surface deposit column. Thus, the dynamics of the contact zone should be considered the physical basis of lithodynamics.

To evaluate borders of the contact zone, one should consider it as an area where interaction of sediment, water, and immobile floor produces dissipation of mechanical energy of the moving sediments and water.

Two main types of motion can be distinguished in the group of hydrogenic processes:

- the transport of bottom sediments by traction or rolling, and by saltation. In the gravitational transport, one can differentiate sediment collapse and talus on the one hand, and slide on the other. Movements of the first type are accompanied by the interaction between solid particles and underlying surface, processes of shifts of the whole mass of particles are typical of slides and similar phenomena-debris flows and mud flows;
- the transport of suspended particles, which can be regarded as a type of viscous liquid flow, strongly depends on the flow density. This relation is so strong that one can talk about qualitatively different processes of suspension flow motion with a high and low density.

There are lithodynamic processes in the world ocean, which are not involved in the dynamics of the bottom contact zone and occur beyond it. These processes are the horizontal and vertical sediment transports occurring in the entire water column and its top layers. These motions, as a rule, involve fine grained terrigenous particles and biogenic material into the water column. The inflow of sediment load brought by the rivers can occur outside the contact zone even on the continental shelf, while in the areas with greater water depths, accumulations of such particles with fine grain sediments brought by suspension flows can form nepheloid clouds, migrating several hundred meters along the isobaths and gradually descending towards the continental slope. Continuous deposition of the skeletons of sea microorganisms, being a lithodynamic process itself, is accompanied by their constant transport along the sea floor. Although this process is not related directly to the flow of the terrigenous material, it forms sediments, which together with the terrigenous component take part in the lithodynamic processes of the contact zone. The pathway of fine grained terrigenous material towards the contact zone is even more complicated, because this material is first absorbed by the living organisms and then excreted by them with changed mechanical and hydraulic properties. Coarse grained material driven by the ice is sometimes transported into the contact zone. Regularities of these migrations differ greatly from the regularities of the contact zone dynamics, but their participation in the general lithodynamic process of the ocean is evident and their existence should not be ignored when developing the regional and global models of ocean lithodynamics.

The sediment transport on the surface of the lithosphere causes a number of phenomena, which follow the laws dictated by the water transport. The most essential of these phenomena is sediment differentiation according to its hydraulic properties and topography variations related to the changing volume of the clastic material moving towards the contact zone. On the other hand, migration of sediment is accompanied by numerous phenomena, which are not directly related to the mechanics and energies of the lithodynamic processes but influence them greatly. These processes include coagulation of fine grained particles, chemical and thermal weathering of rocks, which contribute to their subsequent destruction and mobilization by water flows, as well as the motion of organisms on the ocean floor and in the water, causing transport and transformation of fine grained sediments. These phenomena are not caused by lithodynamic processes and do not follow their regularities but should be also considered in the lithodynamic research. Investigation of such sediment transport consequences as its differentiation according to the mineral composition or formation of definite sediment textures and structures should not be regarded as an object of lithodynamics, though their understanding requires the knowledge of the regularities of the contact zone dynamics. Thus, the major object of lithodynamics is to study the process of transport itself rather than the analysis of migrating sediments or resulting sediment forms. Morphodynamic phenomena and differentiation of sediments according to the hydraulic coarseness are the consequences immediately governed by the regularities of the sediment transport; hence they are related to the secondary lithologic, geomorphologic, and other consequences of the lithodynamic processes.

The regularities of the ocean contact zone dynamics can be used to solve many applied and scientific problems. They include all kinds of engineering problems connected with the dynamics of sediment and topography of shallow depths, protection and reinforcement of coasts, construction of hydrotechnical stations in the near-shore and shelf zones, provision of navigation security, prospecting and exploitation of deposits on the ocean shelf and coastal zones. Understanding the surface sediment accumulation and transport forming the sequence of the ocean floor deposits is most essential at greater depths. It is difficult to have a clear picture of the depositional history and development of the ocean floor without full understanding of the dynamics of these sediments.

Finally, the construction of an overall picture of the sediment transport from the continents to the ocean floor and the creation of a reliable model of all links of global lithodynamic processes are the major tasks of the ocean lithodynamics as a whole.

The whole variety of lithodynamic phenomena and processes in the ocean can be divided into two methodically distinct groups and consequently into two types of models of the systems under study. These models can be conventionally called physico-mathematical and physico-geographical. Investigations of the first group are included into the contents of the dynamics of the oceanic contact zone, while the research complex of the second group represents the subject of the physical geography, which can be called regional lithodynamics of the ocean.

The concept of sediment transport in the ocean as a phenomenon representing the subject of our investigation, should be considered as a starting point for both types of research. The sediment transport is a general concept: it includes overall, unidirectional sediment transport averaged over any given period of time. In accordance with the models of the lithodynamic system, the sediment transport may be also divided into the local and regional. We understand the local transport as the simplest implementation of the processes of unidirectional sediment transport with the shortest averaging time interval (seconds and minutes). The local transport models usually imply a possibility of raising a two-dimensional problem, while transport sections to be modeled are rather short (up to several tens of meters) in accordance with the averaging time intervals. Thus, the regional transport means sediment transport across the regions from 100 m to 100 km long with the averaging time intervals from several hours to several years. Natural regional transports may be measured only very roughly over short sections. When studying the regional transports, researchers rarely undertake direct investigation of the transport processes. Instead, they study its integral consequences and later try to relate them to the energetic, hydrologic, and other integral parameters. The most important parameter of any flow is its discharge, expressed in the units of sediment mass transported in a unit of time through a unit cross-section normal to the general flow direction. The value of the total discharge transport of sediments through a cross-section during the averaging time interval is sometimes used for the regional flows. In geomorphology this total discharge, as applied to the alongshore currents, is called the “power” of the transport. Discharge distribution, normal to the direction of the transport, results in the “cross structure” of the transport, which is of the major importance in many practical cases. We call the combination of sediment transport and the contact zone, in which it moves, a “lithodynamic system”. This system can be hierarchically organized in an order of complication. The initial link of this hierarchy is an elemental system. Only one elemental mechanism of the transport acts in these systems. Uniform systems including only one type of transport: hydrogenic, gravitational, or turbidity current, are the next in the hierarchy. These systems exist in the nature and can be classified according to the parameters of the contact zone topography, sediment nature, water mass regime, etc. Investigation of uniform systems is possible both in the laboratory and field conditions on the specially chosen typical uniform systems. They can be considered as the final stage of research within the dynamics of the contact zone, or dynamics of the local systems. The study of uniform systems in certain natural conditions, which can be referred to as “regional”, begins at this stage. In this aspect one can find non-uniform systems, comprising transports of various types, where various transport mechanisms exist either successively or simultaneously on the given floor area. Regional systems include the individual ocean landscapes and the ocean major regions: shelf, slope, continental rise and abyss, global systems of separate seas and oceans or of their major parts and, finally, general lithodynamic systems of the World Ocean. Real nature conditions, i.e. the environment, in which regional systems are active, should be called a lithodynamic region rather than a contact zone. This definition includes all the factors, causing initiation and development of the regional flows hydrodynamic, geomorphological and lithological, sometimes, anthropogenic.

All investigations of the regional lithodynamic systems can be attributed to the physical geography of the ocean while the dynamics of the contact zone, i.e. the study of elemental and typical uniform systems, should be attributed to the physical research and considered as a branch of physics of the contact zone. Based on this physical aspect we use the theoretical approach and experimental field measurements to study the main regularities of the formation and motion of sediment transport and learn how their dynamics is governed by the factors of contact zone relief, hydrodynamic regime, and floor character. Investigation of the typical uniform systems occupies an intermediate position between the study of the elemental systems and regional lithodynamics. These investigations can be carried out, as mentioned above, both within the dynamics of the contact zone and within the regional lithodynamics of the ocean. Naturally, it is both difficult and unreasonable to draw a sharp distinction between these three methods of investigation. Placing lithodynamics completely into the field of the physical geography, geology or physics would also be unreasonable and not natural. Each of these branches of science considers the same phenomena in the ocean from their viewpoints; they have their own subjects and own tasks of research. Clastic material, undoubtedly, should be studied by marine geology, while its transport is a subject of lithodynamics. At the same time, regional lithodynamic systems are, undoubtedly, the constituent parts of the complexes called ocean or ocean-floor landscapes, and from this point of view these systems should be studied by the physical geography of the ocean. Elucidation of the main regularities of origin, development and movement of sediment transport in the lithodynamic systems is a task of the ocean dynamics of the contact zone, which is a branch of marine physics or geophysics in a broad sense.

Let us return to the description of the main tasks and concepts of the ocean contact zone dynamics or lithodynamics of the local lithodynamic systems. The construction of models of local systems should result in the expression of sediment transport discharge. This expression should be given in a form, suitable for the discharge under given conditions of the contact zone. These conditions include such factors as the nature of the underlying surface, energy parameters and structure of hydrodynamic field for hydrogenic processes, floor gradient and composition of the bottom and moving sediment for suspension flows and gravitational displacements.

The next stage of the investigation of the contact zone lithodynamics is the determination of the influence of unstable environment of the contact zone on transport discharge. At this stage, the main concept of the lithodynamics of any system arises, which is the discharge gradient. The value and sign of the gradient determine the morphologic effect or system performance on the given area and processes of sediment differentiation on the flow route according to the hydraulic coarseness.

If a constant speed is maintained by exogenous forces in a flow, moving above the washed-out floor, this flow becomes saturated with solid load over a part of its route, and during subsequent motion, the interchange between the sediment and the floor occurs, while the load, applied in the saturation area, remains constant. However, even after the saturation the flow still consumes energy to overcome resistance to its motion at a given speed to maintain the entire motion of the solid load. When the energy supply to the flow decreases, the speed becomes slower, negative discharge gradient develops, and a part of sediment is deposited simultaneously with its differentiation in accordance with the hydraulic coarseness. If the energy decrease is smooth, deposition will proceed over some portion of the route until the balance is gained between the consumed and received energies. If the energy supply stops completely or decreases sharply, a local accumulation form will result.

It should be noted that a quantitative solution, which requires the knowledge of the flow discharge parameters, is possible only in rare cases, related to the dynamics of the local systems. In the lithodynamics of the regional systems, it is possible to solve only part of the applied problems with qualitative evaluations or approximate generalized quantitative characteristics.

Referring to the contact zone dynamics, special attention should be paid, besides lithodynamics, to its second part, the hydrodynamics. This part does not play a great role in the analysis of hydrogenic processes but it has its own applied significance, particularly in the coastal dynamics. Elementary and complex hydrodynamic systems can be also distinguished in the hydrodynamics of the contact zone. Finally, hydrodynamics of the contact zone must result in a complete picture of the whole spectrum of speeds in the given dynamic setting in the bottom layers. This picture is necessary for specific reliable computing expressions of the solid load discharge in hydrogenic lithodynamic systems and for the solution of many other problems, related to the physics of the ocean bottom contact zone.

As our knowledge of the contact zone lithodynamics increases, the construction of physical models of increasingly more complex systems becomes possible, though the transition from the models of the local systems to those of the regional systems are yet far from being clear. It is quite possible that the solution of many applied problems of the regional lithodynamics even in the future would require the use of approximate qualitative evaluations and ideas.

Let us discuss some general features of the ocean lithodynamic systems. Comparison of the ocean hydrogenic systems and similar Earth systems shows that they have basic differences. In the fluvial flows on the Earth surface, the water, being an active agent, flows in a restricted channel due to the composite gravity determined by the flow gradient. Thus, a surface water flow eroding its channel is at the same time governed by this channel, and the flow speed depends directly on the properties of this channel. In the hydrogenic ocean flows, the underlying surface "governs" the flow to the extent, to which it (together with the transported sediment) dissipates the energy of the flow. The source of this energy is outside the contact zone and does not depend on the character of the surface underlying the flow. When describing the evolution of the fluvial flows, Velikanov (1948) tried to use a principle of the system's striving for the minimum dissipation of the flow energy, but in the ocean this suggestion is not true, and striving for complete dissipation of the flow energy with the minimum power of dissipation process is most likely the general principle of the development of ocean lithodynamic system. Morphologically this tendency manifests itself in striving for the increase in the energy dissipation and decrease of the gradient, which can be observed when the equilibrium profile is worked out in the coastal zone.

7.3 The Basic Properties of the Coastal Zone Hydrodynamics

Water motion in the coastal zone is determined by external forcing. It is manifested as tidal currents, swell, and wind waves, various kinds of wave currents generated in the wind waves breaking zone as storm surges, and tsunami. Recurrence of these phenomena in the nature and their influence on the underwater slope are different. Tsunami waves and strong storm surges are possible only in the specific coastal regions of the World Ocean, but even here, their recurrence is very low. In the most cases, dynamic processes in the coastal zone of the sea are determined by the surface waves and swell whose velocity fields have a direct impact on the bottom sediments. In addition, during dissipation of the wind waves energy and interaction between these waves and breaking, secondary motions appear in the water: long-period waves, alongshore currents, water circulation in the vertical and horizontal planes whose spatial and temporal scales most likely determine the scales of the morphodynamic elements of underwater slopes and coasts (Kosyan and Pykhov 1991).

Wind is the main energy source of waves, which always blows over the water basins. Parameters of stationary waves are determined by the wind speed, duration of its forcing, and fetch. Wind waves are usually three-dimensional and irregular. After the wind calms or beyond the zone of wind forcing, the waves propagate in the sea in the form of swell; they are characterized by approximately constant period and form.

When waves propagate from the open sea to the coast they reach a point, in which their length becomes shorter than the local depth. From this moment, the waves induce oscillating motions of water near the bottom whose amplitude increases as the waves propagate to shallower depths. Under specific conditions the motion and transport of the bottom sediments particles starts. If the waves propagate not normally to the coast, refraction starts. As a result, they tend to approach the isobaths normally. Deformation of waves occurs simultaneously with refraction: their form and height change. After further deformation the wave breaks, and water motions of various scales are generated as the wave energy dissipates: small-scale turbulence, large-scale eddy motions in the breaking wave, long-period waves, and coastal currents, which determine the intensity and direction of the hydrogenic sediment transport in the surf zone.

Sediment motion in the region offshore the wave breaking zone occurs not only under the wave forcing, but also under the influence of currents of different origin (flood-ebb tides, wind drift, etc.). In the regions, where the velocities of the flood-ebb tidal currents may reach tens of centimeters per second, they can strongly determine the total transport of bottom sediments in the upper region of the shelf (Soulsby 1983). Superposition of surface waves and currents increases intense water motions at the bottom; hence it leads to the increase in the transport of fragmentary material. Beyond the zone of wave breaking, the motion of sediments after its initiation occurs near the bottom; hence, the needs of modeling the hydrogenic transport requires the knowledge of the dynamics of the bottom boundary layer both for the pure wave motion and in the case of joint wave and current forcing.

When surface waves reach shallow depths, oscillatory motions of water at the bottom and bottom friction form the boundary layer. Transformation of sediments motion occurs immediately in the oscillating boundary layer, which is accompanied by the bottom erosion, formation of microforms of bottom topography that actually determine the boundary conditions for modeling of the mass transport of sediments under forcing of sea waves.

7.4 Elementary Hydrogenic Processes

One can distinguish several main elements in the group of hydrogenic displacements of the sedimentary material: initial motion of particles, bottom transport, suspension transport to the ripple and smooth phases of the sediment motion. It was suggested to call the mechanisms characterizing the sediment transport as elementary processes in the analysis of lithodynamic oceanic systems (Longinov and Pykhov 1981). Elementary processes, being the first stage and the basis of the lithological studies, can be investigated theoretically and experimentally as a physical process of the interaction between the suspension flow and bottom.

As a rule, all types of the sediment transport can be observed simultaneously in the natural conditions; although one can distinguish the regions on underwater slopes, in which one or another elementary process dominates. In the outer part of the coastal zone, the extreme offshore point of hydrogenic displacement of sediments is the point on the underwater slope, in which the first displacements of bottom particles occur. This point may move along the slope depending of the size of the sediment particles and parameters of the surface waves. As the velocities of the orbital motion near the bottom increase, more and more particles are involved into motion. In this phase of the interaction between the flow and current, the particles in the bottom layer are involved into the rolling motion, sliding, or saltation (the height of the jumps usually does not exceed a few diameters of the particles), which determine the bottom transport of sediments over a smooth bottom. This regime is called the smooth phase of sediment motion up to the beginning of formation of bottom microforms. The further increase in the velocities upslope leads to the increase in the transport of displaced particles. Formation of ripples starts under specific conditions. Ripples are observed on the bottom up to the zone of wave breaking. Bottom transport of sand over windward slopes of microforms and in the suspension layer whose approximate thickness is of the order of the ripple length occurs simultaneously in this phase of the interaction between the flow and the bottom, which is called the ripple phase.

Ripples are washed out in the region of the wave breaking point where the wave forcing on the bottom is maximal. Here, sand transport occurs in the suspension layer over smooth bottom. We shall call this regime the upper smooth phase of sediment motion. Suspension motion of sediments dominates immediately in the zone of wave breaking owing to the development of eddy motions, while all elementary processes may exist simultaneously closer to the shore in the surf zone where the bottom sediment particles are larger and bottom forms can appear again. The motion in the form of sand layer over smooth bottom dominates when the wave energy finally dissipates in the runup zone; this is the upper smooth phase of sand transport.

In the natural conditions, intensity of elementary processes and their relation to specific zones in the underwater slope are determined not only by the composition of sediments, but also by external forces: variations in the sea level due to the tides or onshore winds, wave currents, infragravity waves, and local bottom slopes.

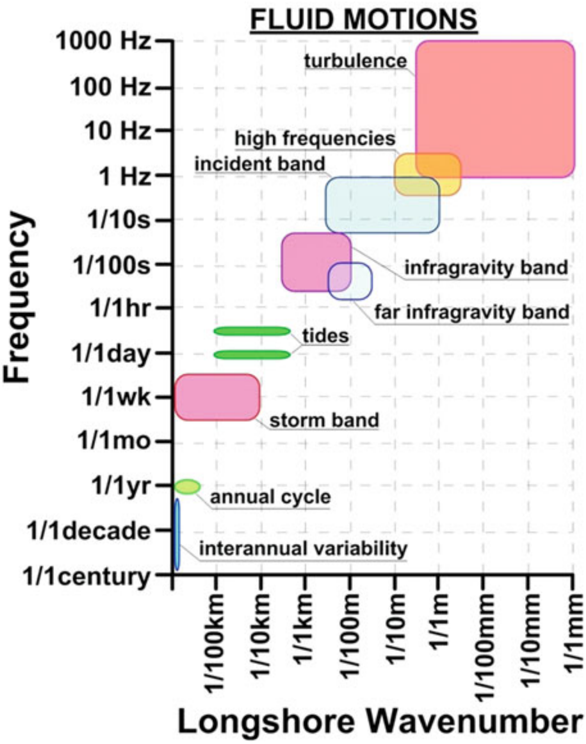
7.5 Problems of Investigation of Hydrodynamic Processes in the Coastal Zone

All dynamical processes in the coastal zone can be separated into three categories: small-, intermediate- and large-scale processes, based on the spatial and time scales of near-shore fluid motions (Fig. 7.1) (State of Nearshore Processes Research 2000; Akivis 2008).

During the last decade, field experiments and numerical modeling have shown that near-shore wave transformations, circulation, and bathymetric change involve coupled processes at many spatial and temporal scales (Fig. 7.2).

Inconsistency currently exists between the level of our knowledge about the hydrodynamic processes in the coastal shelf zone and the necessity of the effective forecasting of possible ecological variations caused by the intense economical

Fig. 7.1 Space-time scales of the near-shore processes



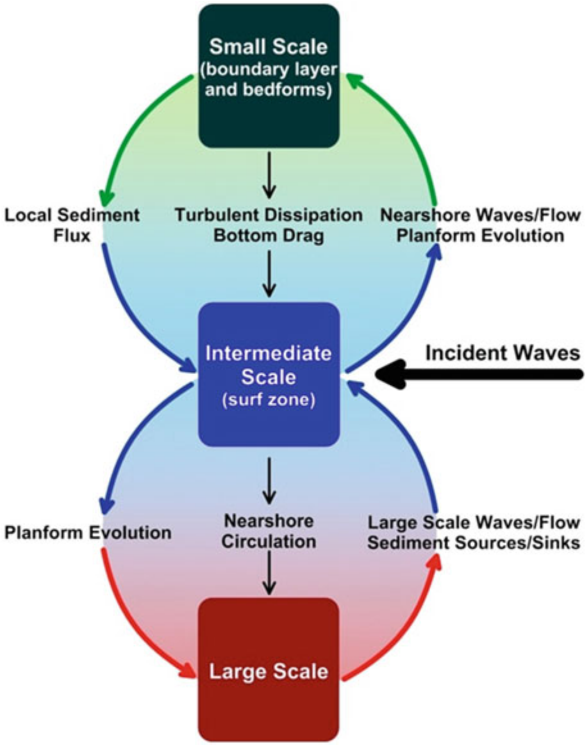


Fig. 7.2 Coupling of the small-, intermediate-, and large-scale processes

development of this zone, which has been increasing in the last years. A possibility to decrease this inconsistency is determined by the results of the recent field investigations, according to which the group structure of waves and infragravity waves strongly influence the sediment transport and currents generated by waves in the zone of wave transformation and breaking. In the existing models, water circulation and sediment transport are considered only as the time averaged characteristics without taking into account the group structure of waves, their transformation in the coastal zone of the sea, and the contribution of the fluctuation component of sediment transport and admixtures at different frequencies of the spectrum of irregular waves.

Since the mid-1980s, a notable progress appeared in the understanding of physical regularities and methods of the calculation of wave parameters, coastal currents, and sediment transport during storms in the coastal zone of the sea. The field studies showed that in the first approximation, the variations in the higher moments (asymmetry, excess, etc.) of the wave motions when the waves approach the shore determine the character of wave breaking, generation of infragravity waves and wave currents, suspension processes, and sediment transport, which is the entire dynamics of the coastal zone. The theoretical studies are mainly focused on the analysis of quantitative characteristics of hydrodynamic processes by means of numerical solution of the Boussinesq equations with additional terms, which parametrically describe the energy losses during wave breaking. This method of the solution of the hydrodynamic problems of the coastal zone is undoubtedly promising after eliminating some disadvantages in the existing models related to our poor knowledge of the group structure of waves and infragravity waves and their influence on the circulation in the coastal zone.

Lack of a clear qualitative picture of nonlinear deformation of irregular waves frequently leads to incorrect interpretation of the experimental data. For example, paradoxes appear like anomalous dispersion of waves (Kuznetsov and Speranskii 1994), which contradicts the generally accepted concepts about non-dispersive wave motion in limiting shallow water. Despite the fact that the Boussinesq equations quite well describe the propagation of irregular waves, the group velocity in the existing models is ignored and the comparison of numerical simulations with the experiment is performed only using the time averaged wave parameters. The existence of the group wave structure and infragravity waves in the natural conditions with a broad spectrum of their scales leads to indefiniteness and frequently to the arbitrary selection of the time needed for averaging and obtaining reliable estimates.

The energetic concept is generally used to calculate the sediment transport normal to the shore and along the shore. According to this concept, sediment transport is determined through the dissipation of the wave energy. The Baillard model developed in 1981 is most frequently used for these calculations (Bailard 1981). Detailed verification of the basic principles of this model on the basis of the field data and spectral and cross-spectral analyses showed that at its best it makes possible to estimate only the order of magnitude of the transport (Kosyan et al. 1999). In the most cases, the model wrongly predicts the direction of the sediment transport normal to the coast at the frequencies of wind and infragravity waves. The contribution of sediment transport at these frequencies to the total sediment transport normal to the shore is especially sensible in the zone of wave breaking. The main mass of sediments is transported in this zone during storms and leads to the morphodynamic changes in the underwater slope and the coastline. The main cause of the divergence is in the fact, that the energetic models are based only on the general physical approach that the sediment transport is proportional to the wave energy dissipation without the account for the actually observed mechanisms of the suspension deposits from the bottom existing in the nature. In addition, they do not take into account the intermittency of the sediment transport and their dependence on the group structure of waves; they skip variations in the spectral composition of individual waves and phase shifts between the velocity of water, parameters of turbulence, and concentration of suspended sediments (Kosyan et al. 1997).

A number of morphodynamic models have been published by present, which use various approaches to the description of the actual mechanisms applied to different regions of the coastal slope. The majority of them are related to the conditions of regular wave forcing applied to the uniform alongshore slope formed of sand sediments uniform by size. Under these conditions, compensation countercurrent is considered one of the main mechanisms of sediment transport along the slope profile (Okayasu and Katayama 1992). However, the other important factors: runup flow, which determines the dynamics of periodically drained part of the beach and fluctuating transport by infragravity and wind waves are poorly studied, but their contribution is significant. This hampers quantitative description of the sediment dynamics in this region. As a result, investigators use various interpolations in modeling the evolution of the submarine slope profile without considering realistic mechanisms of sediment transport.

While considering the morphodynamic problems in the conditions of non-uniform bottom topography there is a need to calculate horizontal circulation of water in the zone of transformation of breaking waves. At present, modern numerical models of the coastal circulation have been developed based on the concept of the radiation stress (Van Dongeren et al. 1994; Pechon and Teisson 1994), and Boussinesq equations (Sorensen et al. 1994). Unfortunately, these models do not take into account the group structure of the waves approaching the shore. In addition, these models are quite expensive in the sense of the consumption of computer time. Their application for specific practical problems related to a large number of time iterations is frequently inconvenient and not efficient. Therefore, the problem remains pressing of selecting an economical hydrodynamic model, which takes into account the influence of the group structure of waves adjusted to the conditions of morphodynamic simulations and provides the acceptable accuracy at minimum expenses.

In recent years, a number of investigations, related to the analysis of the influence of frequency distribution of surface wave energy on the dynamics of the bottom material, have been carried out (Kosyan et al. 2009; Divinsky et al. 2014). In particular, it was found that under equal characteristics of irregular surface waves the specific features of the wave forcing applied to the sandy bottom are determined precisely by the peculiarities of the frequency distribution of wave energy. Concentration of the wave energy in the region of the frequency of the spectral maximum facilitates a transition from irregular to regular waves and to the general regulation of the dynamic impact on the solid bottom. In the physical sense, this mechanism leads to the realization of more stable external conditions for the development of microforms of bottom topography. These data are, of course, not final, but nevertheless they allow us to formulate the general vector of future research.

7.6 Conclusions

The coastal zone is the most dynamic part of seas and oceans. The enormous wave power obtained from wind is damped precisely here. Formation of strong currents and complex water exchange systems, formation and displacement of underwater ridges, suspension and transport of large masses of sediments, etc. are the results of energy dissipation. All these processes are interrelated in various combinations. The state of shores and especially the state of beaches and coastal bottom topography are to a great extent determined by the character of sediment transport in the coastal zone under the influence of waves and currents; therefore, in the conditions of extended economical activity at the coast, the scientific knowledge of the hydro-lithodynamic processes here is extremely important. Calculations of the sediment transport and deformations of underwater slopes are needed for the operation of hydro-engineering constructions, developing of the projects of coast protection, and providing the ecological safety. Constructions of channels for the ships to enter the ports, trestles for oil pipes, mining of construction materials, providing safe communications, and recreation regime on the beaches is impossible without taking the account for the regularities of sediment transport in the coastal zone.

Let us emphasize the poorly studied aspects in the researches of the coastal zone dynamics:

- sediment transport in the zone of wave runup in the conditions of permeable bottom;
- spatial distribution of wave energy due to wave breaking; generation of infragravity waves and their contribution to the dynamics of sediments;
- interaction of surface waves, sea currents, variations in the morphometric peculiarities of the bottom and sediment transport in the coastal zone; this interaction implies a feedback between these processes;
- the influence of frequency-angular distributions of spectral energy of the approaching waves on the transport of bottom sediments;
- transformation of bottom material and interannual changes in its granulometric composition;
- transport of sediments in the conditions of pebble and mixed (sandy-pebble) beaches.

Solution of the abovementioned problems is possible only within a multidisciplinary monitoring of the state of environment with inclusion of the improving instrumental means for measuring parameters of wind waves, currents, bathymetry, and character of the bottom sediments. In this relation we emphasize the importance of laboratory experiments. Despite some specific limits, laboratory experiments allow us to specify, control, and repeatedly reproduce the parameters of the hydrodynamic environment. In this sense, they are more preferable than the field experiments. Laboratory experiments are actually the elements of environmental modeling, whose final results are improved (or developed) physical mechanisms of the coastal zone dynamics.

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Chapter 8
Granulometry of Sediments in the Mamaia Bay Area

Dănuț I. Diaconeasa

Abstract The longshore drift of Mamaia Bay is strongly affected as a result of anthropogenic constructions such as Midia Harbor, Pescarie marina and coastal protection structures, especially detached breakwaters type "breaking wave". Based on 56 samples collected in 2012 the grain size parameters (mean, sorting, skewness and kurtosis) were analyzed in order to determine the sedimentation process of coastal environments. On the backshore area fine and very fine sand classes are prevalent with an average of 68%. The swash area sediments are constituted from accumulations of coarse, medium fine fractions of shell and very fine sand. In the surf zone (1.0–6.0 m deep) fine and very fine sandy sediments are deposited in a proportion of more than 90%. On the nearshore zone the very fine sand class, which varies between 70% to 85%, contributes the most and the very coarse silt reaches generally values from 10% to 20%.

Keywords Grain size sediment • Backshore • Swash • Surf • Nearshore • Black Sea • Romanian shore • Mamaia Bay

8.1 Introduction

The studied area Mamaia Bay is part of the Romanian southern coastal unit and a transitional subunit, respectively, between Cape Midia – Midia Harbor and Cape Singol – Constanta marina (Fig. 8.1)

The Mamaia sand barrier was formed (Caraivan 1982) about 4500–5000 years ago in a marine bay, which was blocked by a sand bar (2500–3000 B.P.) at a depth of about 2 m. Alluvial material brought by the Danube was transported along the coast and captured the shelter Cape Clisargic (Midia Harbor). The current sand barrier was formed bounding the Lake Siutghiol freshwater lagoon. Within the study area the variety of sedimentary deposits is determined by the nature of the source of intake, mainly terrigenous and organogenous, and latest added sediments

D.I. Diaconeasa (✉)
National Institute for Marine Research and Development "Grigore Antipa", Constanţa, Romania
e-mail: ddiaconeasa@yahoo.com

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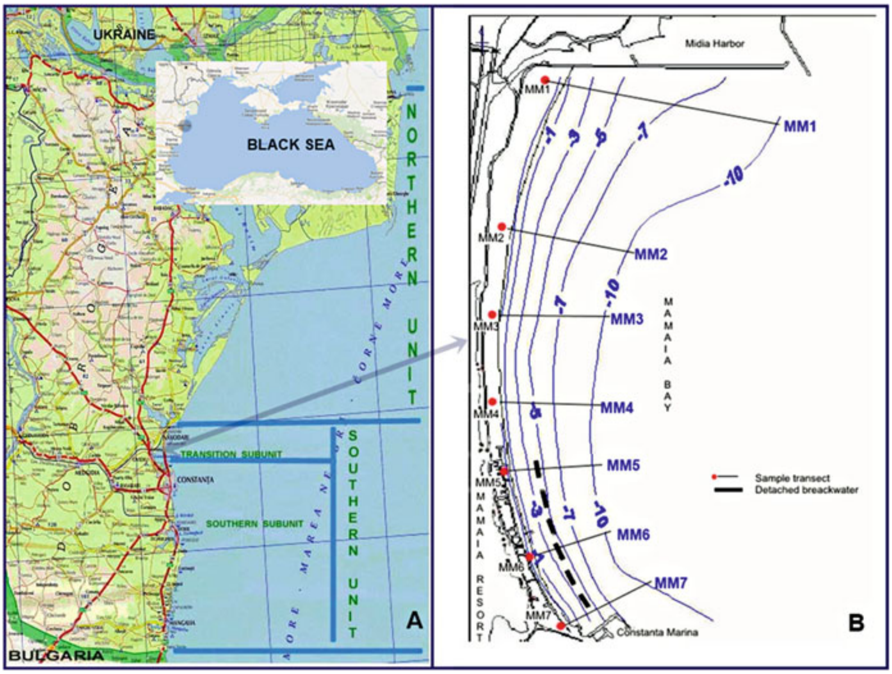

Fig. 8.1 (**a**) Geomorphological units of the Romanian coastline (**b**) Sketch with profiles of sediment sampling in the Mamaia Bay in 2012

of coastal lakes (Lake Tabacarie and Lake Siutghiol) which were used to rebuild the beach Mamaia in the backshore, swash and surf zone (south of Mamaia resort). The most important terrigenous source is bed load of rivers that flow into the north-western Black Sea (Danube, Bug, Dniester, Dnieper). This sediments (Panin 1996), consist, in general, in sands, silts, clays. Sands are gray, consisting usually of quartz fragments, mice, feldspat, lithoclasts, heavy minerals (granite, amphibole, pyroxene, opaque minerals etc.). The Danube with its three branches (Chilia, Sulina, St. George) is the most important source of terrigenous contribution to the Romanian shore. Sands predominantly of terrigenous material are specific to the Danube Delta, which are transported southward, mainly to the Mamaia Bay.

Mamaia Bay with a length of about 13 km, is heavily affected by anthropic constructions especially in the areas of the northern breakwaters of Midia Harbor, of the southern coastal protection and hydraulic structures - detached breakwaters type “breaking wave” (in the sourhern part of Mamaia beach) and of the Constanta marina. Midia Harbor breackwaters constitute a significant obstacle to the longshore drift, in that wide stream sediment drifting toward the southern direction; it deprived the southern part of Mamaia beach as to its sediments, which led to the intensification of beach erosion in the area. To protect this beach sector a longitudinally protection system was built in 1988 and 1989, together with putting in work of artificial nourishing (sand originating in sediments from the Siutghiol Lake) in the southern part of the Mamaia beach. Low permeability longitudinal dams were positioned at 450–500 m from the shore at a depth of about 5 m, on sections of 250 m, with distances between the dams of 250–400 m (Spataru 1996). This protection system proved its efficiency up to 5 or 6 years. Current work as subject of a short, medium and long-term Protection Plan (started in 2015 as far as 2020 and after) along the Romanian coast, includes short and medium – term protection measures for Mamaia sand barrier.

8.2 Method

Sediment samples (56) were collected in 2012 on 7 transects from Mamaia Bay: on the backshore zone 14 samples (upper and medium position of beach), on the swash zone 7 samples, on the surf zone 21 samples (depth of 1 m, 3 m and 5 m) and on the nearshore zone 14 samples (depth of 7 and 10 m) (Fig. 8.1b). Sediment analyses were carried out to analyze the grain size of the sediments (Anastasiu and Jipa 1983, Jipa 1987, Blott and Pye 2001) using the standard of dry sieving techniques (1/3 phi sieving interval). Data were statistically analysed according to Folk and Ward formulae (1957), in terms of mean grain size (mean), standard deviation (sorting), skewness and qurtosis. The classification between coarser and finer particles was based on Wentworth's scale (1922).

8.3 Results

The beach, which develops in Mamaia Bay is a geological formation that was formed recently, primarily from the contribution of terrigenous longshore sediments, with mainly north – south direction and secondary organogenous sediments, which are transported to the backshore, mainly by transversal conveying on land (onshore – offshore).

It is well known that in the nearshore area the wave regime is influenced by local geomorphological configuration of the beach shoreline, marine relief and the coastal and marine hydraulic structures. In this context, there are several medium wave actions in the offshore area, the transformation of waves, surf, swash and backshore. The boundaries of these sectors are highly mobile and determined by the sea state.

8.3.1 Backshore Zone

Backshore area is the beach which extends from the base of dunes or limit of the forward waves on the backshore under stormy conditions until the swash zone. The beach is divided according to the relationship with the land in two types (Shepard 1973). The northern half is the actual beach of about 5 km connected to the land. In the southern half there is a sand barrier, which is separated from the beach by a dried lagoon (Lake Siutghiol) with a length of about 8 km. Deposits on the beach are caused by accumulations of sand and deposits of bivalves. In this area, the storm wave action and deflation are major energy factors, which determine both a change in the geomorphology and transport, accumulation and erosion of the beach.

The categories of fine sand and very fine sand are prevalent in backshore sediments participating on average by 68% (weight almost equal to 34% between the two classes) with variations between 30% (the breakwater area, profile 5 and northern profile, MM1) to 96% in the other profiles. Sand class represents 34% on average, with variations between 19% (lowest in the north) and 47% (highest in the north). The percentages of the very fine sand class of 34%, range between 56% (in northern sections) and 10% (lower share in the southern sector with the lowest percentages in the breakwater area by 10–30%).

The mean has a wide range of variation from 0.13 to 0.58 mm. The degree of sorting is very poor to poor in the north and moderate to poor in the south. Sedimentary deposits have generally a statistical distribution of very coarse skewness, with qurtosis frecvently platycurtic, for the northern part, and mezocurtic for the southern area (Table 8.1).

8.3.2 Swash Zone

Swash zone overlaps the area of foreshore and shoreline with two components: uprush and backwash (advancing and withdrawing the pellicle of water on the backshore), which is consuming final wave energy by throwing the jet upward bathing on the shore. The swash zone sediments are deposited from accumulations of coarse, medium and fine shell fractions, fine and very fine sand.

Accumulated sedimentary deposits ranging from fine sand, in the extreme north (Midia Harbor) and south (Constanta marina) and very coarse, coarse and medium in the breakwater area and central area. The average diameter ranged from 1.2 to 0.12 mm. The degree of sorting is very well for very fine sandy sediment and poorly to very coarse and coarse sand. Asymmetry generally is very coarse and kurtosis is from very leptocurtic to platycurtic (Table 8.2).

8.3.3 Surf Zone

This area is the result of wave dissipation by generating turbulence in the water and sediment transport driven by the bottom.

In this area sediments (considered at depth of 1 m, 3 m and 5 m for sampling) become more homogeneous, as an effect of the environmental conditions (waves,

Table 8.1 The sediment texture in the backshore area

Transect	Sand	Mean	Sorting	Skewness	Kurtosis
MM1	Medium	0.30	Very poorly	Symmetrical	Platycurtic
	Medium	0.25	Poorly	Very coarse	Very platycurtic
MM2	Fine	0.13	Moderately	Very coarse	Extremy
	Medium	0.38	Poorly	Very coarse	Very platycurtic
MM3	Fine	0.13	Very well	Very coarse	Platycurtic
	Fine	0.17	Poorly	Very coarse	Very platycurtic
MM4	Fine	0.22	Poorly	Very coarse	Very platycurtic
	Coarse	0.62	Very poorly	Coarse	Platycurtic
MM5	Fine	0.22	Poorly	Very coarse	Mesocurtic
	Coarse	0.58	Poorly	Coarse	Platycurtic
MM6	Fine	0.20	Moderately	Very coarse	Mesocurtic
	Fine	0.20	Moderately	Very coarse	Mesocurtic
MM7	Fine	0.20	Moderately	Very coarse	Mesocurtic
	Fine	0.22	Poorly	Very coarse	Leptocurtic

Table 8.2 The sediment texture in the swash area

Transect	Sand	Mean	Sorting	Skewness	Kurtosis
MM1	Very fine	0.12	Very well	Very coarse	Leptocurtic
MM2	Medium	0.38	Poorly	Very coarse	Very platycurtic
MM3	Medium	0.39	Very poorly	Very coarse	Very platycurtic
MM4	Coarse	0.74	Poorly	Fine	Leptocurtic
MM5	Very coarse	1.2	Poorly	Very fine	Very platycurtic
MM6	Fine	0.17	Moderately	Very coarse	Very leptokurtic
MM7	Very fine	0.13	Very well	Very coarse	Very leptocurtic

currents). The fine and very fine sands compose more than 90%. In the northern and southern areas very fine sand evinces higher percentages than 70%. In the central and breakwater areas the grading categories of very fine sand have a balanced accumulation up to depths of 1 to 3 m. The average diameter has a smaller range of variation between 0.10 and 0.15 mm. The degree of sorting is well and very well, asymmetry ranging from very fine to very coarse (breakwater area) and kurtosis is from very leptocurtic to leptocurtic (Table 8.3).

8.3.4 Nearshore Area

In the nearshore area the seaward limit is set at the depth where wave “feels” the seabed, which is variable depending on sea conditions and where basically no substantial changes in the submerged relief are occuring. During storms this depth can be located (Bay Mamaia) between depths of 8 to10 m at distances from

Table 8.3 The sediment texture in the surf area

Transect	Sand	Mean	Sorting	Skewness	Kurtosis
MM1	Very fine	0.12	Very well	Symmetrical	Very leptocurtic
	Very fine	0.10	Well	Fine	Leptocurtic
	Very fine	0.10	Very well	Very fine	Leptocurtic
MM2	Fine	0.13	Very well	Very coarse	Mesocurtic
	Very fine	0.12	Well	Very coarse	Very leptocurtic
	Very fine	0.11	Very well	Symmetrical	Very leptocurtic
MM3	Fine	0.13	Well	Very coarse	Mesocurtic
	Very fine	0.11	Very well	Symmetrical	Very leptocurtic
	Very fine	0.10	Very well	Symmetrical	Very leptocurtic
MM4	Very fine	0.12	Very well	Very coarse	Leptocurtic
	Fine	0.11	Very well	Very coarse	Mesocurtic
	Very fine	0.11	Very well	Very coarse	Very leptocurtic
MM5	Fine	0.14	Well	Very coarse	Mesocurtic
	Very fine	0.12	Very well	Very coarse	Very leptocurtic
	Very fine	0.12	Well	Very coarse	Very leptocurtic
MM6	Very fine	0.12	Very well	Coarse	Very leptocurtic
	Very fine	0.13	Well	Very coarse	Very leptocurtic
	Fine	0.15	Moderately	Very coarse	Extremely leptocurtic
MM7	Very fine	0.12	Very well	Symmetrical	Very leptocurtic
	Very fine	0.12	Very well	Coarse	Very leptocurtic
	Very fine	0.11	Moderately	Very coarse	Extremely leptocurtic

the shoreline of 800–1000 m. Under the regime of the medium sea state the depth transformation of waves can appear on the strip at the depth of 5–7 m at distances of 500–700 m from the shoreline. Inasmuch as water depth decreases the wave shape change takes place as a result of the limitation of water particles motion near the bottom.

The categories of predominant fine sand (from depths of 7 and 10 m) varies between 70 and 85% and the very coarse silt shows values from 10 to 20%. The mean size range between 0.09 and 0.11 mm. The degree of sorting is very well, well and moderately well, the statistical distribution type is generally symmetrical and the kurtosis ranges from very leptocurtic to leptocurtic (Table 8.4).

The smallest average grain size of 0.04 mm was determined in the north at a depth of 10 m (MM2) and represents sediment mud and the coarsest grain size of 0.69 mm in the south, at a depth of 7 m (MM7), representing local organogenous coarse sediment.

Table 8.4 The texture sediment in the nearshore area

Transect	Sand	Mean	Sorting	Skewness	Kurtosis
MM1	Very fine	0.10	Moderately well	Symmetrical	Leptokurtic
	Very fine	0.10	Moderately well	Fine	Very leptocurtic
MM2	Very fine	0.10	Well	Symmetrical	Very leptocurtic
	Medium	0.04	Poorly	Symmetrical	Very platycurtic
MM3	Fine	0.13	Well	Symmetrical	Very leptocurtic
	Very fine	0.09	Well	Symmetrical	Leptocurtic
MM4	Very fine	0.11	Moderately well	Coarse	Very leptocurtic
	Very fine	0.09	Moderately well	Symmetrical	Leptocurtic
MM5	Very fine	0.11	Very well	Symmetrical	Very leptocurtic
	Very fine	0.11	Very well	Symmetrical	Very leptocurtic
MM6	Very fine	0.14	Moderately	Very coarse	Extremely leptocurtic
	Very fine	0.11	Well	Fine	Very leptocurtic
MM7	Very coarse	0.69	Poorly	Very fine	Mesocurtic
	Very fine	0.10	Well	Fine	Very leptocurtic

8.4 Conclusion

The grain size distribution of sediments in Mamaia Bay analyzed in 56 samples, collected in 2012, indicates these maine prevalent characters:

– sand sediment are the most heterogeneous in the swash zone, where there are varieties from very coarse sand to fine sand with a mean of 0.45 mm, sorting good to very poor, skewness generally very coarse and kurtosis from very leptocurtic to very platycurtic;
– the sediments become finer starting from the backshore to the surf and the nearshore zones. Thus on the backshore the sand is fine, with an average grain size of 0.27 mm and a moderatly poor sorting, with a very coarse skewness and a very platycurtic and platycurtic kurtosis. In the surf zone the sand is very fine with an average grain size of 0.12 mm, sorting very well and well, skewness very coarse, kurtosis very leptocurtic. The nearshore sand is very fine, with an average grain size of 0.10 mm, sorting very well, well and moderately well, symmetrical skewness and very leptocurtic kurtosis.

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Part III
Physics

Chapter 9
Inertial Currents in Western Continental Black Sea Shelf

Maria-Emanuela Mihailov

Abstract The western Black Sea shelf has the largest width of the continental platform of entire Black Sea basin, except for the north-western corner. The Black Sea dynamics is driven by two synergic mechanisms: the considerable river input in the north-western corner, deflected southward by the Coriolis force and the surface wind stress that has an average anticlockwise curl. Their combined action controls the global mass transport in the upper (active) layer. In this paper, in-situ measurements of the currents data and diagnostic calculations for the inertial currents are analysed and discussed. The purpose of the present work is to furnish relevant arguments using the Progressive Vector Diagram as well as the Discrete Fourier Transform on the sea currents data and to report the results on inertial motion in the western Black Sea shelf. The selected time series were recorded in the middle of the Romanian shelf, at 44°10′N, 29°22′E (52 m of water depth), with the one or two instruments suspended from a ship anchored for several days, only one series at the southern end of the Mamaia bight at 44°12′N–28°20′E (12 m water depth). The depth-averaged current amplitudes varied by time from 7.6 to 21.3 cm/s. Calculated inertial currents periods in the north-western Black Sea range between 16.5 and 17.5 h.

Keywords Black Sea • Inertial currents • Sea currents • Progressive Vector Diagram • Discrete Fourier Transform

9.1 Introduction

Inertial flow is the type of movement that is supposed to be accelerated only by the Coriolis force per mass unit, without being affected by the frictional force. The inertial motion, as shown by K. Rossby in1930s, is manifested in fluids by the balance of gravitational force and the Coriolis force. Upon termination of the

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M.-E. Mihailov (✉)
National Institute for Marine Research and Development “Grigore Antipa”
Constanta – Romania, Mamaia Blvd. No. 300, RO-900591 Constanta, Romania
e-mail: emihailov@alpha.rmri.ro; http://www.rmri.ro

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driving force (e.g. wind speed, wind-driven circulation, instability of flows), the inertial currents are developed, due to inertia and the Coriolis force.

In the Black Sea, average diameters of inertial circulations range from 200 m at depths exceeding 1000 m to 1.8 km in the 0–200 m layer (Filippov 1968; Belyakov 1979; Blatov et al. 1984; Boguslavsky et al. 1996; Ivanov 1996; Ivanov and Belokopatov 2011). According to previous research, the average duration of inertial vortexes is 2–3 days (up to 8 days) and the average orbital velocity and amplitude of components u and v in the surface layer is 10 cm/s (up to 40 cm/s) down to 1 cm/s at a depth of 1500 m. Some oscillations with a period greater than the inertial ones, were observed (Morozov 2001; Zhurbas et al. 2002, 2003) and explained by amplitude modulation of high frequency motions with low-frequency processes (Zhurbas et al. 2002).

Recently, for the area of Main Black Sea Current (MBSC or RIM current) off the southern coast of Crimea, hodographs of inertial currents were determined with amplitudes of fluctuations from 5 to 24 cm/s. (Dzhiganshin and Polonsky 2011).

The aim of the paper is to furnish relevant arguments on the inertial currents using the Fast Fourier Transform evolution (FFT) and progressive vector diagrams (or integrated hodograph) together with the vector component using in-situ sea currents measurements on the north-western Black Sea shelf.

9.2 Data and Method

The analysed data consist of current speed and direction time series recorded by mechanical, paper printing, Alexaev type instruments and currentmeters, during 1977–1991. The values of the sea currents using the Alexaev type instrument are the average speed (measured by a four plane blades, vertically mounted rotor) and the instantaneous direction (indicated by a magnetic compass) at the end of the averaging period (the last 100 s of the sampling interval).

The selected time series were recorded in the middle of the Romanian shelf (44 10′N, 29 22′E) and at the southern end of the Mamaia bight (44°12′N–28°20′E). The measurement method consists with the one or two instruments suspended from a ship anchored in 52 m or 12 m of water for several days (2–6 days) and sampling interval was 5, 10 and 15 min, continuously during the period.

The progressive vector diagrams with the vector component evolution that indicates the presence of various wave events of different nature, periods, intensities, and durations are used. Due to the short length of the records, and taking into account the time scale of the identified motions, different processing approaches were used.

9.3 Results

As propagation of the sea currents direction is roughly the same with the wind and the speed as an approximation of the momentum generator tangential speed, the equations of motion $\left(\frac{\partial p}{\partial x} = \frac{\partial p}{\partial y} = 0\right)$ are reduced to horizontal flow. For a circle with a diameter $D_i = 2\ V/f$, the final equations of inertial oscillations (or current) have the form:

$$
\begin{aligned}
u &= V \sin ft \\
v &= V \cos ft \\
V &= u^2 + v^2
\end{aligned}
$$

and the inertial period (T_i): $T_i = \frac{2\pi}{f} = \frac{T_{sd}}{2 \sin \varphi}$, where V is the component of the velocity for the formula in the final equation of the equation of motion, the Coriolis parameter $f = 2\Omega \sin \varphi$, the sidereal day $T_{sd} \cong 23\,\text{h} \quad 56\,\text{min} \quad 4.1$ s and φ is the latitude.

Based on the T_i formula, the calculated inertial period for the analysed latitude ranged from 16.5 to 17.5 h.

The progressive vector diagrams or integrated hodograph, together with the vector component evolution indicated the presence of various wave events of different nature, periods, intensities, and durations. Due to the short length of the records, and taking into account the time scale of the identified motions, different processing approaches were used. In all analysed data series, the integrated hodograph revealed the presence of periodic motions (Table 9.1, Fig. 9.1). The trends on the east and north directions of the sea current vector highlights oscillations with periods close to the inertial (17h10m) and gyratory motions with tens of minutes' periods. The time series were divided into two categories (Table 9.1): long waves (periods of hours) and short waves, with periods of less than an hour.

For long waves, the use of the spectral method was inappropriate, because the lunar semi-diurnal (M2) and diurnal (S1) tides are separated from the local inertial period (17 h) by a frequency difference of about 0.02 cph, almost the same as Fast Fourier Transform evolution (FFT) of the analysed time series. To this are considered the possible presence of transverse seiches on the western half of the Black Sea (Fig. 9.2).

In the field of large frequency range, close to the cut-off Nyquist frequency, numerical analysis process admits the interference processes between similar frequencies. The exact frequency of the oscillations was achieved by calculating the residual variation for different frequencies from the domain of interest (5 min step) (Fig. 9.3).

For this reason, various methods have been adopted for the two categories of phenomena. In both cases, the series were smoothed using sliding average method on three terms (Fig. 9.3). This reduces the noise contribution in dispersion calculation. Prior spectral analysis indicated that there are no significant energies at very high frequencies (~4 cph, corresponding to periods of less than 15 min).

Table 9.1 Sea currents characteristics, during 1976–1991, at water depth = 52 m, 5 min

No.	Code	Max. water depth (m)	Time (h)	Period (h)	Average speed (cm/s)	Resultant direction (degree)	Resultant speed (cm/s)
1	77a	10	50.00	15.67	16.5	325	7.6
2	77b	30	50.00	15.83	7.7	345	3.0
3	78c[a]	10	56.00	17.50	21.3	265	16.1
4	82a	30	59.83	15.83	7.6	70	4.6
5	83a	10	112.17	17.17	13.7	135	0.6
6	83b	30	43.33	16.92	13.9	240	5.7
7	84a[b]	10	40.00	16.25	9.1	95	2.9
8	91a	20	21.83	19.08	10.4	330	3.6
9	*78a*	*10*	*21.83*	≤ 1	*14.1*	*95*	*9.0*
10	*78b*	*25*	*21.67*	≤ 1	*17.7*	*295*	*1.4*
11	*79a*[c]	*5*	*105.33*	≤ 1	*20.6*	*295*	*2.2*
12	*91b*	*30*	*21.67*	≤ 1	*14.8*	*360*	*1.5*

Sampling were [a]10 min sampling; [b]15 min şi [c]44°12′N–28°20′E, 12 m water depth

Whereas residual dispersion curves exhibit one minimum (Fig. 9.3), it was selected for the subsequent analysis and corresponding oscillation was extracted from the original data.

In the case of inertial with short periods, the rotation of the current vector has a sense of cyclonic and the periods are tens of minutes (Fig. 9.4). For short periods spectral method has been used, using sections of varying lengths of the initial data series.

The short period motions represent a superposition (interference) of some different waves types typical for the continental shelf area (Fig. 9.5).

Due to the transient nature of the processes, most of the series have to be truncated. In order to avoid an arbitrary selection, the length of the final data sets was chosen as to meet the FFT requirements (number of records equals a power of 2). This method also facilitates the comparison between series, as the spectra will contain amplitude estimations at the same frequency values (Figs. 9.6 and 9.7).

For the high frequency waves, the calculated spectrums by the method of the Fast Fourier transform (FFT) highlight waves with very close frequency (Figs. 9.6 and 9.7).

9.4 Conclusion

In this paper were analysed the characteristics of the inertial currents on the western Black sea shelf. The analysed data consist of current speed and direction time series recorded during 1977–1991 on two fixed oceanographic stations: in the middle of

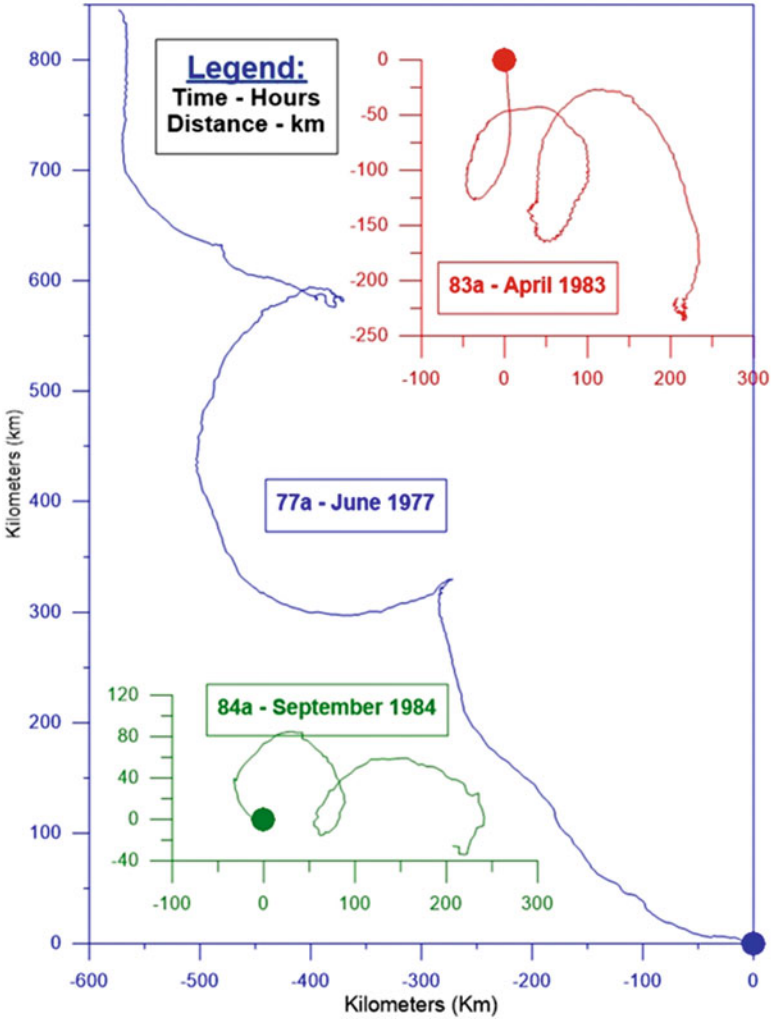

Fig. 9.1 Long period inertial currents charts, on the western Black Sea

the Romanian shelf (44 10′N, 29 22′E) and offshore Mamaia Bay (44°12′N–28°20′E).

The inertial oscillations are a transient motion developed by Coriolis force and inertia which results from a dynamic adjustment (such as surface wind stress). For the Romanian shelf was calculated the inertial period which range from 16.5 to 17.5 h. The extracted inertial periodic component does not always correspond

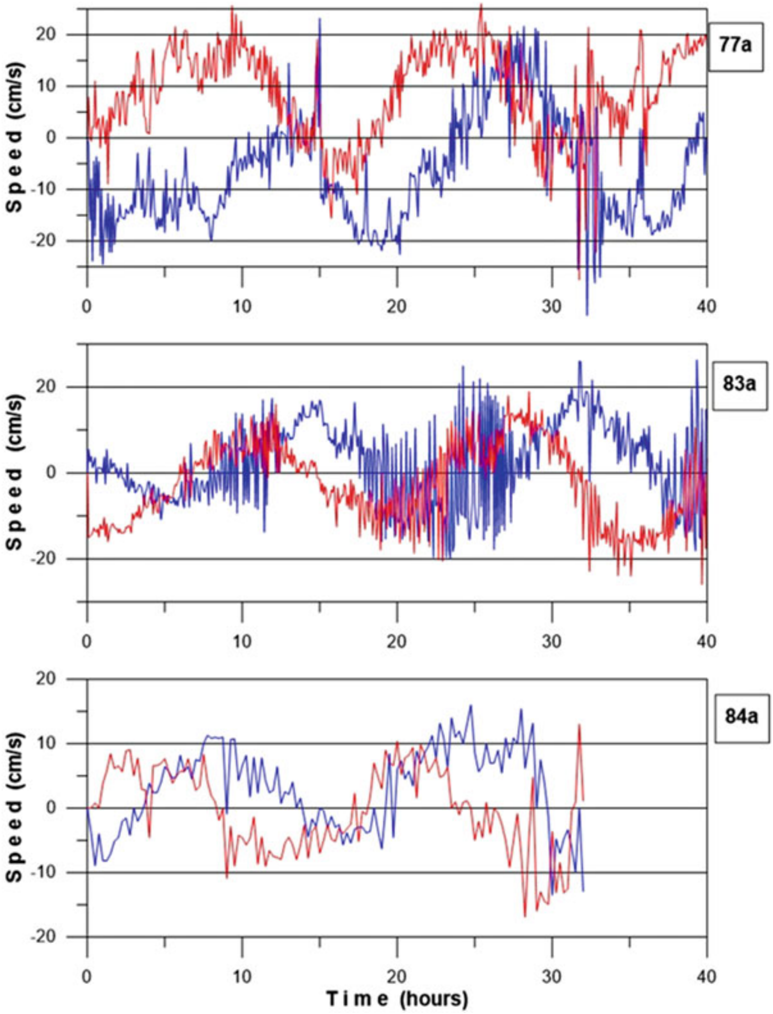

Fig. 9.2 Development of the inertial current vector during sampling

exactly to the theoretical value that was calculated at the point of the sampling (Table 9.1). The differences are due to the nonhomogeneity of the measured current velocity in different time (month ad year).

Different processing approaches were used: the integrated hodograph and the Fast Fourier Transform. In the western continental Black Sea shelf are showed the presence of periodic motions: long waves (periods of hours) and short waves

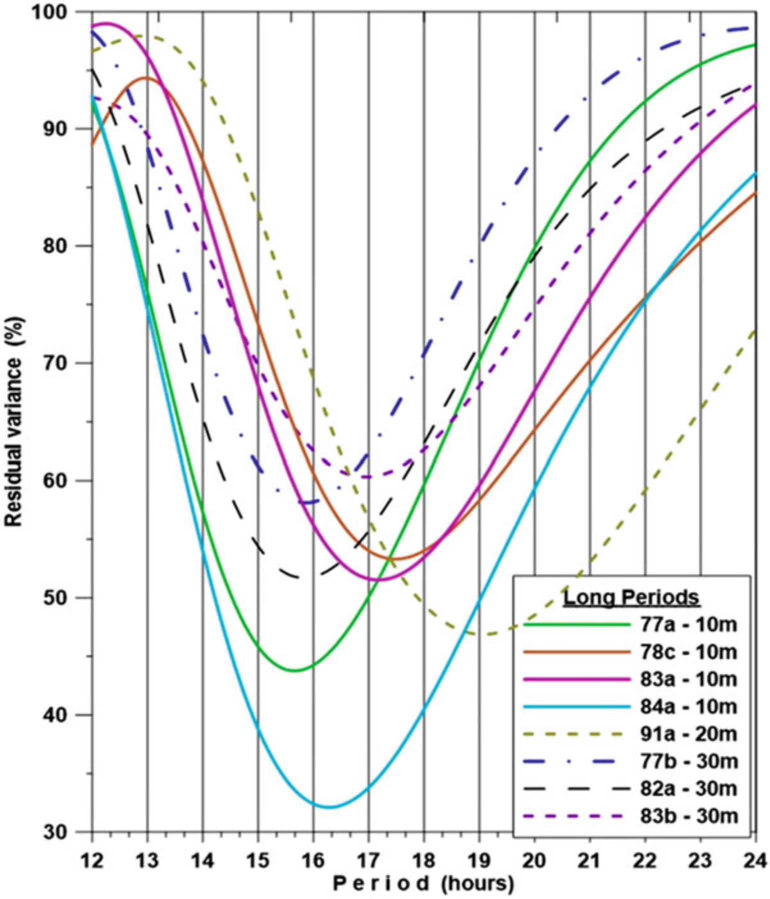

Fig. 9.3 The oscillation frequency of long periods inertial currents

(periods $\leq$1 h). In the case of inertial with short periods, the rotation of the current vector of the short period motions has a cyclonic sense of and the periods are tens of minutes.

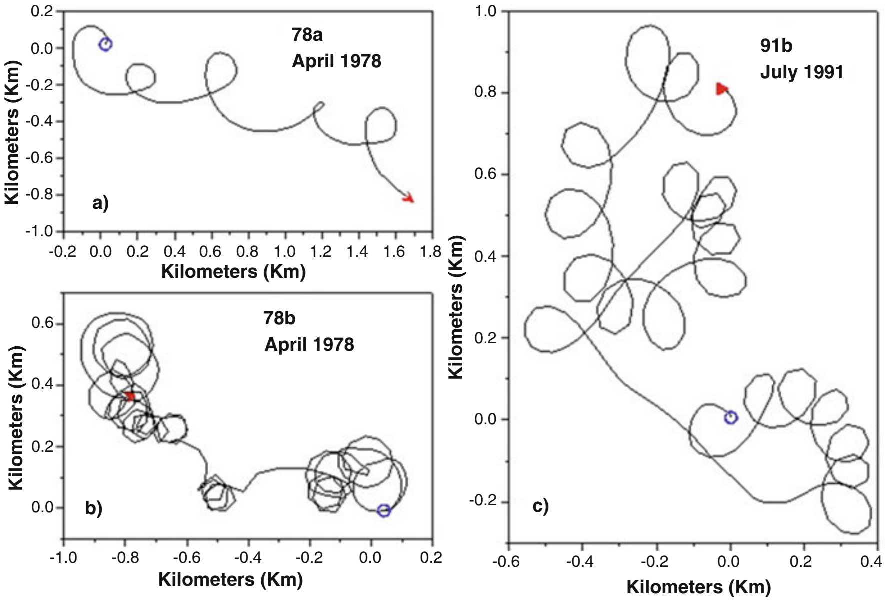

Fig. 9.4 Determined short period inertial motions in the western area of the Black Sea: (**a**) April 1978, water depth 10 m, sampling time 10 h 40 m; (**b**)1978, water depth 25 m, sampling time 21 h 20 m; (**c**) 1991, water depth 30 m, sampling time 21 h 20 m

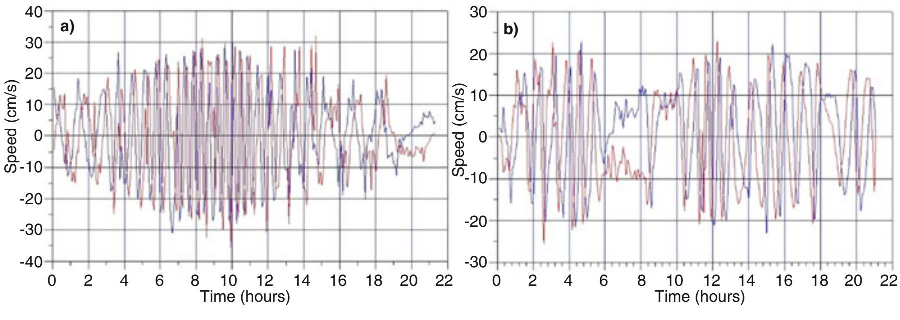

Fig. 9.5 Time evolution of the inertial currents components: (**a**) 78b (1978 year), (**b**) 91b (1991 year)

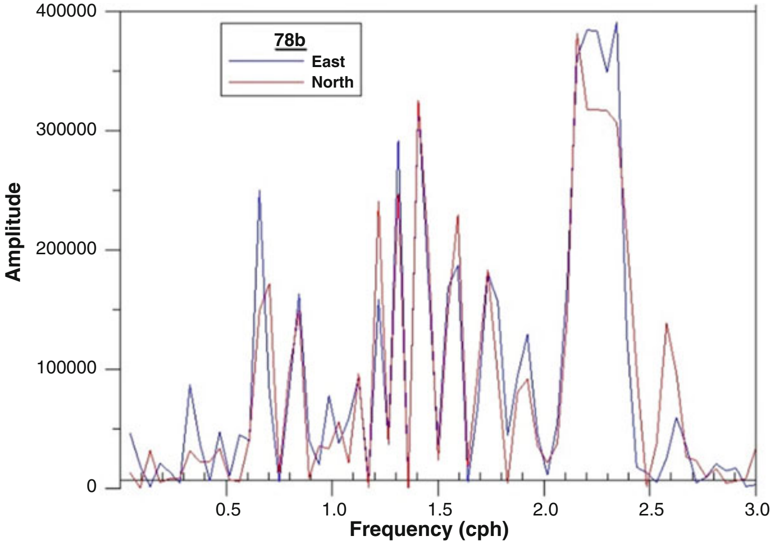

Fig. 9.6 Fast Fourier Transform (FFT) for 1978 current components data series

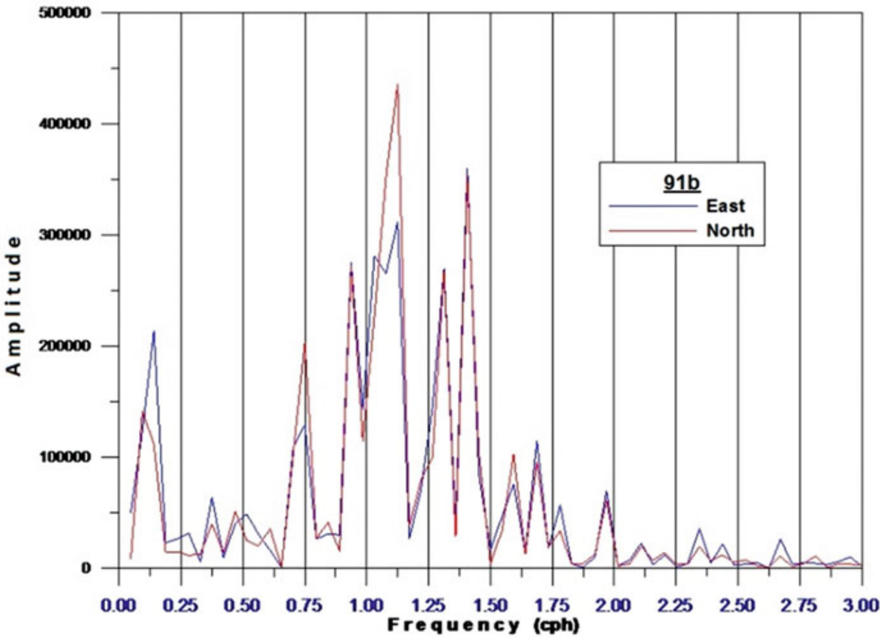

Fig. 9.7 Fast Fourier Transform (FFT) for 1991 current components data series

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Chapter 10
Seasonal Changes of Hydrobiological and Bio-Optical Parameters in the Coastal Areas of the Western Part of the Black Sea

Alexander S. Kukushkin

Abstract Study of the Black Sea neritic ecosystem is of great theoretical and practical significance owing to the anthropogenic load on its coastal areas. Variability of the ecological condition of these areas can be defined by the results of studying spatial-temporal variability of the nutrients and the suspended organic matter (SOM) content distributions. Such studies permit to assess the marine ecosystem productivity, intensity of biochemical processes, and flexibility of this ecosystem to the impact of various natural and anthropogenic factors. In recent decades, along with the expeditionary studies, satellite observations of the marine environment bio-optical parameters obtained by color scanners became widely used. Such kind of observations allows obtaining qualitatively new (as for its spatial-temporal characteristics) information. Based on the multi-year (1979–1995) expeditionary observations of distribution of the SOM components' concentration and the bio-optical parameters (chlorophyll *a* concentration, light absorption and scattering indices) resulted from the satellite data (SeaWiFS, MODIS, 1997–2015), considered are the peculiarities of spatial-temporal variability of their distribution in the shelf areas of the western Black Sea. The degree of the effect of the riverine discharge and the open sea water masses upon the distribution of the parameters under study in the northwestern part of the sea makes it possible to define four areas (western, northern, central and eastern), and in the coastal zone of the western part – the Romanian and the Bulgarian ones. The statistical assessments of seasonal variations of the considered indices are obtained for these areas. Increase of the SOM components' concentrations in the summer-autumn period in late 1980s and early 1990s with their anomalously high values in 1992 is noted. It is shown that the seasonal interannual variability in the concentrations of the SOM components and the values of the bio-optical parameters is conditioned by the variations in the riverine discharge volume, its run to the sea, and climatic shifts.

A.S. Kukushkin (✉)
Marine Hydrophysical Institute – RAS, Sevastopol, Crimea, Russian Federation
e-mail: kukushkinas@mail.ru

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10.1 Introduction

The study of the Black Sea neritic ecosystem is of great theoretical and practical significance owing to the anthropogenic load on its coastal areas. The intensity of such a load is largely conditioned by the variability of hydrochemical, hydrobiological and climatic conditions in these areas of the sea. Consequently, studying the spatial-temporal variability of the nutrient and the suspended organic matter content distributions, which can indicate variability of the ecological condition of the sea coastal areas, becomes more relevant.

Hydrochemical and hydrobiological conditions in the coastal areas of the western Black Sea significantly changed in 1960–1980 (Aubrey et al. 1996; Bologa 1977, 1978, 1985, 1992; Cociasu et al. 1996; Gevorgiz et al. 2005; Rozhdestwensky 1979, 1985, 1990, 1998; Zaitsev 1992; Zaitsev and Aleksandrov 1997). The reason consisted in a sharp increase of the nutrients' content in the waters of large rivers (the Danube, the Dniester, the Dnieper and the Southern Bug) flowing into the northwestern Black Sea (NWBS). Thus, the concentration of these elements on the Danube shelf increased by 3–5 times (Garkavay et al. 2006; Yunev et al. 2007) as compared to the 1950s that resulted in intensive development of phytoplankton ("bloom" of water) and suffocation phenomena. Until 1970, in the Romanian and the Bulgarian shelf sectors, the phytoplankton bloom was rare (Bodeanu 1992; Bodeanu et al. 1998). However, already in the 1980s almost 50 cases of this phenomenon were noted.

Study of the suspended organic matter (SOM) composition, an important biogeochemical element of the Black Sea ecosystem, as well as the variability of its components (suspended organic carbon and nitrogen) permits to assess the marine ecosystem productivity, the intensity of biochemical processes, and flexibility of this ecosystem to the impact of various natural and anthropogenic factors. Such research is of particular importance in NWBS, which is a significant area for recreation, fishery and fish farms. NWBS differs from other sea areas by high anthropogenic load including pollution by the coastal discharge (riverine, industrial and domestic waste water, runoff of fertilizers, etc.), intensive navigation, oil and gas exploration, and seabed mining, etc. The nutrients flowing into the sea with the river discharges and their fast turnover provide favorable conditions for high biological productivity in the region affected by the rivers. The productive and destructive processes taking place in this region result in the fact that large amounts of SOM are constantly involved and present in the biogeochemical cycle followed by the subsequent sedimentation.

Based on the long-term (1979–1995) observations, the main features of the spatial-temporal variability of the distribution of the SOM components' content in the surface and photosynthesis layers in the NWBS four areas (the northern, western, central and eastern ones) differing in the degree of the effect of the riverine discharge and open sea water masses, and on the Bulgarian shelf (Vostokov 1987, 1996) were considered in the papers (Burlakova et al. 1988, 1997; Kukushkin et al. 2004, 2006, 2008). It was revealed that the variability of the distribution of the

SOM components' content is conditioned by the following factors: the amount of the riverine discharges containing SOM and nutrients, conditions of the riverine and sea waters mixing and its dynamics, as well as the variability of climatic conditions (Voskresenskaya et al. 2004, 2011).

In recent decades, along with the expeditionary research the remote sensing is widely applied. Satellite measurements of the radiation ascending from the sea surface performed by the optical color scanners (SeaWiFS, MODIS) made it possible to obtain qualitatively new information on its spatial-temporal characteristics (Kopelevich et al. 2004, 2009). The obtained data on the marine environment bio-optical parameters is used for assessing bio-productivity of seas and oceans and controlling their ecological condition.

The chapter presents the results of generalizing and analyzing the multi-year investigations of the spatial-temporal variability of the distribution of the SOM components' content (1978–1995) and the bio-optical parameters (1997–2015) in NWBS and in the coastal areas of the western Black Sea.

10.2 Materials, Methods, Results and Discussions

The data obtained on scientific cruises were obtained from the datasets of the Marine Hydrophysical Institute and Institute of Biology of the Southern Seas. Several parameters were considered, including the concentration of suspended organic carbon (C_{SOM}) and suspended organic nitrogen (N_{SOM}) obtained on 20 scientific cruises. In total, data collected for 198 stations were analyzed, including 33 stations covered by two winter cruises (the second part of December–March), 58 stations on five spring cruises (April–May), 77 stations on seven summer cruises (June–September), and 45 stations on six autumn cruises (October–first part of December). We have also analyzed the concentrations of chlorophyll a (C_{Chl}) obtained on 37 cruises at 123 stations, including 102, 60, 152, and 123 stations for each season, respectively, as well as monthly averages of C_{Chl} concentration according to CZCS radiometer observations for the period of 1978–1986 (Kopelevich et al. 2002; Nezlin and D'yakonov 1998) and data obtained by the SeaWiFS and MODIS satellite sea surface scanner for the period of 1997–2015 (Information on Black Sea Color Data Processing and Distribution. http://blackseacolor.com; http://oceancolor.gsfc.nasa.gov). To determine the concentration of chlorophyll a satellite data were used regional calculation algorithm (Suslin et al. 2008). Was also used satellite observations of main bio-optical parameters using the scanner Sea WiFS color in 1997–2010: the absorption coefficient of light colored organic matter with the nonliving suspended matter at a wavelength of 490 nm – a_g (from here on, absorption coefficient) and the particle backscattering at a wavelength of 550 nm – b_{bp} (from here on, scattering coefficient).

The water samples for suspended matter analysis were collected with a CTD rosette. A water sample 1.0–2.5 L in volume was sieved through pre-combusted (400 °C) glass fiber Whatman GF/F filters. Several drops of hydrochloric acid (HCl, 0.01 M) were placed onto the filter to remove inorganic carbonates. The C_{SOM} and N_{SOM} concentrations were measured on a CHN–1 analyzer (Czech Republic). The accuracy of the method was 1% for C_{SOM} and 0.3% for N_{SOM} relative to the analyzed sample mass (Burlakova et al. 1988, 1997). The C_{Chl} concentration was analyzed by fluorometric methods (Yunev and Berseneva 1986).

The SOM destruction was assessed by the atomic ratio of C_{SOM}/N_{SOM} (from here on, C/N), the ratio between the detritus (dead) and phytoplankton (live) organic fraction in SOM was calculated as C_{SOM}/C_{Chl} (from here on, C/Chl) (Hobson et al. 1973), where C_{SOM} [μM] × 12 (atomic mass of C) = C_{SOM} [mgC/m^3], C_{Chl} [mg/m^3]. The average values of these ratios were calculated additionally using the C_{SOM} and chlorophyll a concentrations measured simultaneously.

10.2.1 The Spatial Structure of the Hydro-Biological and Bio-Optical Parameters

Features of the distributions of components of SOM war and bio-optical parameters and their variability are considered for areas NWBS different level of impact on these areas of the runoff waters and the open sea (Fig. 10.1a), and coastal western part of the sea (Fig. 10.1b). The size of the zone of influence of transformed river waters in these areas were limited to isohalines 17 PSU (Fig. 10.2), adopted for the border of their distribution (Bol'shakov 1970). Distribution of seasonal concentrations of these parameters in the surface layer shown in Figs. 10.3, 10.4 and 10.5.

10.2.1.1 The Northwestern Part of the Sea

The western and northern areas NWBS were located in the area of transformation of river waters. Here, the highest SOM concentrations were found in every season in comparison the other areas of the NWBS. During the winter, when riverine discharge was low and the width of the water transformation zone was relatively small (Bol'shakov 1970; Kukushkin et al. 2004), the concentrations of SOM components in the surface water layer in the preestuarine areas of the Danube River and Dnieper–Bug estuary were nearly equal and relatively low, according to several observations (Figs. 10.3a,b and 10.4a; Table 10.1). The average C_{SOM} concentrations were 10.0–12.8 μM; of N_{SOM}, 1.63–1.70 μM. The average C_{Chl} concentration in these areas varied as 1.83–2.01 mg/m^3, according to numerous observations performed in 1984–1988. The average C/Chl ratio was 99–140; of C/N, 7.6–8.4. This may be evidence of phytoplankton and detritus as the main SOM components; the detritus was represented by particles at different stages of biochemical transformation.

The weighted averages of the SOM components in the photosynthetic water layer (0–20 m) were less by a factor of 1.3–1.5 compared to those observed in the

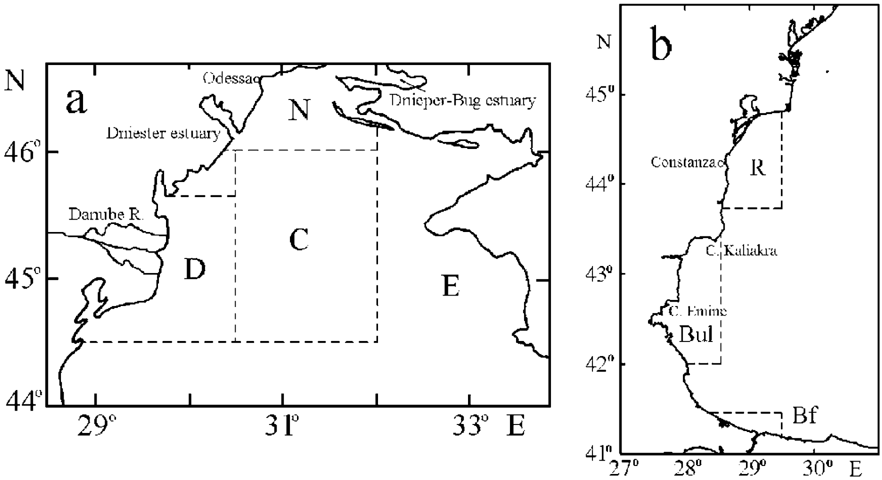

Fig. 10.1 Study areas map in the northwestern part of the sea (**a**): *D* Danube, *N* northern, Dnieper-Bug estuary, *C* central, *E* eastern; coastal regions in the western part of the sea (**b**): *Rom* Romanian, *Bul* Bulgarian, *Bf* Bosphorus

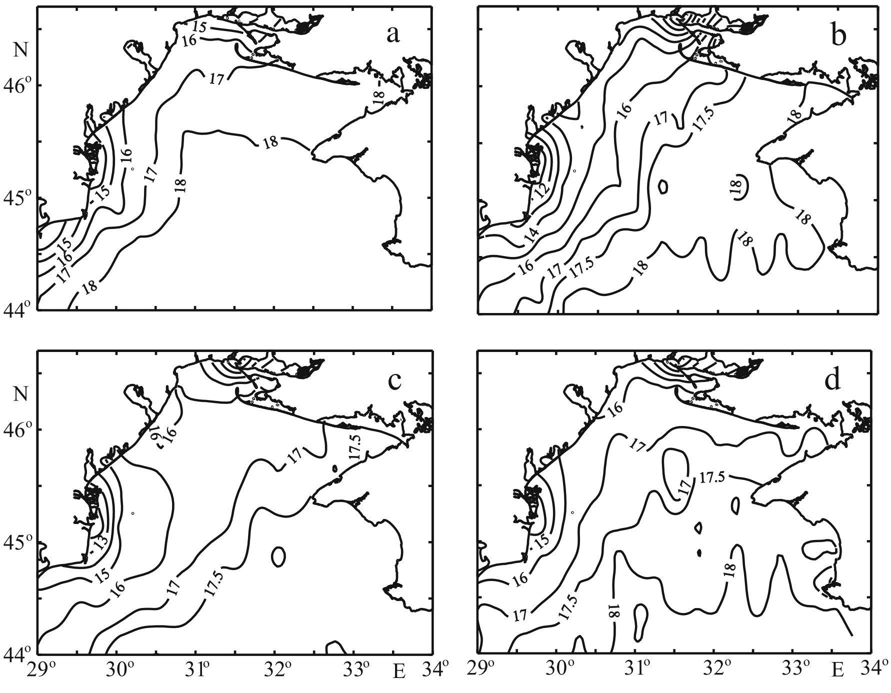

Fig. 10.2 Distribution pattern of salinity in the surface water layer of the NWBS in winter (plots **a**), spring (plots **b**), summer (plots **c**), and autumn (plots **d**)

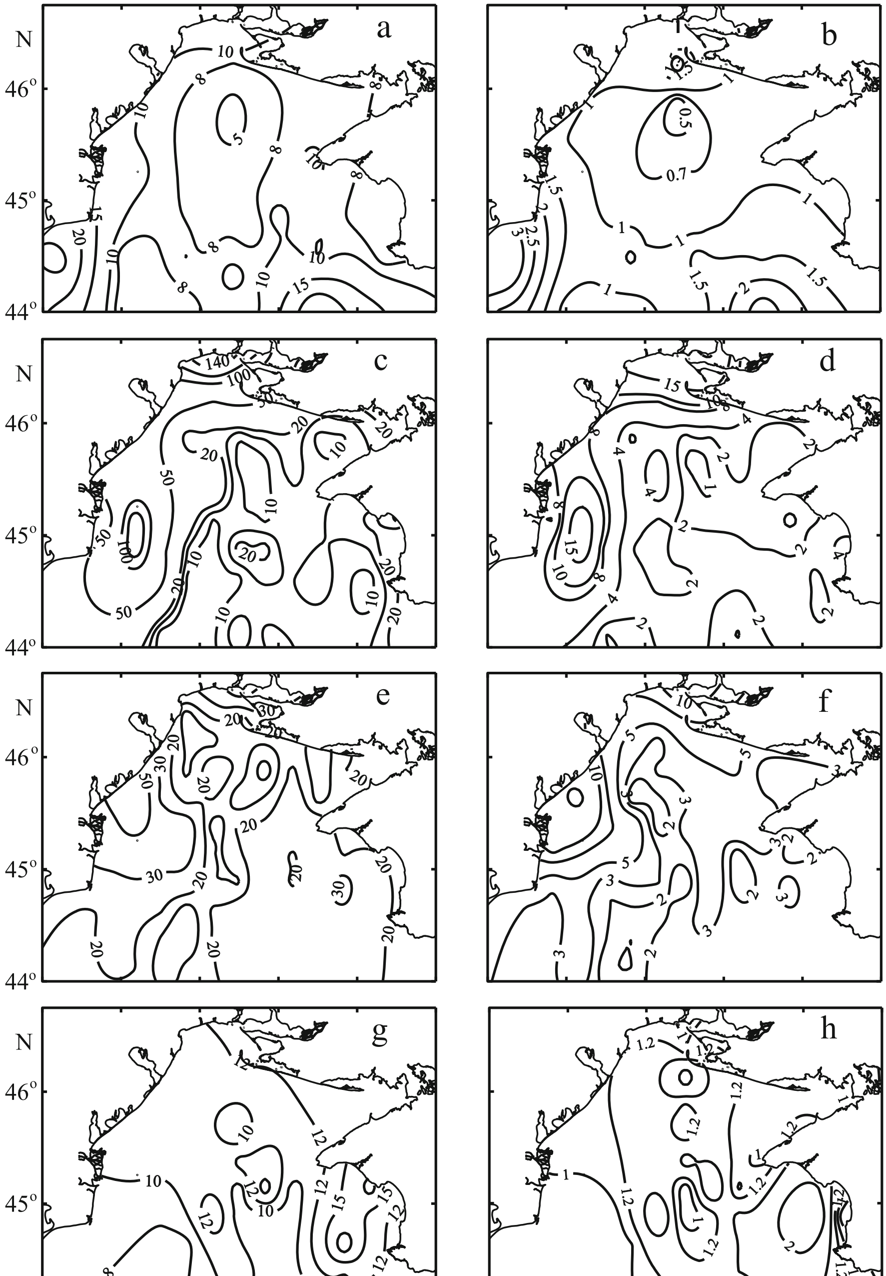

Fig. 10.3 Distribution pattern of C_{SOM} concentration (μM; plots (**a**), (**c**), (**e**), and (**g**)) and N_{SOM} concentration (μM; plots (**b**), (**d**), (**f**), and (**h**)) in the surface water layer of the NWBS in winter (plots (**a**) and (**b**)), spring (plots (**c**) and (**d**)), summer (plots (**e**) and (**f**)), and autumn (plots (**g**) and (**h**))

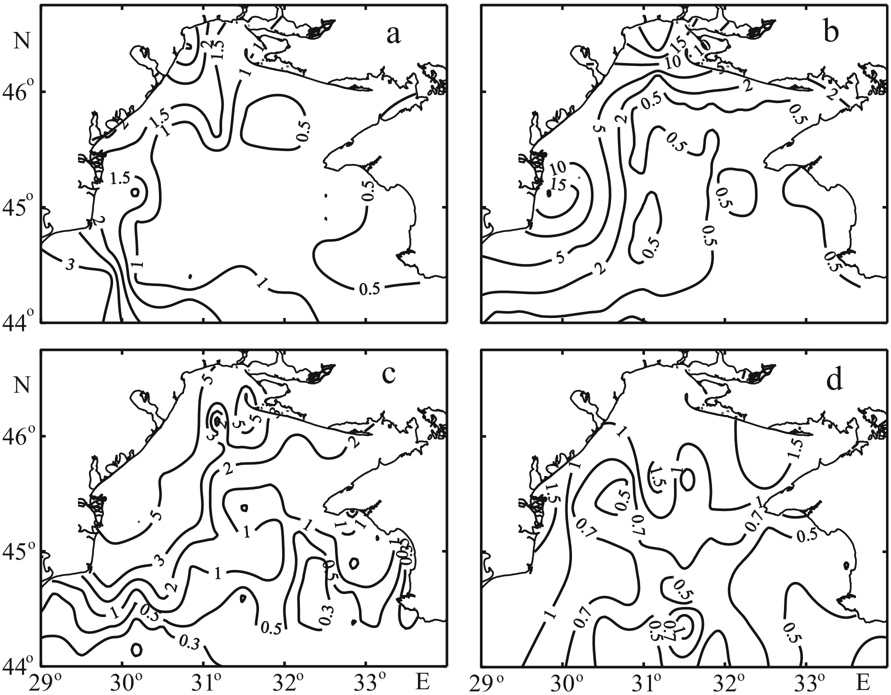

Fig. 10.4 Distribution pattern of C_{Chl} (mg/m^3) in the surface water layer of the NWBS during the winter (**a**), spring (**b**), summer (**c**), and autumn (**d**) periods

surface water layer (Table 10.1). Regard must be paid to comparison of the data obtained by measurements performed during each season at the same stations repeatedly. The C/Chl and C/N values did not change greatly compared to the surface water layer; this pertains to a similar SOM composition in these layers, represented mostly by phytoplankton and newly formed detritus.

Riverine discharge became high during the spring period (Bol'shakov 1970; Kukushkin et al. 2004; Voskresenskaya et al. 2011), so the concentrations of SOM components in the surface water layer increased six to twelvefold (Figs. 10.3c,d and 10.4b). The average C_{SOM} concentrations were 71.4–87.7 μM; N_{SOM}, 13.05–20.36 μM (Table 10.1). The average concentration C_{Chl} in these areas also increased compared to the winter period and varied as 8.5–10.3 mg/m^3. The highest C_{Chl} concentrations exceeding 20 mg/m^3 were recorded in the pre-estuarine areas of the Danube River and Dnieper–Bug estuary. High concentrations of SOM components in these areas may testify to both active photosynthetic and phytoplankton growth processes and the arrival of freshly transformed detritus with riverine discharge. The latter is supported by higher ratios of C/Chl (150–265) and C/N (6.8–7.7) compared to the winter period.

The weighted averages of the SOM components in the photosynthetic water layer increased five- to eightfold compared to those observed during the winter

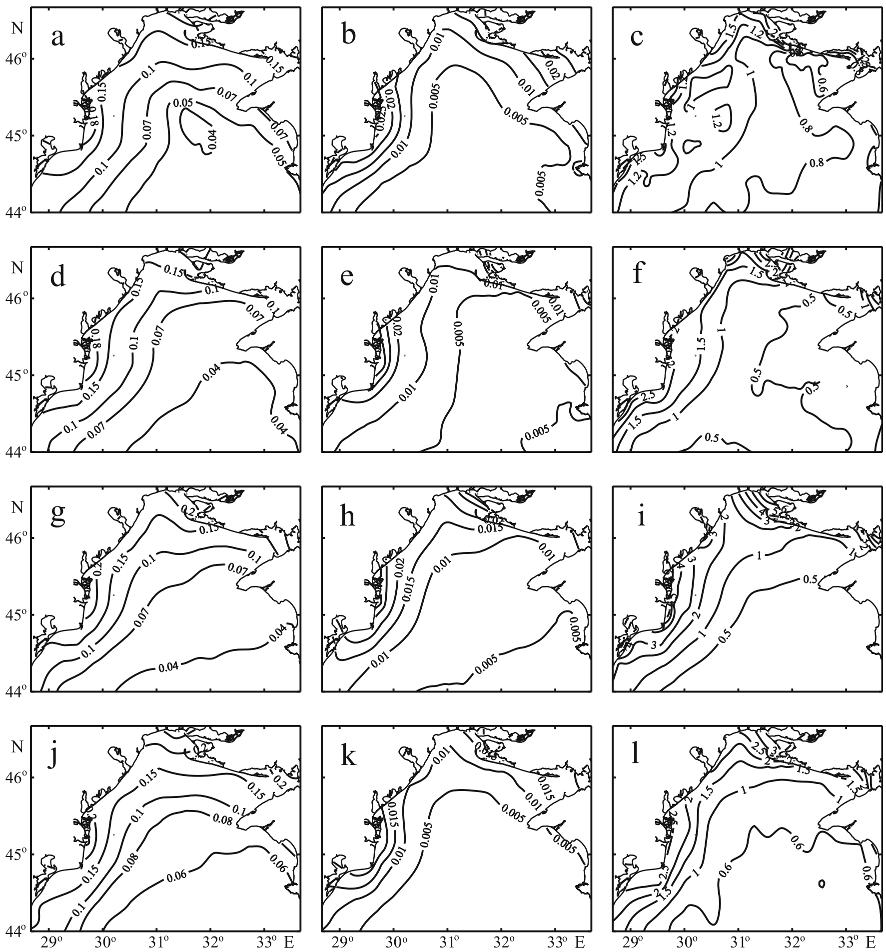

Fig. 10.5 Distribution pattern of a_g (m^{-1}; plots (**a**), (**d**), (**g**), and (**j**)), b_{bp} (m^{-1}; plots (**b**), (**e**), (**h**), and (**k**)), and C_{Chl} (mg/m^3; plots (**c**), (**f**), (**i**), and (**l**)) in the surface water layer of the NWBS in winter (plots (**a**), (**b**) and (**c**)), spring (plots (**d**), (**e**), and (**f**)), summer (plots (**g**), (**h**),and (**i**)), and autumn (plots (**j**), (**k**), and (**l**))

period, but were less than 1.5–2.1 times compared to those observed in the surface water layer. The C/Chl values did not change greatly in either layer, but the C/N ratio decreased (6.4–6.5) compared to the surface water layer and came close to the value of 6.7 characteristic of newly synthesized SOM (Romankevich 1977). Therefore, a similar SOM composition was observed for the 0–20 m layer, and SOM was represented mostly by phytoplankton and newly formed detritus.

During the summer period, the concentrations of SOM components in both water layers decreased compared to the spring period by approximately 2.0–2.5 times (Figs. 10.3e,f and 10.4c; Table 10.1); however, it remained relatively high. Meanwhile, the concentration N_{SOM} in the northern area decreased by 1.3 times, and

Table 10.1 Seasonal variability of the concentrations of SOM components and their ratios in the surface water layer of different NWBS areas

Area	Sezon	C_{som}, μM	N_{som}, μM	C_{Chl}, mg/m^3	C:N	C/Chl
Western	Winter	12.8 ± 7.8 10.0 ± 3.7	1.63 ± 1.15 1.27 ± 0.56	1.83 ± 1.48 1.42 ± 1.08	8.4 ± 1.9 8.2 ± 2.3	140 ± 83 137 ± 47
	Spring	71.4 ± 39 51.7 ± 46.5	7.93 ± 5.73 8.8 ± 8.15	10.31 ± 7.27 7.2 ± 4.3	7.7 ± 1.2 6.6 ± 0.5	150 ± 48 138
	Summer	28.4 ± 16 25.2 ± 20.1	2.84 ± 3.66 3.83 ± 3.24	2.2 ± 2.4 1.59 ± 1.76	7.4 ± 2.3 6.7 ± 1.8	433 ± 312 590 ± 448
	Autumn	14.2 ± 9.1 14.5 ± 10.4	0.92 ± 0.12 1.0 ± 0.29	1.47 ± 0.73 1.69 ± 1.0	10.5 ± 0.9 9.7 ± 2.5	161 ± 54 134 ± 47
Northern	Winter	10.0 ± 2.0 9.4 ± 1.7	1.7 ± 0.7 1.41 ± 0.19	2.01 ± 1.2 1.34 ± 0.02	7.6 ± 4.4 7.0 ± 2.1	99 ± 28 84 ± 16
	Spring	87.7 ± 67.6 77.9 ± 53.9	13.05 ± 8.94 11.16 ± 6.7	8.5 ± 12.1 6.73 ± 6.25	6.8 ± 1.6 6.4 ± 1.0	265 ± 178 287 ± 165
	Summer	39.2 ± 29 56.1 ± 18.5	10.2 ± 3.23 6.7 ± 5.12	3.54 ± 2.2 3.6 ± 2.26	5.9 ± 1.2 6.5 ± 1.5	369 ± 171 293 ± 45
	Autumn	12.1 ± 3.4 11.5 ± 4.1	1.9 ± 0.64 1.69 ± 0.43	1.5 ± 0.45 1.35 ± 0.24	7.5 ± 3.6 7.0 ± 1.8	126 ± 45 103 ± 29
Central	Winter	7.6 ± 2.1 7.1 ± 2.4	0.98 ± 0.45 0.86 ± 0.26	1.07 ± 0.71 1.0 ± 0.68	9.17 ± 3.8 9.0 ± 1.9	146 ± 71 126 ± 33
	Spring	15.3 ± 7.9 12.8 ± 5.8	2.35 ± 1.55 1.87 ± 0.96	0.56 ± 0.4 0.65 ± 0.37	7.6 ± 1.9 6.9 ± 2.4	396 ± 264 274 ± 159
	Summer	15.1 ± 8.4 17.7 ± 6.4	1.4 ± 1.33 2.26 ± 0.82	0.9 ± 1.2 0.61 ± 0.45	10.2 ± 6.5 8.3 ± 1.8	802 ± 602 770 ± 478
	Autumn	10.7 ± 5.8 10.9 ± 7.2	1.17 ± 0.58 1.11 ± 0.55	0.88 ± 0.56 0.74 ± 0.55	9.3 ± 3.3 9.1 ± 2.5	217 ± 194 201 ± 106
Eastern	Winter	8.9 ± 2.0 10.3 ± 2.0	1.05 ± 0.1 1.3 ± 0.06	0.57 ± 0.24 0.56 ± 0.06	8.7 ± 2.8 8.1 ± 2.2	173 ± 48 207 ± 32
	Spring	14.5 ± 6.9 11.7 ± 4.4	2.18 ± 1.02 1.96 ± 0.76	0.49 ± 0.28 0.51 ± 0.24	7.0 ± 2.2 6.1 ± 0.8	600 ± 599 302 ± 105
	Summer	18.9 ± 7.5 17.8 ± 8.9	2.85 ± 1.34 3.38 ± 1.22	1.1 ± 0.97 0.86 ± 0.65	8.9 ± 3.3 6.7 ± 2.3	826 ± 398 475 ± 167
	Autumn	16.4 ± 6.0 15.1 ± 5.1	2.37 ± 1.07 1.88 ± 0.72	0.73 ± 0.52 0.72 ± 0.48	7.7 ± 2.3 8.5 ± 1.9	605 ± 249 494 ± 217

Note: The numbers above the line indicate the component values in the surface water layer, and the numbers below the line, the values in the photosynthetic layer

C_{Chl}, by 80%. The average C/Chl in both areas increased up to 369–397, but C/N decreased (5.9–7.4). We assume a large part of the freshly transformed detritus in SOM composition.

The weighted averages of the SOM components in the photosynthetic water layer in the northern area decreased by 1.4–1.9 times, and in the western area, by 2.1–2.7 times, compared to those observed during the spring period. C_{Chl} decreased by 4.5 times. In comparison to the surface water layer, these values decreased by 1.1–1.7 times. The average C/N ratio did not change greatly (6.5–6.7). The C/Chl ratio did not change either in the northern area in comparison, but, in the western area, it increased more than fourfold and reached its maximum of 590. We assume an increasing ratio of freshly formed detritus in SOM in the photosynthetic layer in the western area.

During the autumn period, the average C_{SOM} and C_{Chl} concentrations in the surface water layer decreased by 1.2–2.5 times compared to the summertime, and N_{SOM}, by 60 to 80% (Figs. 10.3g,h and 10.4d; Table 10.1). The average C/Chl ratios also decreased in both areas and varied as 126–161. Since the average C/N ratio in the northern area was 7.5, this testified to both phytoplankton and freshly formed detritus here during the autumn period. In the western area, the detritus was well transformed (C/N = 10.5).

As was found for the surface layer, the concentrations of SOM components also decreased in the photosynthetic layer compared to the summer period. In the western area, the weighted average C_{SOM} concentration decreased by 1.7 times, but the C_{Chl} concentration changed insignificantly. In the northern area, these parameters decreased by 4.4. and 2.7 times, respectively. The weighted average N_{SOM} concentrations in both areas decreased by approximately four times. An insignificant difference between the average SOM concentrations in the surface and photosynthetic water layers was a peculiarity of the autumn period. The average C/Chl ratio in the photosynthetic layer decreased significantly and was even lower (103–143) than in the surface water layer (126–161). The average C/N ratio increased up to 9.7 (western area) and 7.0 (northern area). This may evidence that phytoplankton and freshly formed detritus constituted a large part of SOM in the northern area; in contrast, well-transformed detritus together with the phytoplankton was the major component of SOM in the western area.

Central and the eastern areas were less affected by riverine discharge. The transformed riverine water masses came to the central area in the late spring and summer periods. The area affected by this intrusion depended on the wind conditions, which in turn influenced the water circulation peculiarities in the NWBS (Bol'shakov 1970; Kukushkin et al. 2004, 2006).

During the winter, the concentrations of SOM components in the surface water layer of the central and eastern areas were lower compared to other areas of the NWBS (Figs. 10.3a,b and 10.4a; Table 10.1). The lowest concentrations of C_{SOM} (4.3 μM), N_{SOM} (0.25–0.50 μM), and C_{Chl} (0.35–0.55 mg/m^3) were recorded in the northern part of the central area in December 1987 (Kukushkin et al. 2004). The average C/Chl ratios in both areas were 146–173; average C/N, 8.7–9.2. This may testify to well transformed detritus as the main SOM components.

The weighted averages of the SOM components in the photosynthetic water layer (0–40 m) in the central area were similar compared to those observed in the surface water layer; however, in the eastern area, the C_{SOM} and N_{SOM} concentrations increased by 1.2 times, but C_{Chl} remained the same. The C/Chl ratio slightly decreased in the central area and slightly increased in the eastern area, but the C/N ratios decreased in both areas. This pertains to the relative similarity of the SOM composition in the photosynthetic layer of the central area to the SOM composition of the surface layer in the eastern area. The detritus rate increased slightly in the photosynthetic layer in the eastern area; however, the composition remained nearly the same.

In the spring, the minimal concentrations of SOM components were recorded for the surface water layer of the northern part of the central area, as was also observed for the winter period (Figs. 10.3c,d and 10.4b). The average concentrations of C_{SOM} (14.5–15.3 μM) and N_{SOM} (2.18–2.35 μM) increased by 2.0–2.4 times compared to the winter period (Table 10.1). Meanwhile, the average C_{Chl} concentration decreased in the central area half as much and by 1.2 times in the eastern area, varying 0.49–0.57 mg/m^3. The ratios of C/Chl (400–600) and C/N (7.0–7.6) in both areas may testify to low productivity in these regions during the spring period.

The weighted averages of C_{SOM} and N_{SOM} in the photosynthetic water layer increased by 1.8 and 2.2 times in the central area, and by 1.1 and 1.5 times in the eastern area, respectively, compared to those observed during the winter period. However, they were less than 1.2–1.3 times compared to those observed in the surface water layer. The C_{Ch}l concentration in both areas remained the same compared to the winter period. The average C/Chl values decreased down to 274–302 in both areas, and the C/N ratio also decreased down to 6.1–6.9. We argue the increasing rate of phytoplankton in SOM compared to the winter period and the fact that SOM was represented mostly by phytoplankton and newly formed detritus.

During the summer period, patches of low concentrations of SOM components remained in the central area (Figs. 10.3e,f and 10.4c). The average C_{SOM} concentration did dot change in the surface layer compared to the spring period. Meanwhile, the N_{SOM} concentration in the northern area decreased by 1.7 times, but the C_{Chl} concentration increased by 1.6 times. In the eastern area, the concentrations of C_{SOM} and N_{SOM} increased by 1.3 times, and the C_{Chl} concentration, in 2.2 times, exceeding the values recorded in the central area. The high C/Chl (800) and C/N (8.9–10.2) ratios in both areas testified to prevailing well transformed detritus in the SOM composition.

The weighted averages of C_{SOM} and N_{SOM} in the photosynthetic water layer in both areas increased by 1.2–1.7 times compared to those observed during the spring period. Meanwhile, the chlorophyll a concentration decreased insignificantly in the central area and increased by 1.7 times in the eastern area. The concentrations of C_{SOM} and N_{SOM} here increased by 1.1–1.4 times compared to the surface layer (a decrease in these parameters was recorded in spring). In the eastern area, the C_{SOM} concentration decreased by 1.1 times, but the N_{SOM} concentration increased slightly. The average C/Chl ratio decreased slightly in the photosynthetic layer compared to the surface layer, but still remained high (475–770). The average C/N ratio in this layer also decreased slightly, constituting 8.2 in the central area and 6.7 in the eastern area. This may testify to an increase in the ratio of freshly formed detritus in the SOM in the photosynthetic layer. We also assume that the biological productivity of the central and eastern areas was lower in the summer period compared to the springtime.

During the autumn period, the average concentrations of C_{SOM} and N_{SOM} in the surface water layer decreased by 1.2–1.4 times compared to the summertime.

Meanwhile, compared to the winter period, they were higher by 1.2–1.4 times in the central area and 1.8–2.2 times in the eastern area. The average C_{Chl} concentration also decreased in the eastern area but remained the same in the central area compared to the summer period. The average C/Chl and C/N ratios also decreased in both areas and constituted 217 and 9.3 in the central area, and 605 and 7.7 in the eastern area, respectively. We assume that detritus of different stages of transformation was the major component of SOM in both areas during the autumn period, as was observed during summer.

The C_{SOM} and N_{SOM} concentrations also decreased in the photosynthetic layer (0–30 m) by 1.2–2.0 times compared to the summer period. The weighted average C_{Chl} concentration decreased by 1.2 times in the eastern area, but it increased by the same magnitude in the central area. In comparison to the winter period, the C_{SOM} and N_{SOM} concentrations in both areas were higher by 1.3–1.5 times, but the C_{Chl} concentration was less than 1.4 times in the central area and higher by the same magnitude in the eastern area. The weighted average SOM component concentrations were less than 1.1–1.4 times in the photosynthetic layer compared to the surface layer. The average C/Chl ratio in the photosynthetic layer decreased significantly (201) in the central area and remained the same in the eastern area (404) compared to the summer period. The average C/N ratio increased up to 8.5–9.1 in both areas and did not differ greatly, so we conclude a similar composition of SOM within the photosynthetic layer.

10.2.1.2 Distribution of the Bio-Optical Parameters

Distribution of the seasonal values of the bio-optical parameter is shown in Fig. 10.5. It is in good agreement with the experimentally obtained seasonal distribution of the chlorophyll *a* concentration (Fig. 10.4). The increased seasonal values of the bio-optical parameters were observed in the areas of constant riverine discharges (in the western and northern ones), the decreased values – in the central area (Table 10.2). Note a satisfactory agreement of the seasonal chlorophyll *a* concentrations derived by the CZCS (1978–1986) and the SeaWiFS (1997–2010) color scanners. The minimum values of all the parameters were observed in NWBS in winter. In spring, due to the additional nutrients brought to the sea by the river waters, and insolation and water temperature growth, phytoplankton starts to bloom actively. This fact explains increase of the chlorophyll *a* concentration in the areas subjected to the river impact (Tables 10.1 and 10.2). In the western area, the increased values of the absorption and scattering coefficients were also observed (Table 10.2) that is, apparently, related to a large amount of yellow substance, and mineral and organic particles of the suspended matter brought by the Danube waters. In summer the increased values of all the bio-optical parameters were revealed in NWBS. In autumn the chlorophyll *a* content in the western and northern areas decreased, whereas in central one – increased. During this period the scattering coefficient values in all the areas decreased up to a minimum value. This fact partially confirms rather high water

Table 10.2 Seasonal variability of the bio-optical parameters of different NWBS areas

Area	Parameter		Seasons			
			Winter	Spring	Summer	Autumn
Dnieper	C_{Chl}, mg/m^3	SW	1.2 ± 0.6	1.0 ± 1.0	2.6 ± 1.4	2.1 ± 1.1
		CZCS	1.48 ± 0.6	1.71 ± 0.75	2.25 ± 1.0	2.0 ± 0.7
	a_g, m^{-1}		0.154 ± 0.055	0.135 ± 0.055	0.17 ± 0.062	0.171 ± 0.064
	b_{bp}, m^{-1}		0.013 ± 0.007	0.012 ± 0.008	0.022 ± 0.011	0.012 ± 0.006
Danube	C_{Chl}, mg/m^3	SW	1.26 ± 0.78	2.7 ± 2.0	2.2 ± 1.6	1.7 ± 1.12
		CZCS	1.37 ± 1.0	2.2 ± 1.5	2.24 ± 1.4	2.0 ± 1.6
	a_g, m^{-1}		0.113 ± 0.054	0.14 ± 0.06	0.116 ± 0.062	0.139 ± 0.072
	b_{bp}, m^{-1}		0.016 ± 0.011	0.02 ± 0.012	0.018 ± 0.013	0.013 ± 0.01
Central	C_{Chl}. mg/m^3	SW	0.85 ± 0.58	0.8 ± 0.77	0.67 ± 0.52	1.1 ± 0.75
		CZCS	0.76 ± 0.39	0.74 ± 0.25	1.0 ± 0.52	0.96 ± 0.45
	a_g, m^{-1}		0.062 ± 0.038	0.066 ± 0.037	0.08 ± 0.04	0.081 ± 0.051
	b_{bp}, m^{-1}		0.0044 ± 0.003	0.0055 ± 0.005	0.008 ± 0.006	0.004 ± 0.003

Note: The concentration of chlorophyll *a* (C_{Chl}) according to the scanners Sea WiFS (SW, 1997–2010), and CZCS (1978–1986) transparency in NEBS in autumn (Kukushkin 2013b). Note also the increased values of the absorption coefficient in all the areas. It testifies to high content of yellow substance and detritus which condition the value of this coefficient.

Comparison of the seasonal values of the chlorophyll *a* concentration derived from the experimental and satellite data showed some differences. The close values of concentrations differing within the range 10–30% were obtained in summer and autumn in the western and northern areas and in course of a year – in the central area. The most significant differences were noted in the winter-spring period in the areas subjected to the rivers' impact. In winter the measured concentrations exceeded the satellite-derived ones by approximately 1.5 times, and in spring – by 4–5 times.

10.2.1.3 Distribution of the Bio-Optical Parameters in the Western Part of the Sea

Hydrological and biogeochemical features of the coastal waters in the Romanian and Bulgarian sea sectors result mainly from the transformed river waters and the coastal sewage interaction. The transformed nutrient-rich river waters propagate from NWBS to the south by the alongshore current (Markov and Esin 1979). The biogeochemical characteristics of the coastal waters are noticeably affected by the coastal sewage (industrial, domestic, riverine and rainwater, runoff of fertilizers, etc.). The distribution of the transformed river waters in various seasons is well traced due to the salinity distribution (Fig. 10.6). In winter these waters with salinity lower than 17 PSU reach Cape Kaliakra. In spring and summer they migrate up to the Bosporus, whereas in autumn – up to the Romanian sea sector.

The spatial seasonal distributions of the bio-optical parameters in the western sea coastal waters are shown in Fig. 10.7. In all the seasons these distributions are characterized by decrease of the parameters' absolute values in the southern direction. The maximum values are obtained in the Danube estuary region, the minimum ones – in the Bosporus one (Table 10.3). In the Danube region the increased values of the parameters were usually observed in the spring-summer period. In the coastal areas located to the south off this region, the maximum values of the chlorophyll *a* concentration and absorption coefficient were observed in autumn when phytoplankton bloomed intensively. At the same time the increased value of the scattering coefficient was obtained in the spring-summer period when the transformed river waters flowed into these areas.

The detailed spatial distribution of the chlorophyll *a* concentration and the absorption coefficient in different seasons is well seen on the alongshore section (Fig. 10.8) located at the distance of 7–15 km off the coast. In winter and spring in the region of the Burgas Bay and Varna, the section crossed a number of coastal areas (their dimensions did not exceed 20 km) with the increased and decreased values of these parameters. At that, in winter their absolute values exceeded those observed in spring. In the summer-autumn period, the chlorophyll *a* concentration in this area changed insignificantly. More noticeable changes (especially for the

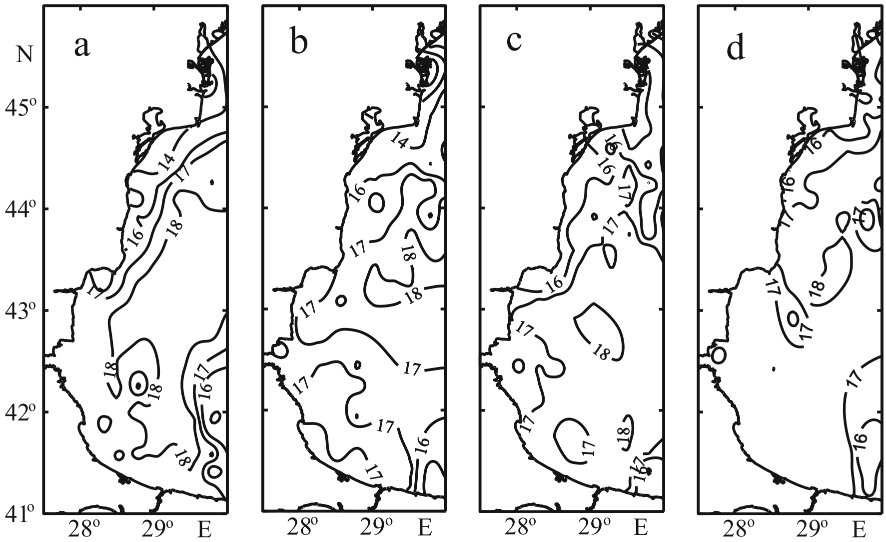

Fig. 10.6 Distribution pattern of salinity in the surface water layer of the western part Black Sea in winter (plots **a**), spring (plots **b**), summer (plots **c**), and autumn (plots **d**)

absorption coefficient) were noted in autumn to the north off Varna. A considerable growth of these values observed in all the seasons took place to the north from Conztanza. Their maximum values were observed near the Danube estuary region. To the north from this region the parameters' values decreased (except for the chlorophyll *a* concentration in the summer-autumn period). A slight increase of the values was observed in the Dniester estuary area. A more noticeable increase of the parameters under study was in the region of the Odessa Bay (Odessa), where, besides the urban industrial and domestic waste, the Dnieper-Bug estuary waters were present.

10.2.2 Inter-Annual Variability of the Hydrobiological (1978–1995) and Bio-Optical (1997–2015) Parameters

In the last 20 years against the background of global warming certain climate changes took place in the western and northwestern parts of the Black Sea region (Matygin et al. 2013; Popov et al. 2009). In course of this period the air temperature in winter increased, while the number of cold winters noticeably decreased. In winter in NWBS the surface water average temperature increased by 2 °C, and in the bottom layer – by more than 3 °C. During the warm period of a year repeatability of warm and very warm summer months grew, whereas cold months were absent. Up to the mid 1990s, the winter and summer temperature trends were of an anti-phase character (cold winter was followed by warm summers and vice versa).

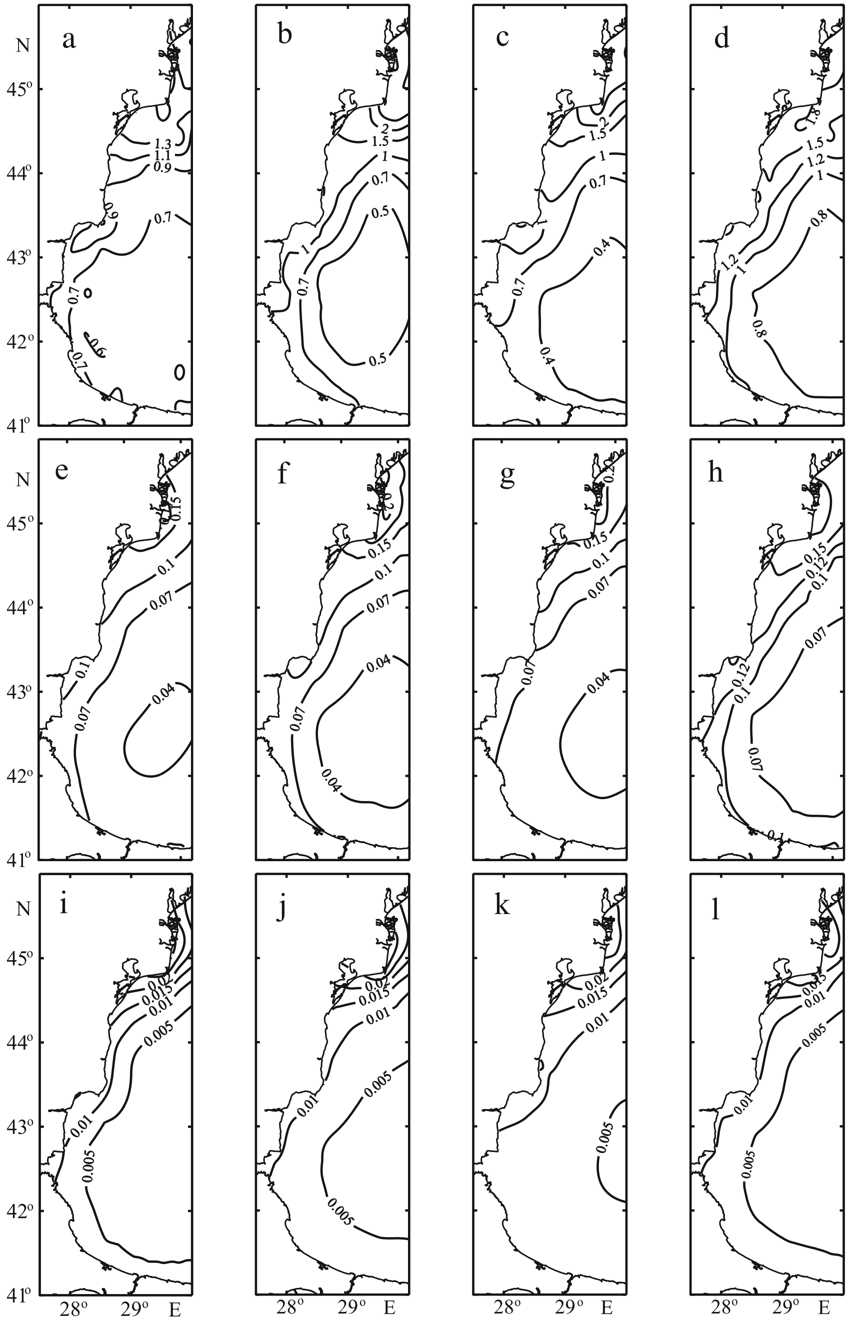

Fig. 10.7 Distribution pattern of C_{Chl} (mg/m^3; plots (**a**), (**b**), (**c**), and (**d**)), a_g (m^{-1}; plots (**e**), (**f**), (**g**), and (**h**)), b_{bp} (m^{-1}; plots (**i**), (**j**), (**k**), and (**l**)) in the surface water layer of the western part Black Sea in winter (plots (**a**), (**e**) and (**i**)), spring (plots (**b**), (**f**), and (**j**)), summer (plots (**c**), (**g**),and (**k**)), and autumn (plots (**d**), (**h**), and (**l**))

Table 10.3 Seasonal variability of the bio-optical parameters of in the coastal areas of the western part of the Black sea

Area	Parameter		Seasons			
			Winter	Spring	Summer	Autumn
Danube	C_{Chl}, mg/m^3	SW	1.26 ± 0.78	2.78 ± 2.0	2.2 ± 1.6	1.7 ± 1.12
		CZCS	1.37 ± 1.0	2.2 ± 1.5	2.24 ± 1.4	2.0 ± 1.6
	a_g, m^{-1}		0.113 ± 0.054	0.14 ± 0.06	0.116 ± 0.062	0.139 ± 0.072
	b_{bp}, m^{-1}		0.016 ± 0.011	0.02 ± 0.012	0.018 ± 0.013	0.013 ± 0.01
Romanian	C_{Chl}, mg/m^3	SW	1.06 ± 0.85	1.18 ± 1.0	1.21 ± 1.1	1.38 ± 0.95
		CZCS	1.05 ± 0.52	1.23 ± 0.61	1.3 ± 0.7	1.23 ± 0.56
	a_g, m^{-1}		0.097 ± 0.046	0.1 ± 0.046	0.089 ± 0.045	0.124 ± 0.054
	b_{bp}, m^{-1}		0.01 ± 0.009	0.011 ± 0.009	0.012 ± 0.01	0.008 ± 0.007
Bulgarian	C_{Chl}, mg/m^3	SW	0.71 ± 0.5	0.78 ± 0.6	0.72 ± 0.61	1.02 ± 0.74
		CZCS	0.95 ± 0.45	1.0 ± 0.62	0.88 ± 0.44	0.98 ± 0.43
	a_g, m^{-1}		0.072 ± 0.031	0.07 ± 0.033	0.066 ± 0.032	0.1 ± 0.043
	b_{bp}, m^{-1}		0.007 ± 0.006	0.008 ± 0.007	0.008 ± 0.007	0.007 ± 0.005
Bosphorus	C_{Chl}, mg/m^3	SW	0.64 ± 0.44	0.59 ± 0.45	0.48 ± 0.26	0.82 ± 0.58
		CZCS	0.8 ± 0.4	0.73 ± 0.32	0.6 ± 0.25	0.85 ± 0.46
	a_g, m^{-1}		0.058 ± 0.02	0.053 ± 0.019	0.049 ± 0.02	0.085 ± 0.037
	b_{bp}, m^{-1}		0.005 ± 0.004	0.006 ± 0.005	0.006 ± 0.005	0.006 ± 0.004

Note: The concentration of chlorophyll *a* (C_{Chl}) according to the scanners Sea WiFS (SW, 1997–2010), and CZCS (1978–1986)

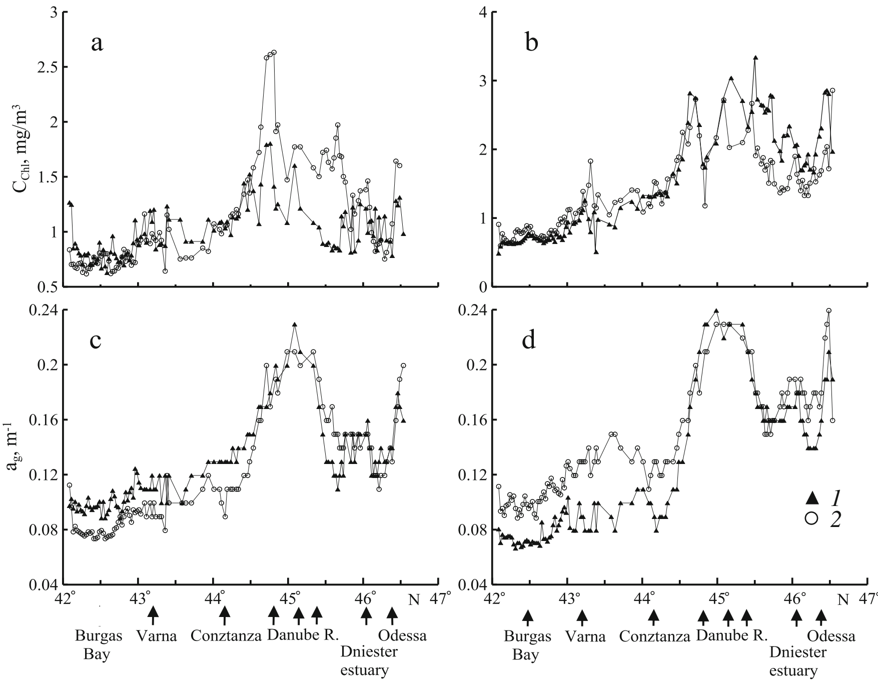

Fig. 10.8 Distribution pattern of C_{Chl} (a, b) and a_g (c, d) on the section along the western shore of the sea winter (a, 1), (c, 1), spring (a, 2), (c, 2), summer (b, 1), (d, 1), and autumn (b, 2), (d, 2) periods

In the last 20 years a summer following a warm winter usually was also warm. Besides, a change of the wind conditions was observed. In summer, repeatability of the northern and eastern winds increased along with the simultaneous decrease of the western ones. This phenomenon limited the transformed river water flowing into the shelf central area and promoted their propagation to the south.

The listed climatic changes induced the ones in the phytoplankton community structure and development. As a result, its species diversity and abundance increased, and the development phases changed. The winter bloom was observed more often.

10.2.2.1 Variability of Hydrobiological Parameters in NWBS

Inter-annual seasonal variability anomalies of the chlorophyll a concentration are presented on Fig. 10.9, where the winter and spring values are pooled together for areas affected by riverine discharge (northern and western) and the central area extending up to 32°30′ E and affected by fresh water influx from time to time. The anomaly is defined as deviation of seasonal values from the average long-term, normalized by the standard deviation.

It was found earlier that regional meteorological conditions and the volume of riverine discharge might affect the water transparency and the concentration of

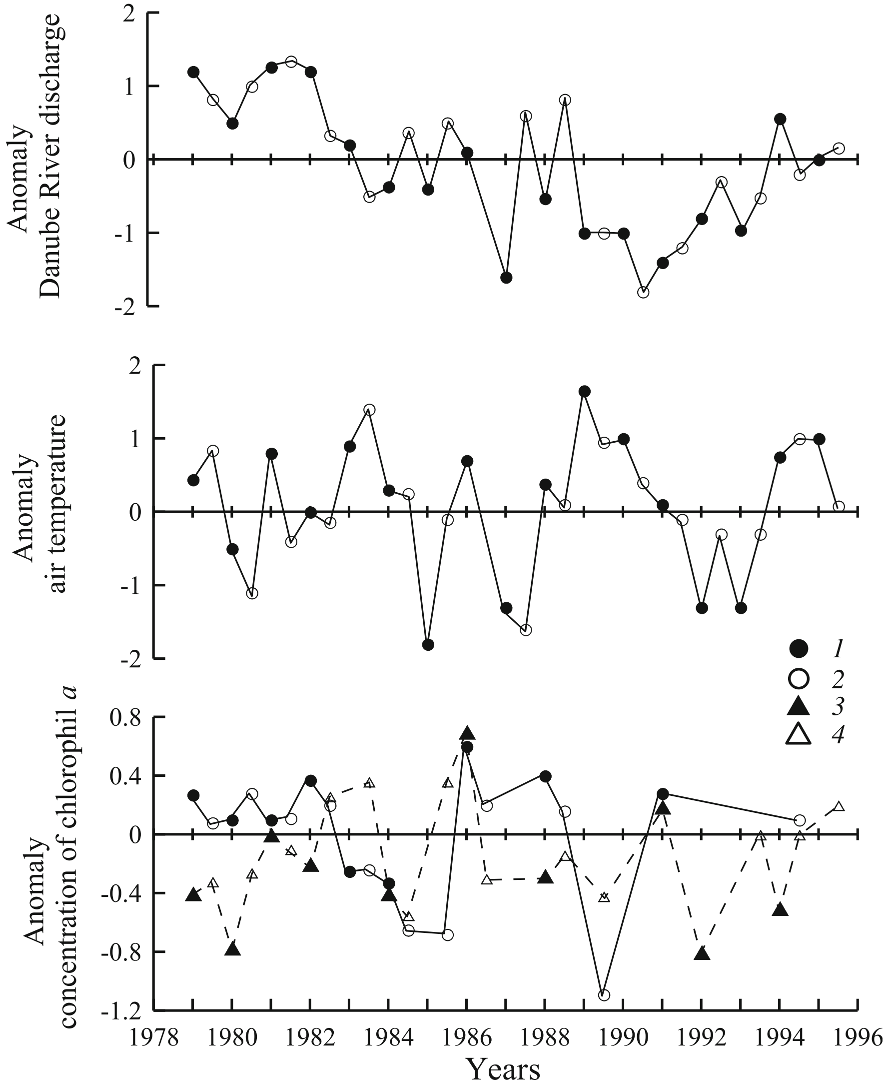

Fig. 10.9 Inter-annual variability of the average anomalies in the Danube River discharge, air temperature, and chlorophyll *a* concentration in the surface water layer in the northern and western (*1*, *2*) and central (*3*, *4*) areas of the NWBS during the winter (*1*, *3*) and springtime (*2*, *4*) periods. The solid line connects the seasonal averages of the anomalous values in the northern and western areas; the dashed line refers to the central area

suspended matter in the NWBS (Kukushkin 2013b; Voskresenskaya et al. 2004, 2011). In turn, the meteorological conditions and riverine discharge are affected by the variability of global climatic shifts (North Atlantic Oscillation, NOA, and Southern Oscillation, SO) during different El Niño–Southern Oscillation (ENSO) periods or absence thereof. That is why we used anomalies in the Danube River discharge and air temperature during this period (Voskresenskaya et al. 2011) to analyze the interannual variability of SOM in the winter–spring period (Fig. 10.9). Analysis allowed us to reach several conclusions.

The period of 1979–1982 was characterized by the absence of ENSO, relatively mild winters (except winter 1980) and positive anomalies in Danube River discharge (Fig. 10.9). Such conditions favored relatively intensive phytoplankton growth in areas affected by riverine discharge in the winter–spring period. The C_{SOM} (Kukushkin 2013a) and chlorophyll a concentrations (except winter 1980) exceeded the annual average. In 1984–1988, ENSO was also absent. High C_{SOM} and C_{Chl} concentrations during the warm winter of 1986 may be explained by the intensive vegetation of phytoplankton during that period (Yunev 1989). In spring, the C_{SOM} (Kukushkin 2013a) and C_{Chl} concentrations decreased significantly in the central area. This may be linked with intrusion of open sea water masses with a low productive potential, which did not compensate the balance of micronutrients assimilated by phytoplankton during the winter period. In 1984 and 1986, when similar meteorological conditions were observed (in "average" winters, the Danube River discharge in winter was lower, and in spring, higher, compared to the multiyear average), the C_{SOM} and C_{Chl} concentrations differed significantly in the winter and spring periods. A probable explanation may be found in the meteorological conditions that affect the phytoplankton community in previous periods. In particular, the warm autumn of 1983 might have favored the state of the phytoplankton community (the C_{Chl} concentration exceeded the average values (Kukushkin et al. 2008)), which resulted in exhaustion of the micronutrient stock by the end of the year. In addition, the low Danube River discharge in 1984 did not promote intensive phytoplankton growth in winter. However, the cold year conditions of 1987 were also unfavorable (low Danube River discharge again). That is why the micronutrient stock was not limiting factor for phytoplankton in the winter period of 1988, and the C_{SOM} concentration significantly exceeded the values observed in 1984.

During ENSO years (1983, 1987, 1991–1995), the pattern differed. In 1983, the winter was relatively mild and the Danube River discharge was similar to the multiyear average. In the winter period, the C_{Chl} (satellite observations) and C_{SOM} (Kukushkin 2013a) concentrations were lower than average in areas affected by riverine discharge. In 1987, the winter was cold and the Danube River discharge was low, so water transparency on the northwestern shelf was also high (Voskresenskaya et al. 2004, Kukushkin et al. 2004). That is why we conclude that the C_{SOM} and C_{Chl} concentrations were low also in the winter–spring period compared to the average year, even taking into account the absence of in situ measurements for these parameters. During the period of 1991–1995, which was characterized by a long-lasting ENSO with several development and fading phases, the cold winters of 1992 and 1993 can be cited when the Danube River discharge was low. The measurements performed in winter 1992 in the central area testified to low concentrations of C_{SOM} (Kukushkin 2013a) and chlorophyll a. In spring 1993, the concentrations of these components increased but remained relatively low. The relatively mild winters of 1994 and 1995 and a Danube River discharge volume similar to the multiyear average promoted intensive phytoplankton production and a significant increase in the C_{SOM} concentration in comparison to previous years.

Two temporal intervals can be distinguished for the summer periods: 1979–1985 and 1985–1992 (Kukushkin 2013a), which are characterized by a high variability of C_{SOM} and C_{Chl} concentrations and their components. The first period (1979–1985) is characterized by an uneven decrease in the concentrations of these compounds observed for all stations situated on the northwestern shelf. In 1979–1981, when the summer was moderately warm (Titov 2003), the C_{SOM} and C_{Chl} concentrations were nearly equal (except for higher in situ concentrations of C_{SOM} in 1980). The second part of this period, when the summers of 1982–1984 were relatively cold, and in 1985, cold, the C_{SOM} and C_{Chl} concentrations in the northwestern area were lower compared to the multiyear summer average in 1985; the same pattern was observed for C_{SOM} for the entire period of 1982–1985. During the period of 1982–1985, an uneven increase in the concentrations of both C_{SOM} and C_{Chl} was observed in the northwestern area, when the maximal concentrations were recorded in the extremely warm year of 1992 after a cold winter. In the central area, high C_{SOM} and C_{Chl} concentrations were recorded in 1986 (warm summer) and in 1989–1990 (average summer). We assume that the anticyclonic circulation observed in the summers of 1989–1990 may be a possible reason for these events, since it may have fostered the transport of SOM and nutrient-rich riverine water masses to the central shelf area (Kukushkin et al. 2006). In 1993, when the summer was moderately cold, the C_{SOM} and C_{Chl} concentrations decreased in the northwestern area; the opposite pattern was observed for the central area. In addition, the absolute concentrations of these parameters were close to the values obtained in 1979–1981.

Two temporal intervals may be also defined for the autumn periods, 1980–1987 and 1989–1992, that are characterized by high interannual variability of C_{SOM} and C_{Chl} concentrations, and different patterns of such variability (Kukushkin 2013a). In 1980–1987, the variability was relatively high. The low concentrations of SOM components were recorded by both onboard (in situ) measurements (1980, 1987) and satellite observations (1979, 1982, 1984), and high concentrations, in 1981, 1983, and 1985. We assume that the intensive phytoplankton production in October of 1985 might have fostered high concentrations of measured C_{Chl} and calculated C_{SOM}; this event was favored by the intrusion of transformed riverine water masses to the central shelf area (Kukushkin et al. 2008). In addition, the cold winter and summer suppressed active phytoplankton production and, therefore, helped keep the micronutrient stock at a high level. The low C_{SOM} and C_{Chl} concentrations in early December 1987 can be explained by the low temperatures of both water and air (Kukushkin et al. 2008). After 1989, the concentrations of SOM components began to increase, when the maximal concentrations were recorded in the extremely warm year of 1992.

10.2.2.2 Variability of the Bio-Optical Parameters

In 1998–2015 in the winter-spring period the inter-annual variations of the chlorophyll *a* concentration (the MODIS scanner data) in the NWBS western (the Danube) area (Fig. 10.11) are less dependent on the changes in the Danube discharge volume (Fig. 10.10) as compared to the previous time interval (1978–1995). Especially in spring, these variations were conditioned to a large extent by the water temperature changes. Thus, the chlorophyll *a* concentration grew in spring, 1998–2001 and 2005–2009, accompanying increase of the water temperature (T_w) during these periods (Fig. 10.11). Its sharp decrease in 2011 and increase in 2013–2014 was followed by the same variations of C_{Chl}. In the summer-autumn period in 1997–2003 C_{Chl} and T_w varied synchronously (Fig. 10.11). At the same time, in summer, 2004–2012, the water temperature increased, and the chlorophyll *a* concentration decreased. Note a good agreement between the variations of the Danube discharge and C_{Chl} in summer, 2000–2010. In the autumn period such an agreement was not observed.

In the central NWBS the C_{Chl} variations in winter practically did not depend on the air temperature (T_a) and the Danube discharge volume. In spring, the impact of the C_{Chl} variations was insignificant. The Danube discharge effect was more significant. Thus, rather high chlorophyll *a* concentrations were in 1999, 2000, 2005, 2009 and 2010 when the Danube discharge was heightened. In summer, 2005–2015, the air temperature increase and C_{Chl} decrease were observed similarly to that in the Danube region.

The annual variability pattern of the chlorophyll *a* concentrations is almost the same both for the Romanian and the Bulgarian coastal zones. The correlation coefficients of C_{Chl} series for the spring-autumn period were rather high (0.7–0.8). The low correlation coefficient, 0.35, was obtained only for the winter period. Some discrepancies in the C_{Chl} variations in winter, 2006–2010 and those in autumn, 2003–2008 were probably related to different hydro-chemical and hydrometeorological conditions in these regions that influenced phytoplankton. On the whole the effect of the air temperature changes upon the C_{Chl} variations was weakly manifested. Perhaps this was due to the fact that such an effect was assessed through the air temperature defined for NWBS, but not for the areas under study.

Comparison of the seasonal variability patterns of the Danube discharge volume and the chlorophyll *a* concentration in the Romanian and the Bulgaria areas showed no good agreement. However such an effect actually exists. For its assessment the correlation coefficients of the seasonal chlorophyll *a* concentrations in the Danube and in these two areas were calculated. The correlation coefficient of the C_{Chl} values in the Danube and the Romanian areas in the spring-summer period was equal to 0.7, and in autumn – 0.6. It testifies to the fact that the phytoplankton bloom and variability in these areas were influenced by the same factors, one of which was the riverine discharge. The correlation coefficient between the values of C_{Chl} in the Danube and the Bulgarian areas was smaller. In spring it was equal to 0.37, and in summer, when the transformed river waters propagated maximally to the south, it

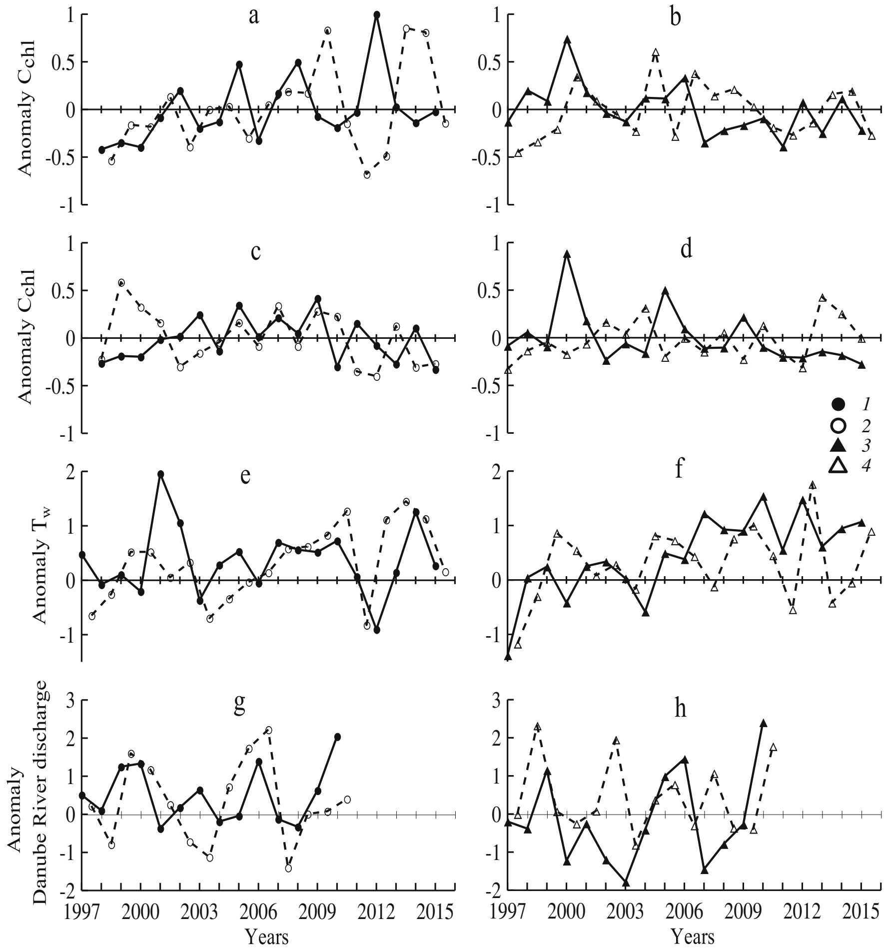

Fig. 10.10 Inter-annual variability of the anomalies chlorophyll a concentration (C_{Chl}) in the Danube region (a, b) and central (c, d) areas of the NWBS, anomalies water temperature (T_w) in the surface water layer (e, f), and the Danube River discharge (g, h) during the winter (1), spring (2), summer (3), and autumn (4)

equaled 0.5. It means that these water masses effected the phytoplankton bloom in these periods weaker than in the Romanian area. In the autumn-winter period the transformed river waters do not practically get to the Bulgarian area (Fig. 10.6). Therefore the phytoplankton bloom in this area is mainly conditioned by the local hydro-chemical and hydro-meteorological conditions.

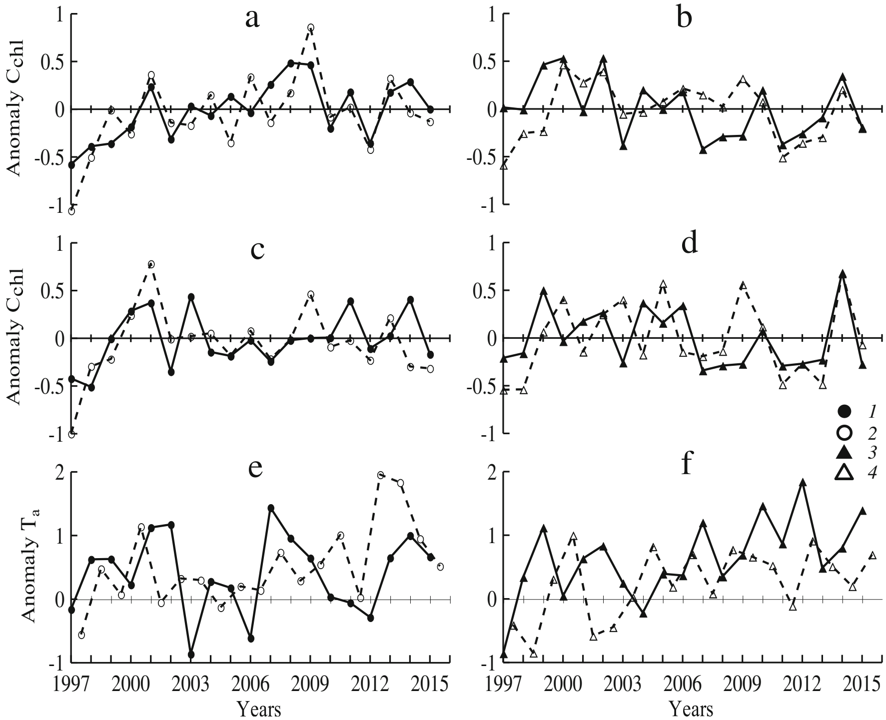

Fig. 10.11 Inter-annual variability of the anomalies chlorophyll a concentration (C_{Chl}) in the Romanian (a, b) and the Bulgarian (c, d) shelf areas, and air temperature (T_a) (e, f) during the winter (1), spring (2), summer (3), and autumn (4)

10.3 Conclusion

The results of analyzing the multi-year (1978–1995) data array made it possible to obtain the basic features of the spatial-temporal variability in the distribution pattern of the SOM components' concentration in the surface and photosynthetic layers in four NWBS areas (northern, western, central and eastern), which differed from each other due to degree of influence both of the riverine discharge and the open sea water masses. The peculiarities of the satellite-derived distribution of the bio-optical parameters in 1997–2015 in NWBS and in the western part of the sea, i.e. the Romanian, Bulgarian and Bosporus areas are also considered.

As compared to other areas, the western and the northern NWBS ones, which are constantly affected by the nutrient-rich transformed riverine water masses, are characterized by high concentrations of the SOM components in course of the whole. Their main peak is observed in spring. In all the seasons SOM is mostly consists of phytoplankton and detritus. In winter and spring, detritus weakly transformed. In summer its portion in SOM increases. In autumn detritus is at different stages of biochemical transformation. In the central and eastern areas, the heightened concentrations of the SOM components are observed in the spring–summer period. Their seasonal variations are noticeably smaller than those in the areas affected by the riverine discharges. In all the seasons the transformed detritus constitutes the SOM predominant component.

The distribution pattern of the bio-optical parameters in NWBS is a good agreement with the obtained experimentally seasonal distribution of the chlorophyll *a* concentrations. Comparison of the seasonal chlorophyll *a* concentration values determined by experimental and satellite data has shown some differences. The concentration close values differing within the range 10–30% were obtained in the summer-autumn period in the western and the northern areas and during the year – in the central area. The greatest differences were observed in winter and spring in the areas affected by the riverine discharges.

In course of the whole year the seasonal distributions of the bio-optical parameters in the coastal waters of the sea western part are characterized by a decrease of the parameters' absolute values in the southern direction. The maximum values are obtained in the Danube region, the minimum ones – in the Bosporus region. In the Danube region the increased values of the parameters were usually observed in the spring-summer period. To the south from this region in coastal areas, the maximum values of the chlorophyll *a* concentration and the absorption coefficient were monitored in autumn when phytoplankton bloomed actively in these areas. The increased value of the scattering coefficient was obtained in the spring-summer period when the transformed river waters flowed into these areas. The detailed spatial distributions of the chlorophyll *a* concentration and the absorption coefficient in different seasons are considered on the section along the sea western coast located at the 7–15 km distance from the coast.

The inter-annual variations of the SOM components' content in the winter-spring period in areas affected by the riverine discharges are mainly conditioned by the volume of the nutrient-enriched riverine discharge and by the air temperature (severe winters); in the central area – by the air temperature only. In summer and autumn, the interannual variations of the SOM component' content is mostly dependent on the temperature regime (during the period of observations and in the previous periods). In the central area, variability of the SOM components' content is also significantly influenced by the transformed river waters which, in their turn, depend on the water circulation pattern in the NWBS. The increase of the SOM components' concentration has been observed in the summer-autumn period in late 1980s and early 1990s, with the highest values in 1992.

The inter-annual variations of the chlorophyll *a* concentration (the MODIS scanner data) in the NWBS the Danube area in the winter-spring periods, 1998–2015, are less dependent on the changes in the Danube discharge volume as compared to the previous time interval (1978–1995). These variations (especially in spring) were conditioned to a greater extent by the water temperature changes. A good agreement between of the variation patterns of the Danube discharge volume and C_{Chl} was observed in summer. In autumn such an agreement was absent. In the NWBS central area the C_{Chl} inter-annual variations in winter did not practically depend on the air temperature and the Danube discharge volume. In spring, the effect of the air temperature variations upon C_{Chl} was insignificant. The Danube discharge impact was more noticeable. In summer, 2005–2015, in both NWBS areas air temperature increase and the C_{Chl} decrease were observed.

The inter-annual variability patters of the chlorophyll *a* concentration in the Romanian and the Bulgarian coastal areas coincided satisfactorily. The correlation coefficients of the C_{Chl} series in these regions in the spring-autumn period were rather high (0.7–0.8). The low correlation coefficient, 0.35, was obtained only for the winter period. The Danube discharge effect on the inter-annual variations of the chlorophyll *a* concentrations in the Romanian and the Bulgarian areas was assessed by the degree of connection between its seasonal concentrations in the Danube area and in these two ones. The correlation coefficient of C_{Chl} in the Danube and the Romanian areas in the spring-summer period was equal to 0.7, and in autumn – 0.6. It testifies to the fact that the phytoplankton bloom and variability in these areas are affected by the similar factors, one of which is the riverine discharge. In the Bulgarian area the Danube discharge produces a weaker effect upon the phytoplankton bloom as compared to the Romanian area. This effect is manifested only in the spring summer period when the transformed river waters flow into the area.

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Chapter 11
Water Mass Measurements Around Benthic Communities: A Comparative Study Between Yo-Yo Conductivity-Temperature-Depth (CTD) Casts and High-Resolution Time Series Data Acquisition of Bottom Waters from the Pagès Escarpment in the Southern Bay of Biscay

Wolf-Christian Dullo, Sascha Flögel, and Andres Rüggeberg

Abstract We performed a comparative test study applying conventional Conductivity-Temperature-Depth (CTD) casts and a self designed mini lander system, which was deployed on the Pagès Escarpment on the Cantabrian Margin at 762 mbsl water depth for continuous bottom water measurements. Our lander data demonstrate that the mechanical movement of CTD gear disturbs the internal structure of the bottom water mass and extreme values are most likely to be missed. This questions the reliability of repeated CTD casts at the same site (yoyo-CTD) with respect to the detailed bottom water mass characteristics bathing the benthic communities. Although, repeated CTD casts may provide information about the amplitude in temperature and salinity variability, our data clearly exhibit that temperature and salinity maxima and minima respectively do not coincide only with the most obvious semi diurnal tidal dynamics but exhibit other tidal frequencies, mainly M4, which are not captured by yoyo-CTD analysis. High resolution CTD measurements in combination with ADCP data reveal a comprehensive picture of bottom water mass dynamics.

W.-C. Dullo (✉) • S. Flögel
GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany
e-mail: cdullo@geomar.de; sfloegel@geomar.de

A. Rüggeberg
Département des Géosciences, Université de Fribourg, Fribourg, Switzerland
e-mail: andres.rueggeberg@unifr.ch

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11.1 Introduction

The interpretation of sedimentary structures on marine shelves, continental slopes and deep-sea basins progressed enormously due to an improved interdisciplinary research between oceanographers and marine geologists. A thorough in-depth analysis was recently published by Hernández-Molina et al. (2016), in which they demonstrate the impact of oceanographic processes of different time scales on morphosedimentary structures of various spatial scales. Although actuogeology as a tool is known since Johannes Walther (1888), this discipline becomes more and more important for the evaluation of recent global change. The deep sea was looked at as a quiet and low energy environment throughout most of the twentieth century. During the last decade it became more and more accepted that different oceanographic processes form and shape deep sea sedimentary environments (e.g. Hübscher et al. 2010; Rebesco et al. 2014).

The rediscovery of cold water non zooxanthellate coral reefs along the NW European continental margin (Dons 1932; Le Danois 1948; Henriet et al. 1998) has stimulated marine geological and oceanographic research of these systems to better understand the processes behind their formation and distribution. Cold-water coral (CWC) reefs are widespread along the continental margins of all ocean basins (Roberts et al. 2006). Since these classical studies (l.c.) many more reef sites have been identified worldwide, predominantly in the North Atlantic. Indeed, the presence of *Lophelia pertusa* as a main frame-builder of CWC reefs is today known from, for example, the Norwegian margin (e.g. Freiwald 2002; Fosså et al. 2002; Hovland et al. 2012), the Porcupine, Rockall and Hatton banks (e.g. White et al. 2007; Mazzini et al. 2012), the Celtic margin (e.g. Wheeler et al. 2007), the Mediterranean Sea (e.g. Taviani et al. 2005, 2011; Fink et al. 2012; Savini et al. 2014), the Gulf of Cadiz (GoC; e.g. van Rensbergen et al. 2005; van Rooij et al. 2011), off Morocco (e.g. Foubert et al. 2008; Glogowski et al. 2015), off Mauritania (e.g. Eisele et al. 2011, 2014), the Angola margin (e.g. Le Guilloux et al. 2009), the Gulf of Mexico (e.g. Hübscher et al. 2010; Hebbeln et al. 2014), and around the Bahamas (e.g. Reed et al. 2006; Correa et al. 2012).

The major frame builder of these modern carbonate mounds is *Lophelia pertusa* (Linnaeus 1758). This species was first observed in the open waters of the Atlantic during the Challenger Expedition by Thomson (1878). This species also dominates modern CWC growth in the Bay of Biscay. The Bay of Biscay can be subdivided into five geographic regions (Fig. 11.1) beginning in the north with the French Celtic and the Armorican margins, the French Aquitaine margin in the southeast, and the Iberian Cantabrian and Galician margins in the south. The Celtic and Armorican margins display a relatively broad shelf from the coast to the shelf break wider than 200 km and a steep slope (Lallemand and Sibuet 1986) which extends from a depth of about 200–4000 mbsl towards the abyssal plain. CWCs occur predominantly in canyons and on the slopes of the American margin (e.g. Reveillaud et al. 2008). They do not exhibit large scale coral mound structures such as those known form the Porcupine Seabight, but are well-developed reef

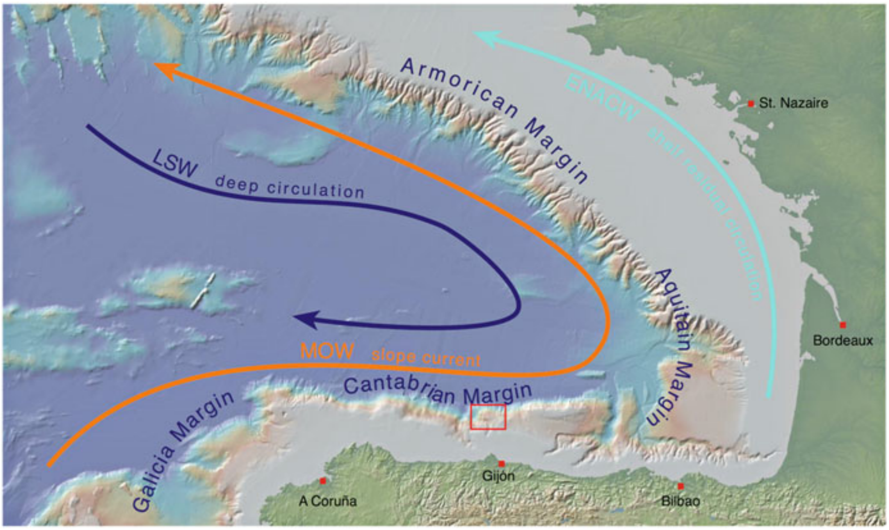

Fig. 11.1 Circulation pattern of the major water masses in the Bay of Biscay. *ENACW* Eastern North Atlantic Central Water, *MOW* Mediterranean Outflow Water, *LSW* Labrador Sea Water. The *red rectangle* shows the location of the detailed map of Fig. 11.2

structures (category II sensu Flögel et al. 2014). The Cantabrian margin has a narrow shelf (5–40 km wide) with a very steep continental slope (17°) between 500 and 4500 mbsl. A few marginal shelves with a steep slope of 10°–12° have been identified (Álvarez-Marrón et al. 1995). The Cantabrian margin hosts one of the sites described by Le Danois (1948), known as "Le Danois Bank" from where living CWCs where reported by Sánchez et al. 2014. CWC occurrences on the Galician margin were reported by e.g. Hernández-Molina et al. (2011) and Somoza et al. (2014).

METEOR cruise M84/5 sailed through the Bay of Biscay in 2011 investigating selected spots of possible CWC occurrences. Here we present our oceanographic observations on an escarpment located west of the much larger structure of Le Danois Bank, which we named Pagès Escarpment in memory of the marine biologist Francesc Pagès (1962–2007).

11.1.1 Oceanographic Setting

The water masses in the Bay of Biscay are predominantly of North Atlantic and Mediterranean origin according to Pollard et al. (1996). Although characterized by a complex topography, the Bay of Biscay hosts a classical eastern boundary current system with poleward flow on the shelf and slope and influence of the eastern verge of the large scale oceanic basin circulation further offshore (Koutsikopoulos and Le

Cann 1996; Pollard and Pu 1985). According to Le Boyer et al. (2013) this condition creates unstable slope currents and eddies in the interior of the Bay of Biscay (Fig. 11.1).

Surface water down to a depth of 450–600 mbsl consists of Eastern North Atlantic Central Water (ENACW) which moves in a cyclonic gyre with an average velocity of 4 cm/s (Pingree and Le Cann 1989) exhibiting a salinity of more than 35.62 psu (Pollard et al. 1996). The lower part of the ENACW reaching down to 600 mbsl seems to be laterally influenced by the Subarctic Intermediate Water (SAIW) indicated by very little to almost no change in density and a salinity minimum around 35.59 psu. Below salinity increases rapidly indicating the influence of Mediterranean Outflow Water (MOW), which extends down to a depth of around 1500 mbsl. Salinity maxima around 35.79 psu occur around 900 mbsl. The MOW forms a contour current along the continental margin, which is controlled by the Coriolis force and seafloor morphology. Therefore salinities are slightly lower on the Armorican margin in contrast to the Galicia margin. Pingree and Le Cann (1989) observed current velocities between 2 and 3 cm/s. Most of the living corals observed in the Bay of Biscay during photo surveys, thrive in a depth interval between 700–850 mbsl and are therefore bathed by the upper portion of the MOW representing the intermediate water salinity maximum

The North Atlantic Deep Water (NADW) underlies the MOW in water depths between 1500 and 3000 mbsl. A small but pronounced salinity decrease around 1800 mbsl is indicative for the influence of the Labrador Sea Water (LSW) according to González-Pola et al. (2006). Over the abyssal plain a cyclonic recirculation cell with poleward velocities of 1.2 ± 1.0 cm/s near the continental margin can be observed (Dickson et al. 1985; Paillet and Mercier 1997).

The continental slope of the Bay of Biscay is considered as one of the most high energy areas of the world (Jézéquel et al. 2002) favouring the formation of internal tides in combination with water mass stratification and steep topography (Holligan et al. 1985; Huthnance 1995; Pingree and Griffiths 1982; Pingree and Le Cann 1989, 1990). Strong barotropic tidal currents are channelled and locally increase flow within the numerous canyons cutting the slope reaching local currents of 14 cm/s or higher (Pingree and Le Cann 1989, 1990). These internal tides, in particular on the upper slope, are a possible explanation for enhanced levels of surface phytoplankton abundance (Van Rooij et al. 2010b).

Canyons and irregularly shaped escarpments usually lack significant covers of draping sediment, because of the strong current regime and low sediment deposition rates (Van Rooij et al. 2010b). Therefore hard substrata in such settings are ideal sites for CWCs to settle. Several studies show that the occurrence of deep-water corals in the Northeast Atlantic correlates well to nutrient supply, high energy current regime, little to very little sedimentation, and hard substratum (Frederiksen et al. 1992; Freiwald et al. 1999; Mortensen et al. 1995). Seawater temperature and salinity in combination yield seawater density which is another controlling factor for living CWC reef growth. Dullo et al. (2008) demonstrated that living CWC reef ecosystems on the Celtic and Norwegian Margin thrive within a density range of sigma-theta ($\sigma\Theta$) = 27.35–27.65 kg/m^3. This has been confirmed for the Bay of

Biscay (De Mol et al. 2011; Sánchez et al. 2014) and expanded with emphasis on DIC concentrations (Flögel et al. 2014). There are some reports about CWCs tolerating different seawater density values in submarine canyons of the Celtic Margin in the Bay of Biscay (Huvenne et al. 2011) and especially in the Mediterranean Sea (Freiwald et al. 2009). White and Dorschel (2010) claim that the described sigma-theta density envelope generally corresponds to a sharp pycnocline that may be helpful in concentrating food particles.

11.1.2 Geological Setting

The Cantabrian Margin bounds the Bay of Biscay in the south characterized by a narrow shelf in contrast to the Armorican and Celtic Margins in the NE. This narrow shelf descends rapidly to the deeper parts of the bay exhibiting a continental slope of variable morphologies (Ercilla et al. 2008). Numerous spurs and canyons intersect the Cantabrian margin in a downslope direction (Cremer 1981; Kenyon 1987) similar to the Armorican and Celtic Margins (De Mol et al. 2011). The Bay of Biscay originated from sea floor spreading that began in the Late Permian/Early Triassic, characterized by normal faults, asymmetric basins, and low angle detachments (Manatschal 2004) which continued until the Lower Cretaceous. During the Upper Cretaceous a passive continental margin formed (Boillot et al. 1979; Derégnaucourt and Boillot 1982). The narrow shelf is the result of a complex tectonic history which culminated in the Oligocene (Tertiary) with a partial closure of the Bay of Biscay and the intense compression, shortening, and lateral shearing of the Cantabrian Margin (Thinon et al. 2001; Gallastegui et al. 2002) and the uplift of the Cantabrian mountains (Pérez-Estaún et al. 1995; Pulgar et al. 1996) as a result of the Iberian and European plate collision (Boillot and Capdevila 1977; Srivastava et al. 1990; Alvarez-Marrón et al. 1997). Subsequent tectonic inversion related to the Pyrenean compression led to the north-directed thrusting of basement units and to the formation of low angle thrust slices or inverted folds in the cover along the northern margin of the basin (Gómez et al. 2002). As a consequence of these tectonic movements, the present day bathymetry and morphology of escarpments, spurs, canyons and valleys as well as graben structures and horst like elevations or buried ridges of various sizes have formed (Gallastegui et al. 2002). One of the largest structural highs on the Cantabrian Margin *sensu strictu* is Le Danois Bank (Van Rooij et al. 2010a).

The Pagès Escarpment is located west of this prominent elevation and forms an E-W oriented structural high (Fig. 11.2), having its highest elevation on the “Aguda de Fuero” High (Gómez-Ballesteros et al. 2014, their Fig. 2) shallower than 500 mbsl (43°59′N, 005°42′W). The escarpment is bound to the south by the Gaviero Cañon which merges with the Corbiro Cañon further west (43°59′N, 005°54′W) to continue in straight W direction as Corbiro-Gaviera-Cañon. To the N, the escarpment inclines gradually down to 2000 mbsl and then continues as a steep cliff down to the abyssal plain, while to the W the spur-like structure

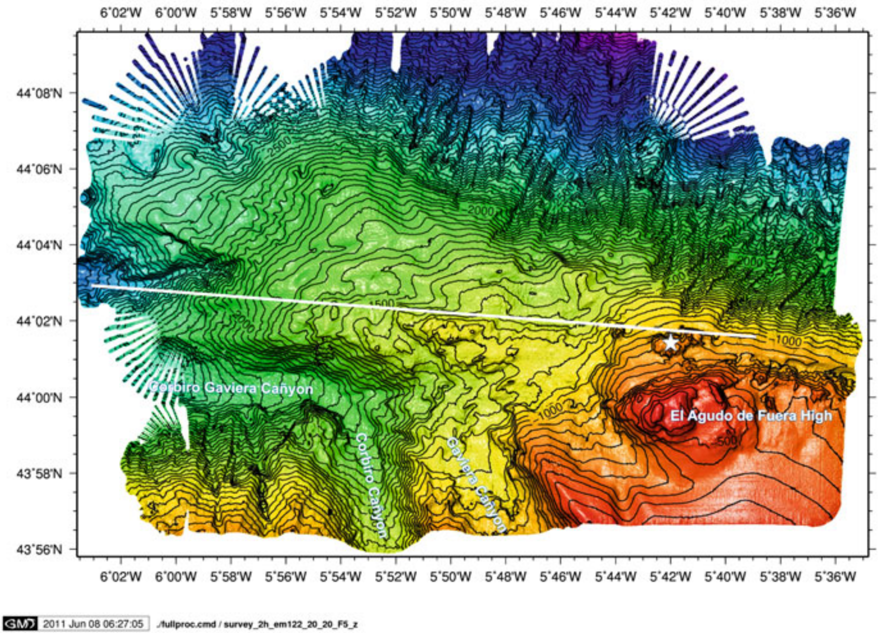

Fig. 11.2 Bathymetry of the "Pagès Escarpment". The location of the lander deployment and the yoyo CTD is indicated by a *white asterix*, the section shown in Fig. 11.4 is indicated as *white line*

pinges out where the Corbiro-Gaviera-Cañon changes its direction to the NW. The dominating structures trend E–W following the general trend of tectonic thrusts. They are intersected and partly displaced by NW–SE structures, which represent the younger dextral transform shear zones (Alvarez-Marrón et al. 1997; Gómez-Ballesteros et al. 2014).

11.2 Methods

Watermass dynamics were studies applying a conductivity, temperature, and depth profiler (CTD) as well as a small scale lander in order to obtain time series data of pressure, temperature, salinity and currents.

11.2.1 CTD Profiler

The CTD profiler used for investigation of the water column during METEOR cruise M84/5 (May–June 2011) was a SEABIRD "SBE 9 plus" underwater unit and a SEABIRD "SBE 11plus V2" deck unit. Additionally, it was equipped with two sensors to measure dissolved oxygen, a chlorophyll-a sensor and a SEABIRD bottle release unit including a rosette water sampler. For the analysis and interpretation of the measurements, the downcast raw data were processed with “SBE Data Processing” software. For the visualization of the data we used “OCEAN DATA VIEW (mp-Version 4.5.7. (https://odv.awi.de)). So-called yoyo (down ..up.. down…) CTD casts were performed (760 mbsl water depth) at 44°01.40′ North and 005°42.17′ West, 1.8 nm North of the “Aguda de Fuero” High (Fig. 11.2). The yo-yo CTD casts were conducted during the time when the lander was at the seafloor. During these casts the research vessel remained at the selected position for 8 h and after 9 h of other station work returned to the same spot for another 7 h where we performed additional consecutive CTD casts. These two time windows allowed for the reconstruction of one complete tidal cycle.

11.2.2 Mini-Lander Operations

The mini-lander system was deployed almost at the same locality at 44°01.414′1 North and 005°42.431′ West at 762 mbsl water depth, to measure the physical characteristics of bottom water dynamics. The deployment was performed fully video-guided by a launching system that is equipped with a Posidonia system for exact positioning on the seafloor and live camera system in order to first visually explore the site and secondly, to select a suitable deployment position. The distance between the yoyo-CTD and the mini-lander system was 4.17 cables. We decided to keep a little distance between the yoyo site and the lander position in order to avoid any interference with the *in situ* current measurements of the lander system.

The lander system was equipped with a Conductivity-Temperature-Depth (CTD) profiler (RBR XR-420CTm) and a high precision pressure sensor with an accuracy of 0.015% of the total water depth. The system also carried an ADCP (Acoustic Doppler Current Profiler) to measure ocean currents above the system. Measurement intervals on both instruments were set to 10 s. To release the system from the seafloor we used a releaser from K.U.M. Umwelt- und Meerestechnik GmbH, Kiel. In comparison to classical lander deployments (e.g. Mienis et al. 2009) the deployed system has the advantage of being a compact design with easy handling and logistics, as well as sensors being closer to the sediment-water interface. ADCP data were visualised by the MATLAB software package, tidal analysis was performed by T_Tide Harmonic Analysis Toolbox (Pawlowicz et al. 2002).

11.3 Results

The water masses within the Bay of Biscay exhibit a coherent structure. The major difference between sites on the Galicia Margin, on the Cantabrian Margin, and on the Armorican Margin is the decrease in the Mediterranean Outflow Water. The salinity minimum of the overlying Eastern North Atlantic Central Water (ENACW) was almost identical in all sites during the METEOR cruise 84/5. We recorded values between 35.60 psu (Cantabrian Margin) and 35.62 psu (Galicia Margin). However, the influence of the MOW was highest in the sites on the Galicia margin, where we observed 36.17 psu, while its effect slightly decreased gradually from 35.83 psu (Pagès Escarpment) to 35.79 psu (St. Nazaire Canyon, Amorican Margin). The core of the LSW within the NADW was only seen in the deep cast on the Galicia Margin and on the Cantabrian margin (Fig. 11.3). Potential temperature profiles were almost identical for all sites, except the data from the Mugia Canyon (Galicia Margin) which showed slightly increased values between 500 and 1200 mbsl well above 11 °C (Fig. 11.3).

The critical seawater density envelope of σ_Θ of 27.5 ± 0.15 kg/m^3 indicative for the occurrence of living *Lophelia pertusa* (Dullo et al. 2008) occurred between 714 and 865 mbsl on the Pagès Escarpment. The existence of this density envelope was verified by van Rooij et al. (2010b) on the Galicia Margin and by De Mol et al. (2011) on the Armorican Margin. In addition, Hebbeln et al. (2014) demonstrated that the amount of change in seawater density with depth is an essential hint for the identification of a habitat of living CWCs. This gradient is calculated by subtracting the measured seawater density in a distinct depth from the equivalent value 10 m above resulting in $\Delta\ \sigma_\Theta$ 10 m. This value is shown in Fig. 11.4a, for the western slope of the Pagès Escarpment. Since seawater density results from both temperature and salinity, we could demonstrate, that the observed density gradient is mainly caused by salinity (Fig. 11.4b).

Single photo shot inspection of the escarpment between 700–900 mbsl revealed coarse sediment with some rocky blocks. Epifauna was present on these hard grounds and several dead and frequently broken colonies of stony corals, mainly *Madrepora occulata* were observed. Even small-scaled CWC frameworks occurred deeper than 800 mbsl, however, very patchy in distribution. Some sponges, sea urchins (*Cidaris*), and coral rubble of *Madrepora occulata* and *Lophelia pertusa* were recognized on muddy bottoms. All sites showed anthropogenic impact by trash and fishing lines. The latter may have caused the damaged CWC colonies and the coral rubble.

11.3.1 Yoyo-CTD Casts

Since we focused on the comparison of different tools measuring bottom water dynamics, the results of the yoyo CTD are displayed in high-resolution for the

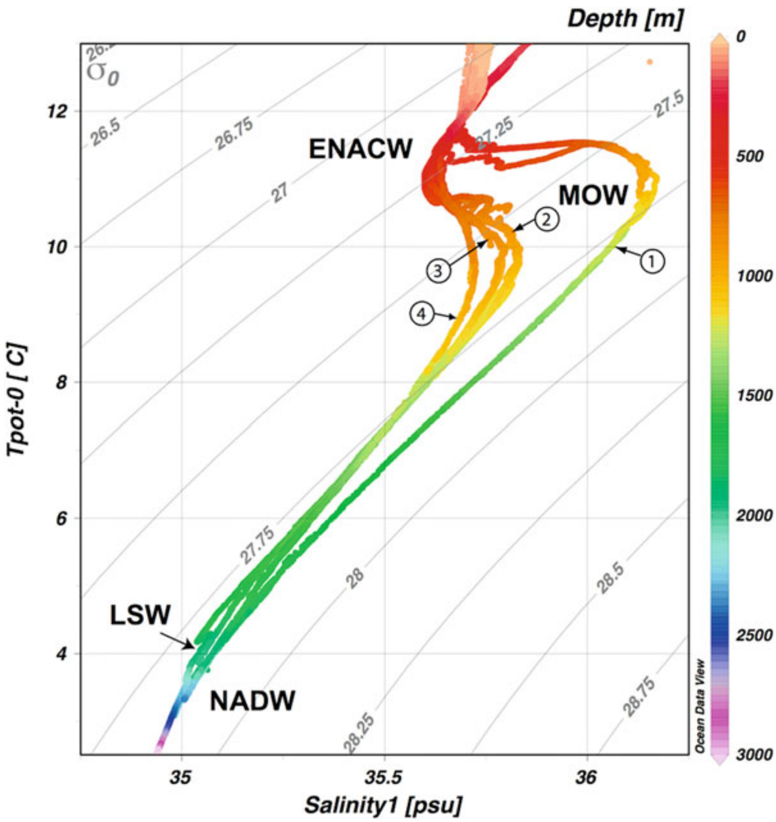

Fig. 11.3 TS-Plot of selected CTD stations in the Bay of Biscay during the METEOR cruise 84/5. *ENACW* Eastern North Atlantic Central Water, *MOW* Mediterranean Outflow Water, *LSW* Labrador Sea Water, *NADW* North Atlantic Deep Water; *1* Muggia Canyon, *2* Pagès Escarpment, *3* Cap Breton, *4* St. Nazaire Canyon. Note the decline in MOW influence from S to N

interval between 740 and 760 mbsl in Fig. 11.5. These time lapse measurements portray a variation which might be related to tidal dynamics. Due to current dynamics and related navigational issues the repeated casts never passed through the water column at the same spot. Even CTD casts performed from a fully DGPS (Differential Global Positioning System) controlled surface vessel still would have to cope with dynamic current regimes in the water masses the CTD is penetrating. This problem is getting larger with increasing water depths. However, plotting the casts as a time series reveals the influence of the tides in this water depth which is in concert to the measured tidal signal from the nearest coastal station in Gijón exhibiting 3 m of vertical variability (Fig. 11.6).

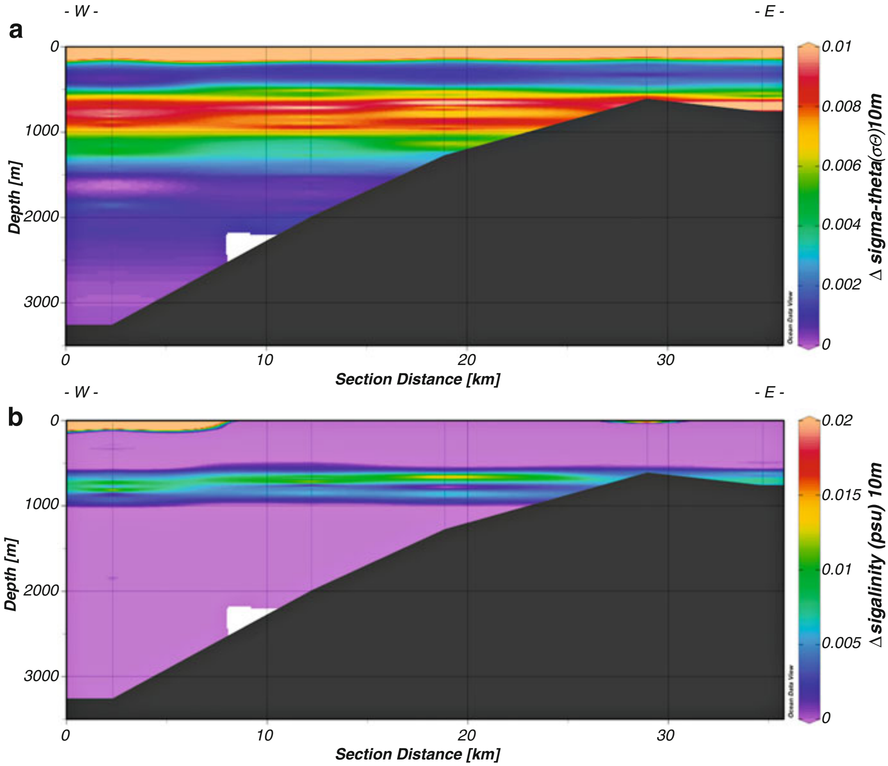

Fig. 11.4 Cross section through water masses from the top of the "Pagès Escarpment" to the west into the basin. (**a**) displays the density gradient sigma theta between intervals of 10 m. (**b**) exhibits the salinity gradient in psu between intervals of 10 m. The gradient is very prominent between 600 and 1000 m, the bathymetric range in which frame building, living cold water corals may occur

11.3.2 Mini Lander Data

Although the scattered data shown in Fig. 11.5 result from tidal dynamics, the overall picture remains heterogeneous (Fig. 11.6) indicating a possible semi-diurnal pattern. The high-resolution data sampling using a lander system and its subsequent processing exhibit a more detailed picture. The pressure data reveal a distinct semi-diurnal tide signal encompassing very little more than 3 m water column variability, which is in good agreement with the record of the tide station Gijón (Fig. 11.6). This is expressed in the varying pressure readings at the deployment site between 775 and 778 mbsl (Fig. 11.7a). The tidal pressure analysis was conducted applying the Matlab software T_Tide. It provides a tidal harmonic analysis including error estimates (Pawlowicz et al. 2002) indicating the influence of the principle lunar semi-diurnal constituent M2 with a dominant signal noise ratio of 9.2e + 05. In addition the lunar diurnal constituent also exhibits a very strong signal noise ratio of 1.3e + 04.

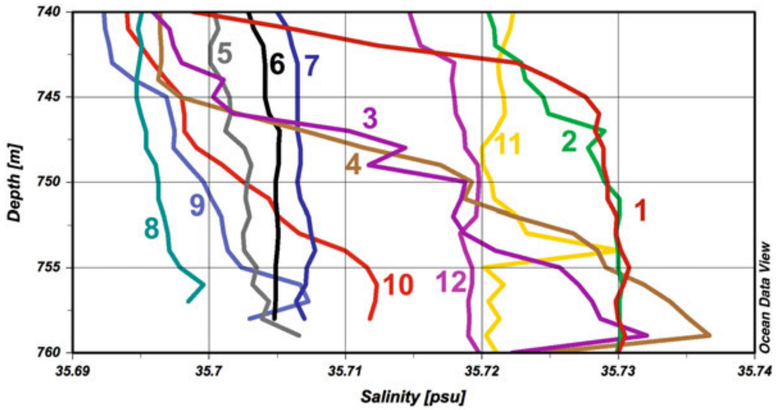

Fig. 11.5 Salinity plots for all yoyo-Casts at the same station between 740 and 760 m water depth. The variability may be real as salinity changes during one tidal cycle, however, the mechanical mixing of the water mass by the instrument may have an influence as well

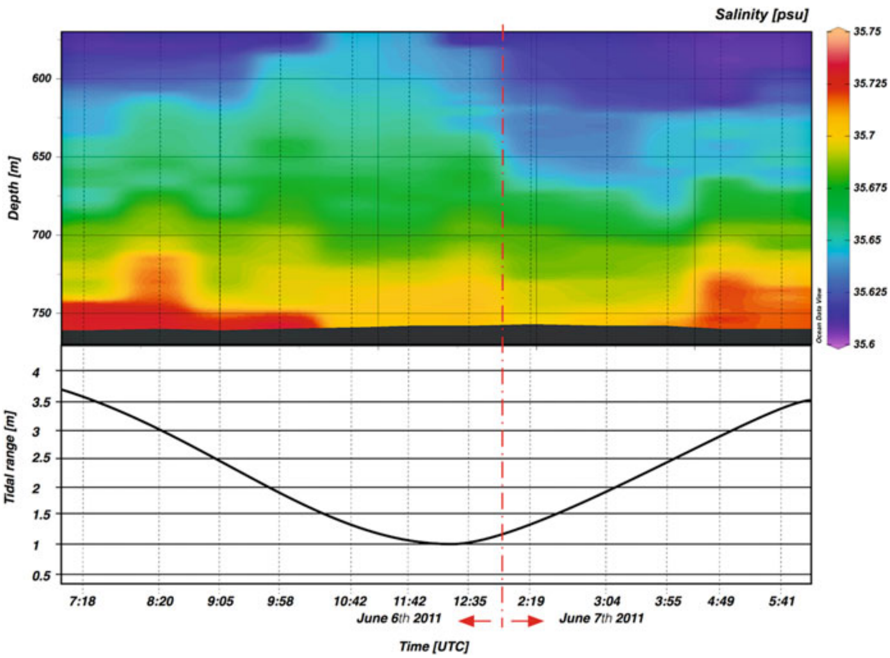

Fig. 11.6 Yoyo-CTD from the Pagès Escarpment combined from two time series between the 6th and the 7th of June 2011. Increased salinities in the bottom water are clearly seen, which seem to correlate with the high tide of the semidiurnal cycle

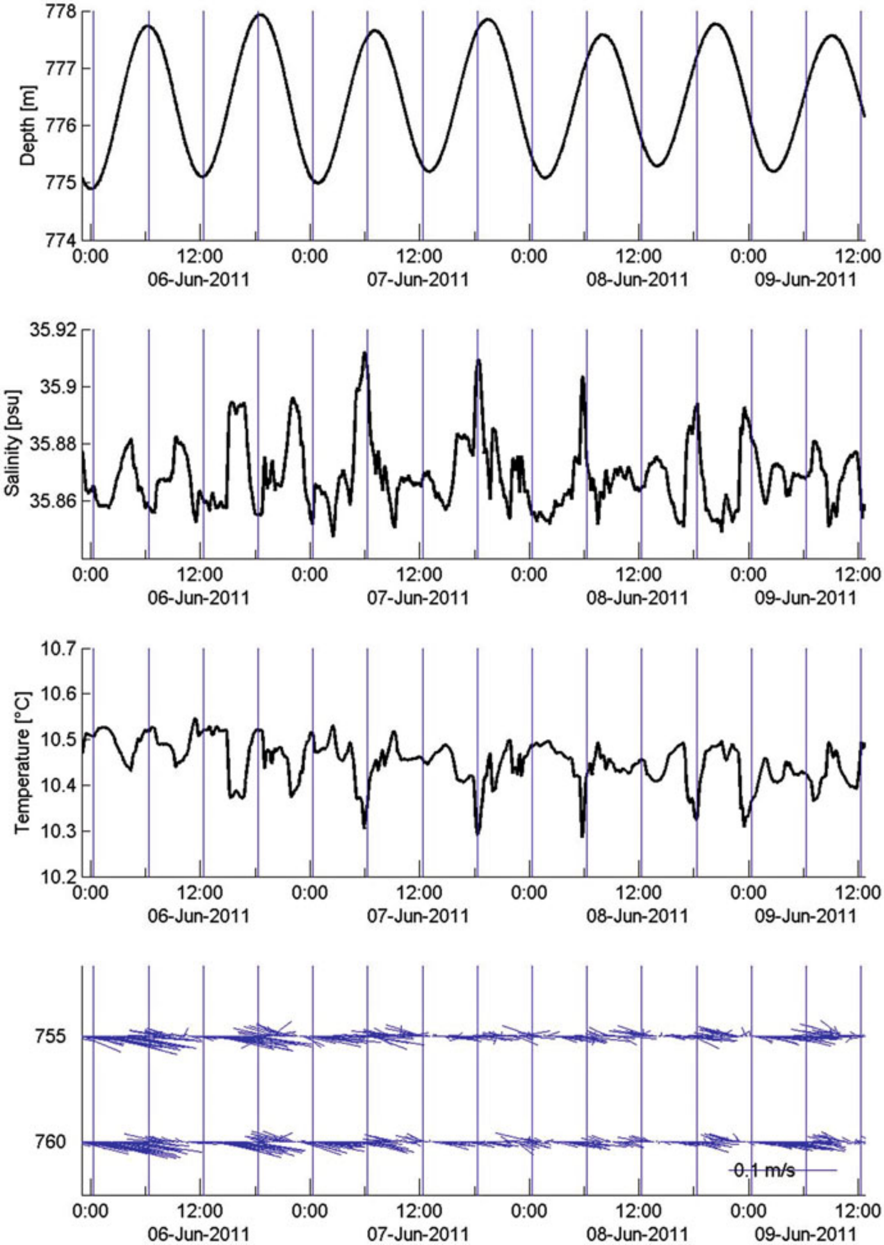

Fig. 11.7 High resolution data of 78 h insitu measurements. (**a**) semidiurnal tide expressed as pressure (water depth). (**b**) salinity, (**c**) temperature, both exhibit a M4 tidal signal. (**d**) bottom water current speed and direction

The 78 h salinity record ranges between 35.83 and 35.93 psu (Fig. 11.7b), which is three times more than the variability recorded in the repeated yoyo CTD casts (Fig. 11.5). The offset in absolute psu values between these two records results from the almost 20 m deeper location of the lander. A similar pattern is displayed in the temperature record varying between 10.55 and 10.28 °C (Fig. 11.7c). Both, salinity and temperature do not exhibit such a clear semi-diurnal pattern (M2) coeval to the tidal signal recorded as pressure variability. Salinity maxima are exactly in parallel to temperature minima, including extreme values and they occur always during the short period between high and low tide and vice versa. However, T_tide frequency analysis indicates a distinct M4 signal which originates from shallow water overtides of principle lunar constituent exhibiting a signal noise ratio of 2.1e + 03 and 2.4e + 03 for salinity and temperature, respectively. While minima in salinity and maxima in temperature plot preferentially during low tide and high tide, warmer temperature and less saline waters prevail for longer time windows than the more pronounced and frequently shorter pulses of cooler and more saline waters.

The tidal current analysis was again performed using T_Tide (Pawlowicz et al. 2002). The ADCP data of 78 h deployment time (Fig. 11.7d, flow direction is given by vector) show a current system that is dominated by currents from the WNW and the ESE. Displayed are the currents at bin 13 (first bin 0-0.88 m, bin size 0.5 m), 6.88 m above the device. Within the 95% confidence level, the principal tidal constituents that influence current dynamics at the deployment site are M2 (principle lunar semidiurnal), M3 (lunar terdiurnal), 2MK5, and M6 (principal lunar shallow water overtides). Most prominent is the M2 (principal lunar semidiurnal constituent) tide with a sound noise ratio of 260 and a direction of 150°, followed by M3 (lunar terdiurnal constituent) with a sound noise ratio of 35 and a direction of 130°. Generally, current speeds do not exceed 0.1 m/s with mean values around 0.03 m/s (Fig. 11.8c). Overall, a complex circulation pattern emerges that is controlled by various frequencies.

11.4 Discussion and Conclusion

Yoyo CTD casts are a tool to document the existence of e.g. a semi-diurnal tides influencing benthic communities in deeper water settings. However the signal is very rough and any other signals than the prominent M2 can not be resolved. The distinct differentiation between the various tidal constituents is only possible with a lander system equipped with high resolution data sampling devices. Moreover, repeated CTD casts may disturb the signal of the water masses due to the weight and the size of the instrument passing through the water and creating small scaled turbulences causing mixing. This is demonstrated in the larger amplitude between minima and maxima in both temperature and salinity recorded in the lander data in contrast to the lower variability recorded by the yoyo-casts. Moreover, single casts

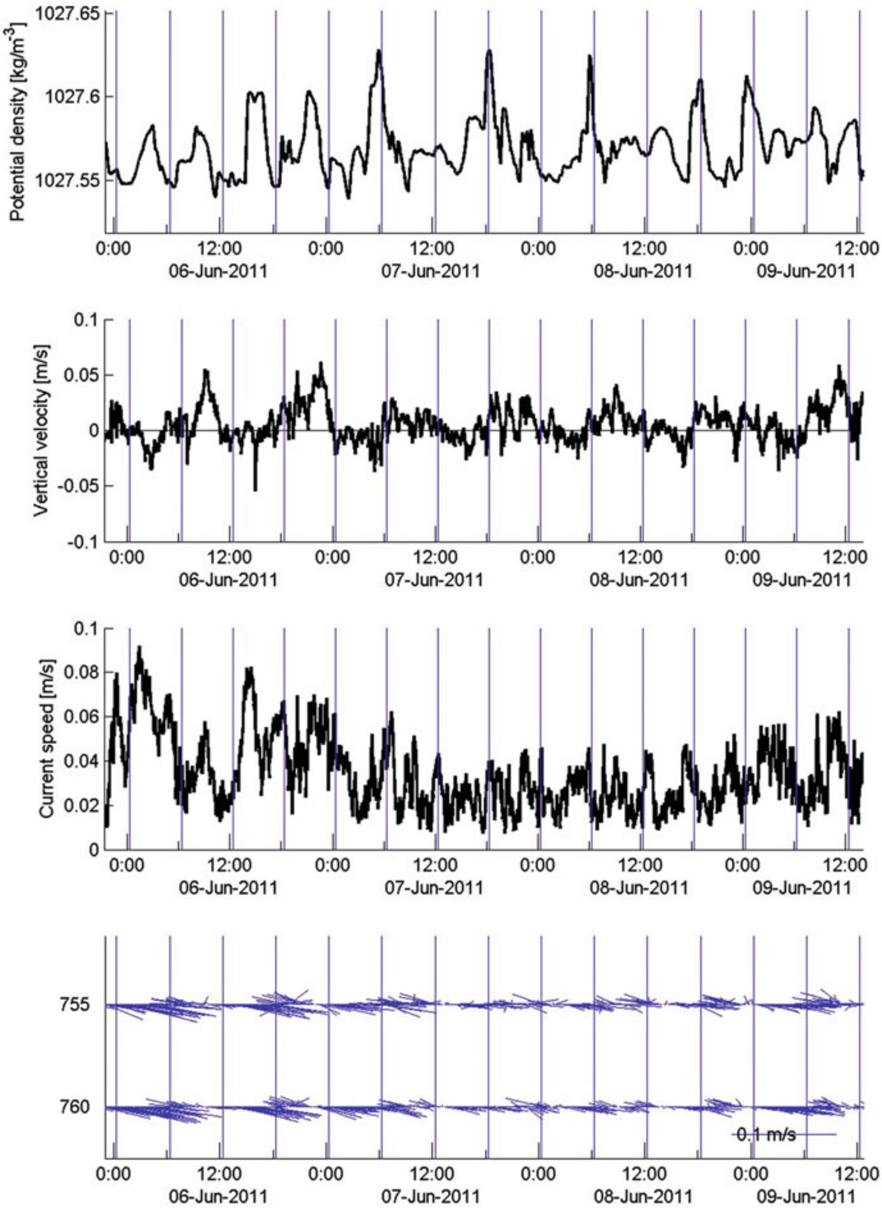

Fig. 11.8 High resolution data of 78 h insitu measurements. (**a**) sea water density variability is identical to salinity variations). (**b**) bottom water vertical velocity, (**c**) bottom water horizontal velocity (**d**) bottom water current speed and direction

reaching the bottom waters only every hour for a short time may miss extreme data values.

The comprehensive data recorded by the lander (Figs. 11.7 and 11.8) reveal different tidal constituents among which the M4 is the most prominent one governing the salinity and temperature variability (Fig. 11.7b, c). So far, this tidal signal has not been described from other bottom water masses around benthic CWC communities. Although both physical parameters vary almost with the same amplitude, the water masses seem to be dominated by the variability in salinity (Fig. 11.7b), since it exactly parallels the variations in sigma-theta (σ_{Θ}) (Fig. 11.8a).

The tides migrate from the open Atlantic in the west towards the east in to the Bay of Biscay. A high tide signal at Ria de Camariñas (43°07.578′ North 009°10.934′ West) occurs 20 min later at Gijón (43° 34.002′ North 005° 41.00 West) and 32 min later at Bayonne (43°31.812 North 001°31.950′ West). This general W-E pattern is slightly deflected on the shelf break and the various escarpments along the Cantabrian Margin towards an ENE direction. This is clearly seen in the current pattern (Figs. 11.7d and 11.8d) with ENE directions during rising tide and WNW directions during falling tide. Although bottom water currents are fairly low in contrast to data presented by Pingree and Le Cann (1989), there are elevated horizontal velocities around high tides and reduced to almost current-less conditions during low tide.

Variations in horizontal current velocities longer than 48 h seen in Fig. 11.8c may be related to a lunar cycle. Salinity and temperature variations are smaller during elevated horizontal velocities, which may be the result of enhanced mixing of water masses. The pronounced parallel signal of saltier and cooler water indicates a clear advection of the deeper, cooler and more saline water, which is ascribed to the upper MOW. The presence of this water mass is also responsible for the steep gradient in salinity between 600 and 1000 mbsl displayed in Fig. 11.4, which does not show up shallower nor deeper. This gradient, which is also a density gradient, is a necessary prerequisite to concentrate nutrients, since their momentum to sink into deeper water depth is reduced in these denser water masses. (Dullo et al. 2008; Flögel et al. 2014; Hebbeln et al. 2014). During times of reduced horizontal velocities the signal of advected MOW is more pronounced due to reduced mixing. Internal waves may result in similar pronounced peaks (Gill 1982; Jeans and Sherwin 2001), however, they would have been recorded in a distinct increase in vertical current velocity, which is not seen in the data.

Living frameworks of CWCs have not been observed, although physical parameters would argue for their occurrence (Dullo et al. 2008). However, we cannot exclude their possible existence entirely, since we had limited ground truthing information of the whole escarpment. The frequent findings of fishing lines and broken skeletons of dead CWCs may indicate their destruction by industrial fishing activities.

In conclusion, only high-resolution lander data highlight the dynamical environmental control of the bottom water mass around benthic communities which have not been known to occur in such settings. Although, repeated CTD casts may provide information about the amplitude in temperature and salinity variability our lander data clearly exhibit that temperature and salinity maxima and minima respectively do not coincide with semi-diurnal tide dynamics only. Therefore, the interpretation of yoyo CTD data with respect to bottom waters and tidal resolution is questionable although previous studies have shown that repeated CTD casts yield valuable information regarding tidal movements if one considers the complete water column. Although the 'hit and run' technique of the yoyo approach is significantly improved by lander data, they are limited since they portray only the dynamics of one spot over time. To better understand the dynamics within a volume of water mass, a minimum of three landers including moorings are necessary to obtain a solid 4D information.

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Part IV
Radioactivity and Radioecology

Chapter 12
Pre and Post-Chernobyl Environmental Radioactivity in Romania: a Review

Constantin Dovlete, Iolanda Osvath, and Sandu Sonoc

Abstract The influence of the Chernobyl accident on environmental radioactivity in Romania (period 1986–1994) was analysed mainly on the basis of gamma spectrometric measurements of environmental samples (atmospheric aerosol and deposition, soil, surface water, Danube and Black Sea water, sediment and biota).

As part of the Romanian environmental radioactivity monitoring programme, environmental samples were systematically collected at the sampling stations of the National Environmental Radioactivity Surveillance Network (NERSN) and analysed for gamma emitting radionuclides at the Environmental Radioactivity Laboratory, Bucharest-Afumati, for gamma spectrometric analyses.

All stations followed a unitary programme and methodology to collect and prepare samples, performing prompt gross beta measurements.

Chernobyl fallout space-time patterns, radionuclide concentration ratios and deposition velocities were determined. The resuspension process was studied and a time dependence model of resuspension factors for ^{137}Cs was proposed. Hot particles were identified in some of the deposition samples. The dynamics of ^{137}Cs in Romanian rivers, Danube and the Black Sea is presented.

Keywords Chernobyl accident • Resuspension • Radioactive aerosols • Sediment • Deposition velocity • Environmental radioactivity • ^{137}Cs • Black Sea radioactivity • Danube radioactivity • Soil radioactivity

C. Dovlete (✉)
Environmental Radioactivity Laboratory, Bucharest-Afumati, Institute of Environmental Research and Engineering, Bucharest-Afumaţi, Romania

Private Consultant, Eze-sur-Mer, France
e-mail: cdovlete@yahoo.fr

I. Osvath
Environmental Radioactivity Laboratory, Bucharest-Afumati, Institute of Environmental Research and Engineering, Bucharest-Afumaţi, Romania

Environment Laboratories, International Atomic Energy Agency, Monaco, Monaco

S. Sonoc
Environmental Radioactivity Laboratory, Bucharest-Afumati, Institute of Environmental Research and Engineering, Bucharest-Afumaţi, Romania

University of Toronto, Toronto, Canada

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12.1 Introduction

In 1962, in response to the need to monitor global fallout resulting from nuclear weapons tests, the National Environmental Radioactivity Surveillance Network (NERSN) was established in Romania in the frame of the existing Hydro-Meteorological network. The network was developed gradually reaching a number of 23 monitoring stations by 1986 and was coordinated scientifically and methodologically by the Environmental Radioactivity Laboratory (ERL) from Bucharest-Afumati. After the Chernobyl accident the number of stations has doubled, reaching 47 fully staffed and operational stations by the end of the 1980s. NERSN stations' locations are of is presented in (Osvath and Dovlete 1992). During the 1990s and afterwards the organisation and the affiliation of the network and its coordinating lab has changed a number of times.

As part of the Romanian environmental radioactivity monitoring programme, environmental samples were systematically collected at the sampling stations of the NERSN. Atmospheric aerosols and wet and dry depositions, soil, vegetation and surface, well and drinking water were sampled regularly. All the stations from NERSN followed the same methodology for the sample collection preparation and measurement programme. Gross beta measurements were performed promptly at each station and the results were centralised by ERL. As of 1977 the samples were forwarded to ERL for radionuclide analyses.

Thus, besides its role to provide methodological development and support for NERSN and to ensure the analytical quality of the network data, ERL carried out research in the area of natural and anthropogenic environmental radioactivity. A short description of the environmental radioactivity studies performed at the ERL before the Chernobyl accident (period 1977–1985) is presented in Sect. 12.2.

In Sect. 12.3, the post-Chernobyl environmental radioactivity in Romania is presented for atmospheric deposition and aerosols, soil, surface waters, Black Sea water, sediment and biota. Research results obtained for the period 1986–1994 are summarised. These include studies of the Chernobyl fallout space-time patterns, radionuclide concentration ratios, and deposition velocities; studies of hot particles identified in some of the deposition samples; the study of the resuspension process and the model developed for the time dependence of resuspension factors for ^{137}Cs; and studies of the radioactivity of surface rivers, including the Danube, the Danube Delta and the Black Sea.

12.2 Pre-Chernobyl Environmental Radioactivity in Romania (1977–1985)

12.2.1 Atmospheric Nuclear Test Signature

After the establishment of NERSN and ERL, the first studies of atmospheric radioactivity were based on gross beta measurements and meteorological parameters (Diaconescu et al. 1966). As of 1977, the environmental samples were also analysed by high resolution gamma-ray spectrometry (Dovlete et al. 1981a; Cuculeanu et al. 1983; Dovlete and Sonoc 1983a; Sonoc and Dovlete 1984a). The influence of nuclear atmospheric tests performed in the northern hemisphere was studied using monthly aerosol and deposition samples and the sediment and water samples from the Danube river.

Shortly after the atmospheric nuclear test of March 1978 fresh fission products were identified in the aerosol and deposition samples: ^{95}Zr, ^{95}Nb, ^{110m}Ag, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{129m}Te, ^{131}I, ^{132}I, ^{132}Te, ^{134}Cs, ^{136}Cs, ^{137}Cs, ^{140}Ba, ^{140}La, ^{141}Ce, ^{144}Ce, ^{154}Eu, ^{155}Eu.

Spatial and temporal distribution of the cosmogenic radionuclide ^{7}Be and fission products (^{137}Cs, ^{106}Ru, ^{125}Sb, ^{144}Ce) for the deposition samples and for the period 1979–1980, for the stations Cluj-Napoca, Iasi, Craiova, Pitesti and Constanta were presented in (Cuculeanu et al. 1983). The role of the injection of radionuclides from the stratosphere and/or increased vertical tropospheric exchanges in spring-summer was demonstrated.

After the atmospheric nuclear test of 16 October 1980 the following radionuclides were identified in the atmosphere (starting with November 1980): ^{95}Zr, ^{95}Nb, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{137}Cs, ^{141}Ce, ^{144}Ce. Using the relative activities of ^{95}Zr and ^{95}Nb, the timing of the nuclear explosion could be estimated accurately (Cuculeanu et al. 1983). The improvement of the simple method of ratio of ^{95}Zr and ^{95}Nb used by us in 1981 were published in (Pomme and Collins 2014).

On an aerosol filter collected on 12 Mars 1981 at the Suceava station (North-Eastern Romania), a hot particle containing ^{95}Zr and ^{95}Nb was identified. The description of this hot particle was presented in (Sonoc and Dovlete 1983a). It could be traced back to the atmospheric thermonuclear test of 16 October 1980.

In order to identify very low concentrations of gamma emitting radionuclides, a composite sample obtained by putting together dry deposition and precipitation samples collected during one year (1981) from all the NERSN stations was used. Besides the above-mentioned radionuclides (like ^{106}Ru, ^{125}Sb, ^{137}Cs, ^{144}Ce) in the studied sample very small amounts of ^{155}Eu (1.9 ± 0.6 Bq/m^2/year) and ^{88}Y (0.2 ± 0.1 Bq/m^2/year) were identified (Dovlete et al. 1981b).

The first identification of ^{155}Eu in nuclear weapons debris was presented in (Aarkrog and Lippert 1967).

Monthly mean of deposition velocities for ^{7}Be, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{137}Cs, ^{141}Ce, ^{144}Ce (period December 1980–December 1981) were published in (Sonoc and Dovlete 1983b)

12.2.2 Natural Radioactivity Studies

The study of the daily variation of radon and thoron daughters in the free atmosphere in connection with meteorological parameters was initiated at ERL in 1977 in order to better understand daily and seasonal variation of natural radioactivity and to improve the response of the network in emergency situations based on gross beta measurements of aerosol filters.

New methodology and formulas for the interpretation and calculation of Radon (^{222}Rn), Thoron (^{220}Rn) and residual (anthropogenic) activities from gross beta measurements of aerosol samples were introduced in daily measurements at the NERSN stations (Sima 1978; Sima et al. 1986).

This methodology, slightly modified, was used for the studies on Radon and Thoron daughters in moffets (Sonoc et al. 1984b) and for the estimation of the diffusion coefficient (K_z) in the atmospheric boundary layer (Dovlete et al. 1986).

More complex meteorological and aerosol radioactivity experiments performed *in situ* on the meteorological platform at ERL, enabled us to confirm that stability class, temperature gradient in the boundary layer and soil moisture were the important parameters influencing the level of natural radioactivity in the lower atmosphere (boundary layer). The influence of snow cover on the concentrations of Radon and Thoron daughters in the atmosphere was the object of the study presented in (Sima et al. 1983).

The methodology based on air filtration for the determination of the gamma emitting daughters of ^{222}Rn and ^{220}Rn from the atmosphere were published and used for ^{214}Pb, ^{214}Bi, ^{212}Pb, ^{212}Bi measurements at ERL (Dovlete 1983). The method for the determination of natural radioactivity on aerosol filters based on alpha spectrometric measurements was presented in (Sonoc and Sima 1992).

12.2.3 Danube Radioactivity

The ERL participated in the Danube International Expedition from Tulcea to Bratislava (24 august–4 October 1978) (Ghedeonov 1983) to study the radioactivity along the river. Water, sediment, aquatic vegetation and fish samples were measured on board of the research vessel using high resolution GeLi detectors and Compton suppression spectrometers. The ^{137}Cs specific activity in Danube water was less than 5 Bq/m^3.

The radioactivity monitoring programme for Danube and Danube delta were continued in the period 1979–1984. Sediment samples from Danube (Drobeta Tr Severin and Sulina) and Razelm Lake for the period 1979–1981 were analysed and the results presented in (Dovlete et al. 1983b; Sonoc et al. 1984a).

Natural radionuclides like ^{40}K, radionuclides from natural radioactive series of U-Ra and Th were identified in sediment samples, together with ^{137}Cs.

In some samples we found small amounts of antropogenic radionuclides like ^{106}Ru,^{144}Ce,^{125}Sb, coming from nuclear atmospheric tests and the cosmogenic radionuclide ^{7}Be (Dovlete et al. 1981a).

12.2.4 Black Sea Radioactivity

The monitoring of marine radioactivity in Romanian waters has been performed jointly by the Romanian Marine Research Institute (RMRI) and the ERL. The first measurements date back to 1981, but the monitoring programme became systematic since 1984–1985 (Dovlete and Bologa 1986).

As in the case of aerosol and deposition samples from the same period, fission products were reported for water samples, seaweed and different species of fish collected from the Black Sea.

The main pathway for ^{137}Cs input to the Black Sea water was direct atmospheric fallout from atmospheric nuclear tests.

Before the Chernobyl accident, measurements of near-shore Black Sea surface water, indicated for ^{137} Cs a specific activity of 10.4 $\pm$ 2.9 Bq/m^{3} and ^{137}Cs in the bottom sediments at Constanta, Agigea, Eforie Sud and Jupiter was in the range 1.7–5.2 Bq/kg dry.

Among the species of marine biota from the Romanian sector of the Black Sea, the radioactivity of which has been systematically measured since 1984, Bryopsis Plumosa green alga stands out due to the relatively high values of ^{226}Ra and ^{228}Ra and their daughters. Based on time dependence of theoretical and experimental ratios of the radionuclides from natural series we have established that this species of alga concentrates radium isotopes from the environment (Dovlete and Osvath 1992). Its concentration factor for Ra is 10^{5}, 3 orders of magnitude higher than the generic values given in (IAEA 2004).

12.3 Post Chernobyl Environmental Radioactivity in Romania

The sampling stations, relatively uniformly distributed on the territory, included two high altitude locations in the Carpathian Mountains (Toaca 1907 m and Babele 2238 m). Aerosol samples from high altitude chemical pollution monitoring stations Paring and Fundata were also used for ^{131}I and ^{137}Cs measurements in the first days of May 1986.

12.3.1 *Resuspension and Deposition Dynamics of ^{137}Cs on Romanian Territory*

The Chernobyl NPP accident spread a huge amount of fission products over Europe (Egorov et al. 2010).

The simulation of the movement of the radioactive cloud starting on April 26 until May 10 is presented on http://www.irsn.fr/FR/popup/Pages/tchernobyl_video_nuage.aspx. NERSN detected the increase of artificial radioactivity in aerosol and deposition samples as of the late hours of April 30, 1986 (Sonoc et al. 1989b). ^{131}I was first measured in aerosol samples collected May 1st, 1986 (103 Bq/m^3) at Paring station and at Toaca Station (63 Bq/m^3).

The highest aerosol and deposition concentrations were registered at the mountain NERSN stations Toaca and Babele. Also locations like Tg.Mures, Cluj-Napoca, Drobeta Tr.Severin situated on the axis NE-SW and Tulcea, registered high values (Osvath and Dovlete 1992). The lesser levels were registered in the NW part of Romania (Oradea and Satu-Mare).

The lowest and highest annual deposition rates for Romanian stations are presented in Fig. 12.1.

Measurements of soil samples confirmed an inhomogeneous deposition pattern of the Chernobyl fallout. Once deposited on the ground the radionuclides undergo a series of biogeochemical processes and may constitute a source for atmospheric radioactivity through resuspension over long periods of time (Raes et al. 1991). The resuspension of radionuclides from contaminated soil into the atmosphere is one of the key processes that should be considered in the estimation of inhalation doses to humans, therefore following the Chernobyl accident many studies focused on the presence and the decline of ^{137}Cs in the atmosphere as a consequence of resuspension process. Research done to better understand the resuspension process and predict the time dependence of the resuspension was published by (Nicholson 1988; Vintersved et al. 1991; Garger et al. 1998; Dovlete and Osvath 1993; Garger et al. 1997; Hatano and Hatano 1997, 2003) and reviewed by (Maxwell and Anspaugh 2011; Garger et al. 2012).

Garger et al. (1998) proposed a temporal dependence of the resuspension factor, K(t), in agreement with experimental data from the Chernobyl region,

$$K(t) = K(0)\exp(-0.002\,t)$$

where t is the time expressed in days.

The majority of the expressions proposed for resuspension as a function of time contained the exponential decrease or/and power law decrease for medium and long term. Different models are analysed in the literature (Maxwell and Anspaugh 2011). The data and model in (Dovlete and Osvath 1993) show that for the first decade after deposition the exponential dependence of the resuspension factor is a good approximation.

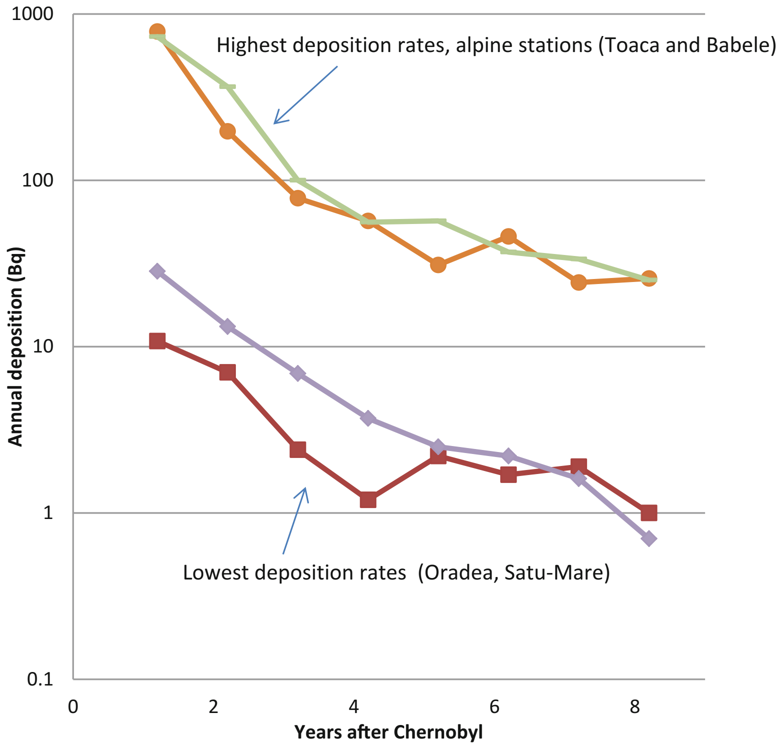

Fig. 12.1 ^{137}Cs annual deposition rates (1987–1994)

Many studies on resuspension are based on experimental data from the Chernobyl region. Garger et al. (1997), using the data from Pripyat and Baryshevka, found an empirical formula for the resuspension factor, which decreases following a power law in function of time:

$$K(t) \sim t^{-1.4}$$

Also based on Chernobyl region time series of data, (Hatano and Hatano 1997) propose a similar power law dependence:

$$K(t) \sim t^{-1.33}$$

Decades after Chernobyl, the resuspension of radionuclides continues to be studied (Viswanathan et al. 2000; Maxwell and Anspaugh 2011; Garger et al. 2012) in order to achieve a better agreement with extended experimental data series and to better understand the resuspension process in the long term.

Garger et al. proposed in 2012 a modified exponential formula based on a longer data time series than his first research from 1990s.

The aerosol and/or deposition dynamics after the Chernobyl accident was presented in the studies (Hötzl et al. 1989; Rosner et al. 1990; Ioannidou and Papastefanou 2006); and statistical analysis of fluctuations of concentrations were presented in (Hatano and Hatano 1997; Viswanathan et al. 2000). The results of the studies show that atmospheric resuspension processes are tightly coupled to the surrounding ecosystems.

Based on annual deposition samples collected in Romania (1987–1994) the following time dependence was found:

$$K(t) \sim t^{-1.47}$$

For t >10 years the power law dependence appears to be a better choice than the exponential one. On the other hand, fitting the time series in the case of power law can be less accurate.

Commonly used methods for analysing power-law data in some commercial packages, such as least-squares fitting, can produce inaccurate estimates of parameters for power-law distributions as explained in (Clauset et al. 2009).

The study presented in (Dovlete and Osvath 1993) is based on monthly data for ^{137}Cs, from 16 selected stations of NERSN having very different climatological profiles, for which the dynamics of resuspension after the Chernobyl accident was analysed for the period 1986–1991. The results show also that, after the initial direct deposition of Chernobyl fallout, the monthly aerosol concentrations of ^{137}Cs and its deposition rate are site dependent. But, over the same period, the time dependence of the deposition rate, as a first approximation, is the same for all sites studied.

Using a simple compartmental model and monthly ^{137}Cs data, it was possible to study the processes with a higher temporal resolution. The time dependence of the resuspension factor K(t), with t expressed in days, of the rate (k) at which the ^{137}Cs from soil becomes unavailable for resuspension is:

$$K(t) \sim \exp(-k\,t)$$

It was found that the rate k, as a first approximation, is not dependent of the site and that the dependence of the resuspension factor K(t), for t sufficiently large, can be expressed as follows:

$$K(t) \sim \exp(-(0.00153 \pm 0.0003)\,t)$$

This corresponds to an effective half-life of 1.26 years.

A very similar decrease over time for ^{137}Cs annual deposition rates, from 1987 to 1992, was reported for Greece (Ioannidou and Papastefanou 2006), resulting in a removal half-life of 1.33 years, or $k = 0.00144$ days^{-1}.

For aerosol concentrations in the Chernobyl region, an exponential decrease with $k = 0.00147$ days^{-1} was reported in (Viswanathan et al. 2000) for the period 1986–1991.

It can be concluded that after the Chernobyl accident the local resuspension is observed to have the main influence on both airborne and ground deposition activities at any given station from the NERSN and other European countries like Ukraine, Germany, Greece etc. The results obtained in different countries show a remarkably similar time dependence for different distances from Chernobyl, soil characteristics, climatological conditions etc. These results confirm that the atmospheric radionuclide resuspension processes are tightly coupled to the surrounding ecosystems and to large timescale weather patterns (Viswanathan et al. 2000).

In further studies the initial experimental dataset for time series of deposition was increased from 16 to 23 stations across Romania, for new analyses of the deposition dynamics of ^{137}Cs, D(t). Using 23 selected stations and a longer period of time (1987–1994), based this time on annually cumulated deposition samples, a value which is closer to the previous one:

$$D(t) \sim \exp(-(0.0017 \pm 0.0007)\, t)$$

This value corresponds to 1.08 years effective half live.

The above was documented mainly for ^{137}Cs, but the same tendency was observed also for ^{125}Sb and ^{106}Ru, based on annual cumulated deposition samples from five NERSN station for the period 1987–1991.

The decline in ^{137}Cs activity concentrations in the environment is found to be remarkably consistent over the period (1986–1992) by (Smith et al. 1999). They linked diffusion of radiocesium into the illite lattice to changes in its long-term environmental mobility and bioavailability. They found a long term exponential decrease with a mean value $k = 0.00128 \pm 0.0005$ day^{-1}.

It is important to note that the study of the post Chernobyl deposition in Romania is based on gamma spectrometric measurements performed at the same laboratory (Environmental Radioactivity Laboratory Bucharest-Afumati) on the samples from different sampling stations of the network (NERSN) having the same methodology for sampling (IMH-CNA 1976; Suschny 1969). The samples were prepared daily at the NERSN, measured beta global immediately and after 5 days, and cumulated monthly for gamma spectrometric measurements. The ERL participated regularly in annual intercomparison runs organised by IAEA Marine Environment Laboratory and IAEA Seibersdorf Laboratories between 1986 and 1993.

12.3.2 Deposition Velocities

Mean deposition velocities (cm·s^{-1}) estimated from atmospheric aerosol and deposition measurements in Romania (May 1986 at 21 stations from NERSN) and their standard deviations, compared to data reported for Neuherberg from (Rosner et al. 1990) are presented in Table 12.1.

Table 12.1 Comparison of deposition velocities (cm s^{-1})

Radionuclide	Romanian stations	Neuherberg
^{137}Cs	0.22 ± 0.16	0.27
^{134}Cs	0.18 ± 0.13	
^{136}Cs	0.19 ± 0.14	
^{141}Ce	1.6 ± 1.1	
^{144}Ce	1.6 ± 1.2	
^{95}Zr	2.8 ± 2.6	
^{110m}Ag	0.33 ± 0.07	0.37
^{131}I	0.35 ± 0.37	0.13
^{132}Te	0.16 ± 0.23	0.08
^{129m}Te	0.21 ± 0.19	
^{140}Ba	0.34 ± 0.33	0.15
^{103}Ru	0.33 ± 0.23	0.08
^{106}Ru	0.29 ± 0.21	0.1
^{125}Sb	0.35 ± 0.18	0.07

12.3.3 Soil Radioactivity After Chernobyl

Top soil (0–5 cm) was sampled from each NERSN station and analysed annually for gamma-ray emitting radionuclides in ERL. Natural radionuclides like ^{40}K,^{226}Ra, ^{234}Th, ^{214}Pb,^{214}Bi,^{228}Ac,^{212}Pb,^{210}Pb,^{212}Bi,^{208}Tl,^{235}U, cosmogenic radionuclide ^{7}Be and artificial radionuclides, mainly ^{137}Cs, were determined by direct gamma-ray spectrometry by counting around 150 g on a HPGe detector. More than 300 soil samples from NERSN were measured and the range of data obtained for ^{137}Cs between 1986 and 1992 is from 2 Bq/kg to 2133 Bq/kg (see Fig. 12.2).

Apart from regular measurements of the soil samples from NERSN stations, some hotspots were identified based on measurements of samples collected for various other research, for example Semenic Mountains in the SW part of Romania (1816 Bq/kg dry ^{137}Cs) and Axente Sever (Sibiu county) with 660 Bq/kg dry ^{137}Cs. The highest level measured by ERL was 4 kBq/kg dry ^{137}Cs (or equivalent of 48.5 kBq/m^2 of ^{137}Cs), in soil sampled in 1993 at the Toaca mountain station (1907 m altitude) (see Table 12.2).

Other hotspots for Romanian soils, having more than 50 kBq/m^2, were reported in the extensive study on migration of ^{137}Cs in the Romanian soils (Toro and Galeriu 1991a, b), mainly for the SW part of Romania (Novaci, Sadova Noua etc).

Compared with the time dependence of deposition rates (which depend on the rate of unavailability of Caesium for resuspension), top soil concentrations decrease more slowly with time by migration processes or washout. Based on available measurements a total of about 1.7–2.7 PBq was estimated for the ^{137}Cs deposited on Romania's territory. This figure could be improved by increasing the density of the sampling points.

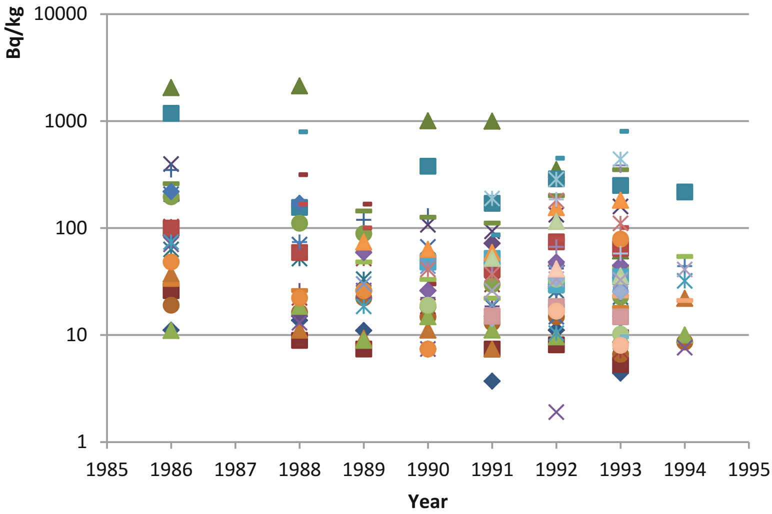

Fig. 12.2 Activity of ^{137}Cs soil in Romania (Bq/kg dry)

Table 12.2 Anthropogenic radionuclides in top soil (0–5 cm)

Radionuclide	Activity (kBq/m^2)
^{137}Cs	48.5
^{134}Cs	2.46
^{125}Sb	0.6
^{154}Eu	0.13

12.3.4 Hot Particles

Before the Chernobyl accident, hot particles found in the atmosphere were due to atmospheric nuclear tests (Sandals et al. 1993; Sonoc and Dovlete 1983a, b).

After the Chernobyl accident (Devell 1987) was the first to report the existence of hot particles due to this accident. Many other studies were dedicated to this subject (Balashazy et al. 1987; Osuch et al. 1989).

Two types of hot particles were reported:

1. Type "A" (almost exclusively containing ^{103}Ru, ^{106}Ru). These contain no Uranium or only traces of it.
2. Type "B" are considered to be fragments of fuel (uranium oxide) and contain fission products and transuranic elements (^{239}Np, ^{141}Ce, ^{144}Ce, ^{103}Ru, ^{106}Ru, ^{95}Zr, ^{95}Nb, ^{140}La, ^{99}Mo, ^{131}I, ^{132}Te, ^{134}Cs, ^{137}Cs, ^{242}Cm, ^{244}Cm, ^{238}Pu).

(Dovlete 1990a; Pollanen et al. 1997) reported the presence of ^{154}Eu and ^{155}Eu, in this type of hot particle.

Seven hot particles were reported in deposition samples from Iasi, Buzau, Tulcea and Craiova stations (Dovlete 1990a) in the period 1988–1990. The radionuclide composition of hot particles coming from Romania's territory and the radionuclide concentrations indicate that they belong to type "B" hot particles. The hot particles identified in Romania by (Dovlete 1990a) were reported in the study of (Pollanen et al. 1997) regarding the hot particles distributions across Europe.

Measurements of resuspended aerosols in the Chernobyl 30 km exclusion zone have shown coarse fuel hot particles in the activity range 1–12 Bq ^{137}Cs per particle.

Our measurements show a maximum of 6.5 Bq/hot particle for ^{137}Cs, 110 Bq/hot particle for ^{144}Ce, 14.7 Bq/hot particle for ^{106}Ru and 3.3 Bq/hot particle for ^{125}Sb.

12.3.5 Post-Chernobyl Radioactivity of Danube and Surface Waters

Water samples were collected at the NERSN stations, from the main rivers, main lakes, Danube and Danube Delta. The Danube river water and sediment radioactivity was investigated in 1978 using high resolution gamma ray spectrometry by an international expedition on-board a research vessel surveying the Danube from Tulcea to Bratislava (Ghedeonov 1983).

Gross beta measurement and gamma spectrometric analysis were performed for water samples from rivers from the following stations: Satu Mare, Oradea, Tg. Mures, Cluj-Napoca, Timisoara, DrobetaTr.Severin, Craiova, Pitesti, Tulcea, Galati, Buzau, Suceava, Bacau, Bechet, Sf.Gheorghe, Cernavoda, Baia-Mare, Zimnicea, Ramnicu Valcea, Piatra Neamt, Arad, Focsani, Botosani, Giurgiu, Tg. Jiu. ^{137}Cs annual mean spatially averaged specific activities of river water collected at all the above-mentioned stations for the period 1987–1993, are presented in Fig. 12.3.

Assuming a simple exponential dependence, the effective half-life for ^{137}Cs is 2.4 years. Fitting the mean specific activity (C(t)) of ^{137}Cs in water with a simple power law, C(t), we obtain:

$$C(t) \sim t^{-0.91}$$

If we select only the Danube river data series and simple exponential dependence, the effective half-life for ^{137}Cs is 2.1 years and for the power law fit we obtain:

$$C(t) \sim t^{-0.89}$$

Besides the water samples, sediment samples were taken along the Danube river and in the Danube Delta twice yearly (June-July and October-December). Besides ^{40}K and gamma emitters from natural radioactivity series, artificial radionuclides of Chernobyl origin such as ^{137}Cs, ^{134}Cs, ^{106}Ru, ^{144}Ce, ^{125}Sb were identified (Sonoc et al. 1989a). The specific activity of ^{137}Cs in the Danube

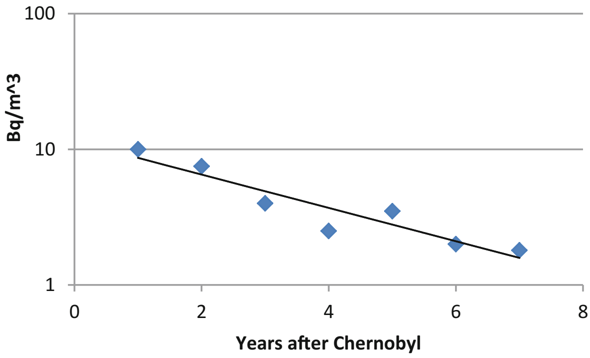

Fig. 12.3 Specific ^{137}Cs activity in Romanian rivers

sediment ranged from 3 to 2000 Bq/kg, the maximum being measured in the fine sediment from the lake upstream the Iron Gate Dam (Portile de Fier) (Oncescu 1994).

12.3.6 *Black Sea Radioactivity Monitoring*

The Black Sea has been the second most contaminated marine basin, after the Baltic Sea, contaminated with artificial radioactivity following the Chernobyl accident (IAEA 1995). The pre-Chernobyl Black Sea ^{137}Cs inventory was estimated at 1.4 $\pm$ 0.3 PBq (Egorov et al. 2010). Chernobyl-origin radionuclides reached the Black Sea mainly through direct deposition on the sea surface and through inputs to the NW shelf area by major rivers Dnieper and Danube.

ERL measurements before the Chernobyl accident, in the near-shore Black Sea surface water, indicate for ^{137}Cs an average specific activity of 10.4 $\pm$ 2.9 Bq/m^3. It is considered that 1.7–2.4 PBq of ^{137}Cs, which corresponded to nearly 4% of the total ^{137}Cs release into the environment following the Chernobyl accident was deposited in the form of atmospheric fallout on the Black Sea surface (Egorov et al. 2010). The estimated ^{137}Cs input of 26 TBq from the Danube and the Dnieper Rivers over the period 1986–2000 was negligible in comparison with the direct contribution of atmospheric fallout.

Coastal surface seawater monitoring data (Fig. 12.4) obtained in the period between 1984 and 1994, was used to describe the dynamics of ^{137}Cs in the North-Western part of the Black Sea basin. Using data series of ^{137}Cs in surface waters from 1987 to 1994 a value of 7.5 years was obtained for the environmental half-life of ^{137}Cs (unpublished data, Dovlete and Osvath).

This value is comparable with the average environmental half-life of 5–7 years proposed in (Egorov et al. 2010) for a longer data series of ^{137}Cs, more precisely for the period of time 1987–2004.

Maxima in the range of 500 Bq/kg d.w. ^{137}Cs were reported for bottom sediment offshore the Danube mouths in September 1986 (Osvath et al. 1988).

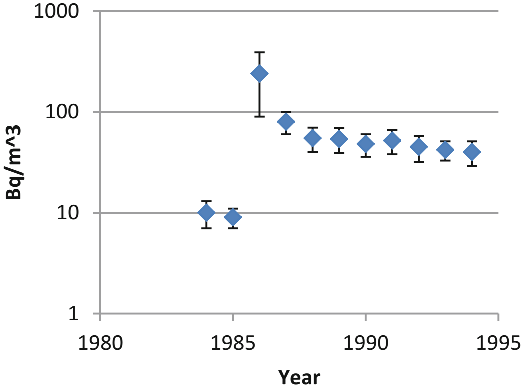

Fig. 12.4 ^{137}**Cs** in coastal N-W Black Sea surface water

In 1986 a more detailed study of the marine bottom water and sediment off the Danube mouths was initiated. Submerged marine sediment and sea water samples, up to 20 m depth were collected off the pre-danubian coast, on Sulina, Sf.Gheorghe, Portita and Buhaz profiles, in 1986, and Sulina and Sf.Gheorghe profiles, in 1987, and the results were reported in (Osvath et al. 1988).

Environmental sediment/water distribution coefficients and biota concentration factors have been calculated for the caesium isotopes. Concentration factors of ^{137}Cs in Black Sea biota are presented in (Osvath et al. 1990a, b) for 14 species of fish, molluscs and seaweed.

In order to determine the extent of removal of ^{7}Be and ^{234}Th from the water column to the seabed a special sampling procedure was developed. Superficial sediment layers were collected by a diver from Eforie Sud station (24 m water depth) in 1994. A custom-designed device with 38 cm^2 surface area, collecting top sediment was used. Four identical samples were collected within an area of about 400 m^2. The gamma spectrometric measurements of the samples were performed immediately (4 days after sampling). Concentrations of ^{7}Be and ^{234}Th were determined with less than 5% uncertainty in each sample. Based on a simple steady state model and a constant deposition rate, the ^{7}Be equilibrium inventory in water can be estimated, if the ^{7}Be mean monthly deposition rate is known.

Using deposition rates measured in samples collected nearshore on land at the nearby NERSN Constanta monitoring station and a simple steady state model, a ^{7}Be equilibrium inventory of 90 Bq/m^2 was estimated. Based on measured concentrations in superficial sediments a ^{7}Be mean equilibrium inventory in superficial sediment of 104 $\pm$ 11 Bq/m^2, which agrees very well with the value estimated from deposition. Furthermore, a mean residence time of ^{7}Be in the Black Sea coastal waters was estimated to be less than 38 days.

The estimated ^{234}Th flux from the sea water column to the sediment based on measurements of unsupported ^{234}Th in top sediments was 4.3 Bq/m^2/day.

12.4 Conclusions

Monitoring by the NERSN and Environmental Radioactivity Laboratory (ERL) - Bucharest, Afumati of the environmental radioactivity of Romanian territory was presented for the period 1977–1994. Monitoring radioactivity in the environment is of utmost importance in the emergency situations. NERSN was created to measure, to alert and to inform the competent authorities regarding an eventual radioactive pollution. This Romanian network contributed to obtain important information regarding the dynamics of levels of gamma emitting radionuclides in environmental samples such as aerosol, deposition, soil, surface water and Black Sea water, following the contamination of the environment by nuclear tests and by the Chernobyl accident. Data time series obtained as results of monitoring programmes can serve sometimes to extract information or parameters useful for environmental modelling and dose assessment. The quality of primary data is important for all these applications.

The results obtained for the time dependence of the resuspension factor, based on a large dataset resulting from measurements done in ERL on samples collected by the NERSN Romanian national network, were compared with those from other European countries. They show, in a first approximation, are remarcably uniform, independent of the distance from Chernobyl, soil characteristics, climatological conditions etc.

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Chapter 13
Radionuclides Assessment for the Romanian Black Sea Shelf

Gianina Chiroşca, Maria-Emanuela Mihailov, Cornel Liviu Ţugulan, and Alecsandru Vladimir Chiroşca

Abstract Radionuclides within the environment are not always a point of concern, in some cases they can be used to trace and identify incidents even long after they occurred. This reports performs a high resolution spectrometry analyses for several samples taken from the Black Sea containing seawater and sediments. The results give us the opportunity to use traceable radionuclides like ^{137}Cs or ^{40}K as tracers for the human activities within the western Black Sea area. Although the presence of such radioisotopes can be related to the Chernobyl event, results can be differentiated using other radioisotopes associated to the same event but having a specific timespan since them as the case for ^{241}Am. Using such tracers one can isolate events from 30 years ago from the more recent ones.

Keywords Marine radioactive • Black Sea • Seawater • Sediment samples • Gamma spectrometry • Radionuclide • Spectrometer calibration coefficient correction

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G. Chiroşca
Doctoral School in Physics, Faculty of Physics, University of Bucharest, 406 Atomistilor Str, 077125 Magurele (Ilfov), Romania
e-mail: gianinachirosca@gmail.com

M.-E. Mihailov (✉)
National Institute for Marine Research and Development "Grigore Antipa" Constanta – Romania, Mamaia Blv No. 300, Constanta RO-900591, Romania
e-mail: emihailov@alpha.rmri.ro

C.L. Ţugulan
Radioactive Waste Management Department Laboratory, Horia Hulubei Institute for Physics and Nuclear Engineering, P.O.B. MG-6, 30 Reactorului str., RO-077125 Magurele Bucharest, Romania
e-mail: lctugulan@yahoo.com

A.V. Chiroşca
Department of Structure of Matter, Earth and Atmospheric Physics and Astrophysics, University of Bucharest, 405, Atomistilor str., 077125 Magurele (Ilfov), Romania
e-mail: alecsadru.chirosca@ccpr.ro

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13.1 Introduction

The Black Sea shelf region is important to our regional ecosystem due the fact that here many of the waters coming from all surrounding countries contribute the composition. A special place in this topic is the Danube as a European River it comes from as far as Germany and can collect in its path many effluents from several installations. This report presents our efforts to perform radionuclide evaluation for both water and sediment samples. As we can expect, to this inventory can contribute the Cernavoda Nuclear Power Plant but we can also point out the effects for the Chernobyl event that releases a large amount of radionuclides within the atmosphere. While previous studies for the Black Sea sector analyze the whole basin, this work focuses on the Romanian sector 30 years after Chernobyl incident (Bologa and Patrascu 1996).

Within this report we employed only high resolution gamma spectrometry for our samples and the report is following the natural radionuclide series and ^{137}Cs as a marker for human activity.

Samples were taken from the locations presented in Fig. 13.1 under the approximate same timing and conditions ensuring that their population is consistent with each other.

Also, a radionuclide occurring mainly through nuclear activities, the ^{241}Am shows a great potential for being used as a tracer for a better assessment of the Chernobyl nuclear incident.

13.2 Material and Methods

Water and sediment samples were collected on-board R/V "Steaua de Mare I" (National Institute for Marine Research and Development „Grigore Antipa" – NIMRD) during 30 March–04 April 2016 on standard monitoring oceanographic stations. Seawater at 2 m above the maximum depth of each station was collected using bathometers and Van Veen grab for sediments samples. The sea currents were measured using the ADCP (Acoustic Doppler Current Profiler) during winter 2010 (February) by the NIMRD. The primary production concentration images and data are retrieved on-line from the dvs.net.ru (Remote Sensing Department Federal State Budget Scientific Institution "Marine Hydrophysical Institute of RAS") for the period of the in-situ water and samples data (images are cropped for the analyzed period).

The method used for sediments samples was adapted on-board taking into consideration the weather and sampling conditions. The sediments samples were collected from the middle of the samples grab using a specialized palette (Figs. 13.2 and 13.3).

All samples are taken from the shoreline (considered 0 m water depth) to off-shore waters (maximum depth of 100 m) and are subject to shoreline specific

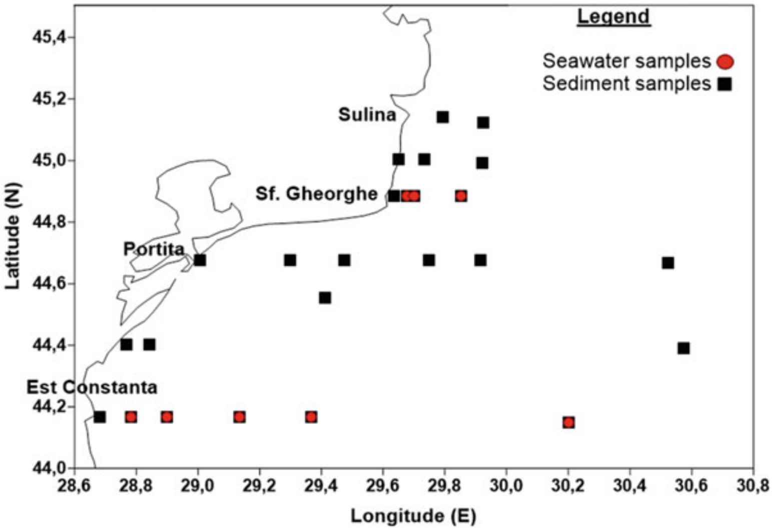

Fig. 13.1 Sample location map with the Romanian Black Sea shoreline

Fig. 13.2 Sediment collection procedure and Van Veen grab sampling instrument on-board R/V "Steaua de Mare I"

models, meaning that after this distance all graphs and interpolations suffer from a dilution in consistency.

In order to avoid sample contamination, each sample was taken using only clean materials and sample cases and ensure that the samples are not touched or any way tampered with for the time in the open. For this, soil and water samples were taken

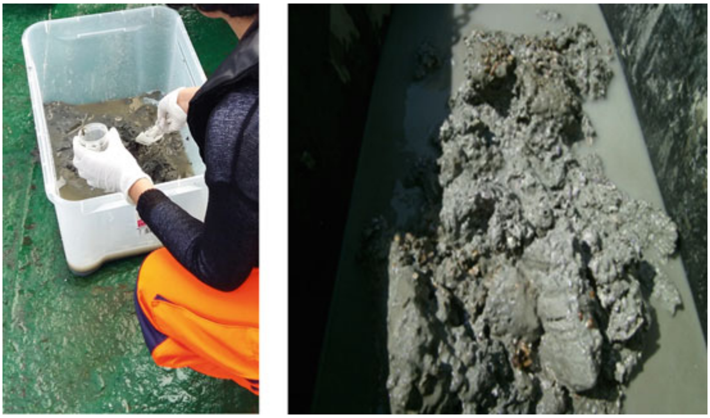

Fig. 13.3 Seiment collection procedure and samples on-board R/V "Steaua de Mare I"

out from the water were isolated in a timespan under 10 s from the moment they are exposed to the air.

The sediment samples, dried at constant mass of about 150 g, were placed in cylindrical hermetically closed boxes. The water samples, about 500 g, were placed in 130 g hermetically closed Marinelli beakers. The samples were stored for 28 days for radioactive equilibrium.

The activity concentrations of ^{232}Th, ^{226}Ra, ^{137}Cs and the ^{40}K radionuclides were determined using a CANBERRA system consisting of a n-type, 0.6 mm epoxy carbon HPGe detector with ISOXCALL characterization, a DSA 1000 multichannel analyzer and 747 type lead shield. The detector has a relative efficiency of 40% and the resolution is 1.96 keV at ^{60}Co 1332 keV and 0.89 keV at ^{57} Co 122 keV line. GENIE 2000 software was used for data acquisition and processing while the efficiency calibration, self-absorption and coincidence summing correction were performed by using a CANBERRA LabSOCS software. The background contribution was obtained as the average of three independent measurements, each of them of 200,000 s. The nuclear data were those provided by Chu et al. (1999) while the spectral lines overlapping were corrected by the method presented in (Tugulan and Duliu 2014).

The ^{232}Th natural series was investigated by means of gamma spectra of descending radionuclides ^{228}Ac (209.25 keV, 794.95 keV, 911.20 keV and 968.97 keV), ^{212}Pb (238.63 keV), ^{212}Bi (with energy 727.33 keV and 1620.50 keV) and ^{208}Tl (583.19 keV and 860.56 keV). In the case of ^{226}Ra series, was used the gamma spectra of ^{214}Pb (295.22 keV and 351.93 keV) and ^{214}B (609.31 keV, 768.36 keV, 934.06 keV, 1120.29 keV, 1661.28 keV, 1729.60 keV and 1847.42 keV). ^{40}K has single gamma emission energy of 1460.83 keV.

For the spectrometric system, the accuracy of radiometric measurements was checked by using the IAEA certified materials IAEA-RGTh-1 (Thorium Ore), IAEA-384 (Fangataufa Sediment) and IAEA-385 (Irish Sea sediment). Differences between the measured and certified values were less than 5%.

13.3 Results

Each sample was evaluated for its radionuclide concentrations and in some cases, like the off-shore water samples from Constanta Est 6 and 7, the measurements were under the minimum detectable activity (MDA) and no radionuclide was clearly identified above the background radiation. Water samples provide specific issues regarded to the gamma scattering and attenuations within the sample and the actual efficiency and calibration correction coefficients needed to be adjusted for the actual experimental setup using LabSOCS detector simulation. While other codes like GESPECOR (Sima and Arnold 2002) provide a consistent overview, we employed LabSOCS as the spectrometer supplier main method for parameter correction (Done et al. 2015) (Table 13.1).

Soil samples, mainly sediments, raised specific issues related to the homogeneity due the fact that each area has specific soil compositions. In order to provide accurate results, each sample has to be corrected to its specific density, weight and size – meaning for each sample, different detector coefficient corrections needed to be applied. The presence of wood and other materials was avoided due the fact that they have high concentrations of ^{40}K (Table 13.2).

Table 13.1 Seawater sample radionuclide evaluation

#	Sample	Radionuclide	Activity [Bq/l]	MDA [Bq/l]
1	Constanta EST 2	^{40}K	5.10 ± 0.6	0.90
2		^{214}Bi	2.59 ± 0.34	0.17
3		^{214}Pb	2.45 ± 0.36	0.20
4		^{241}Am	0.13 ± 0.07	0.12
5	Constanta EST 3	^{40}K	4.40 ± 0.51	0.90
6		^{214}Bi	0.52 ± 0.07	0.18
7		^{214}Pb	0.56 ± 0.08	0.18
9	Constanta EST 4	^{40}K	3.10 ± 0.36	0.98
10	Constanta EST 5	^{40}K	4.7 ± 0.55	0.98
11		^{214}Bi	1.28 ± 0.17	0.18
12		^{214}Pb	1.06 ± 0.16	0.18
13	Sf. Gheorghe 2	^{40}K	8.30 ± 0.95	0.68
14		^{214}Bi	0.25 ± 0.03	0.13
15		^{214}Pb	0.24 ± 0.04	0.14
16	Sf. Gheorghe 3	^{40}K	17.20 ± 1.98	0.84
17		^{214}Bi	2.02 ± 0.26	0.18
18		^{214}Pb	2.06 ± 1.26	0.20
19	Sf. Gheorghe 3	^{40}K	4.90 ± 0.57	0.87
20		^{214}Bi	1.55 ± 0.20	0.17
21		^{214}Pb	1.26 ± 0.39	0.20

Only the valid data (determinations greater the *MDA* Minimum Detectable Activity – were presented

Table 13.2 Detected activity for soil samples

#	Sample	Depth[m]	Lat [N]	Lon [E]	Activity [Bq/kg]			
					^{40}K	^{137}Cs	^{232}Th	^{226}Ra
1	Constanta Est1	14	44,17	28,68	254.00 ± 30.00	2.57 ± 0.37	21.00 ± 3.40	17.10 ± 2.40
2	Constanta Est2	28	44,17	28,78	256.00 ± 30.00	22.90 ± 3.00	13.30 ± 2.60	7.05 ± 1.03
3	Constanta Est3	36	44,17	28,90	210.00 ± 25.00	7.09 ± 1.00	6.63 ± 1.45	4.59 ± 0.67
4	Constanta Est4	47	44,17	29,13	211.00 ± 25.00	11.70 ± 1.60	8.38 ± 1.73	5.42 ± 0.80
5	Constanta Est5	54	44,17	29,36	226.00 ± 27.00	11.50 ± 1.50	10.70 ± 1.60	10.70 ± 1.50
6	Constanta Est6	85	44,15	30,20	92.00 ± 10.80	4.69 ± 0.65	4.46 ± 1.24	6.67 ± 0.97
7	Constanta Est7	95	44,15	30,20	117.00 ± 14.00	3.14 ± 0.55	4.51 ± 1.02	9.15 ± 1.32
8	D-SUD	45	44.55	29.41	211.00±25.00	18.50 ± 2.40	7.08 ± 1.26	6.75 ± 1.00
9	D-EST	90	44,39	30,58	107.00 ± 13.00	9.00 ± 1.20	5.57 ± 1.07	24.6 ± 3.40
10	D-N	90	44,39	30,57	132.00 ± 16.00	6.02 ± 0.86	6.15 ± 1.53	17.4 ± 2.50
11	G Buhaz 1	5	44,40	28,77	176.00 ± 21.00	1.00 ± 0.19	88.10 ± 12.3	66.40 ± 9.10
12	G Buhaz 2	20	44,40	28,84	111.00 ± 13.00	1.59 ± 0.38	6.67 ± 1.51	9.70 ± 1.38
13	Mila 9-1	5	45,00	29,65	195.00 ± 23.00	0.94 ± 0.18	53.30 ± 7.30	39.40 ± 5.40
14	Mila 9-2	20	45,00	29,73	267.00 ± 31.00	16.8 ± 2.20	15.60 ± 3.80	10.30 ± 1.50
15	Mila 9-3	30	44,99	29,92	237.00 ± 28.00	22.60 ± 3.00	14.90 ± 3.70	9.45 ± 1.35
16	Portita 2	20	44,68	29,29	237.00 ± 27.00	16.50 ± 2.20	13.40 ± 2.30	8.55 ± 1.25
17	Portita 3	30	44,68	29,47	258.00 ± 31.00	15.90 ± 2.10	13.80 ± 2.40	11.80 ± 1.70
18	Portita 4	50	44,68	29,75	170.00 ± 20.00	1.06±0.20	8.28 ± 1.46	4.76 ± 0.67
19	Portita 5	57	44,68	29,92	110.00 ± 13.00	12.20±1.60	5.36 ± 2.05	6.34 ± 1.05
20	Portita 6	70	44,68	30,52	91.00 ± 10.80	4.54 ± 0.68	4.44 ± 0.96	4.75 ± 0.70
21	Sf. Gheorghe 1	1	44,88	29,64	175.00 ± 21.00	1.17 ± 0.20	36.20 ± 4.70	30.10 ± 4.20
22	Sf. Gheorghe 2	20	44,88	29,68	262.00 ± 31.00	12.60 ± 1.70	16.30 ± 2.60	9.87 ± 1.40
23	Sf. Gheorghe 3	30	44,88	29,70	262.00 ± 31.00	26.40 ± 3.50	16.80 ± 2.70	8.65 ± 1.28
24	Sf. Gheorghe 4	40	44,88	29,85	156.00 ± 18.00	6.56 ± 0.90	9.40 ± 1.70	7.40 ± 1.15
25	Sulina 2	20	45,14	29,79	257.00 ± 30.00	18.20 ± 2.40	14.70 ± 2.30	14.10 ± 2.00
26	Sulina 3	30	45,12	29,92	77.00 ± 9.30	6.05 ± 0.91	3.51 ± 0.73	3.56 ± 0.52

Sediment samples are more consistent on radionuclides and their concentration can be estimated to an average uncertainty of 20%. As geometries are similar, trends and distributions can be calculated from this information.

This is not the case for seawater samples where only a few of the radionuclides can be evaluated with a consistent uncertainty and no distribution or trend analysis can be performed for the overall set.

13.4 Discussion

The sediment distributions on the western Black Sea shelf follow the sea currents feature in the area. At the Danube mouths there are two main streams: one from north to south and the other from south to north. From north to south current flows near shallow waters (near-shore) on the entire depth with speeds range from 0.33 to 0.47 m/s. The river currents spread fan-shaped with rapid decrease in their speed. After mixing with the Black Sea waters, the river currents are influenced by the coastal currents and the river discharge.

In cold season, winter, the sea currents are stable due to the wind intensity and stability. Current flows from south to north in a compact mass, down to 10 m water depth and a width of 40 nautical miles and tends to push but to maintain the north-south current near the coast. The current from south to north has a maximum speed of 0.47 m/s (Fig. 13.4).

Sediment sample distribution has an expected shape, the shoreline is more consistent for earth like radionuclides like ^{226}Ra and ^{232}Th as the waters a shallow and the radionuclide behavior is similar the one found in ground sites. Their concentration decreases with the distance to the shoreline (Fig. 13.5).

These plots can be referenced as natural radioisotopes specific to the soil it's composition for the Dobrogea seashore areas while the following radionuclides that we evaluated can be linked to the presence of human activities (in the case for ^{137}Cs) or with natural materials for ^{40}K.

The values are in good concordance with the one previously taken for the Black Sea (Valeva et al. 2002) (Fig. 13.6).

Average ^{137}Cs detected concentrations fall under the UNSCEAR (UNSCEAR 2011) reports average for our country and no unusual concentrations were found within this study. The higher concentrations on the Danube Delta interface to the Back Sea can be due to nuclear activities at Cernavoda but the detected value is well less the exception concertation. Concentrations up to 40 Bq/Kg are common to the Chernobyl event (Blebea-Apostu et al. 2012). Activities for similar studies showing higher Cs concentrations can be found in literature (Mohammad Reza Abdi et al. 2009) (Fig. 13.7).

Potassium 40 is one key radionuclide associated to both animal and vegetal concentrations and its distribution can be correlated to such activities or to large deposits of wood or other construction materials leading to higher concentrations within specific regions along the shore line. The above picture presents the

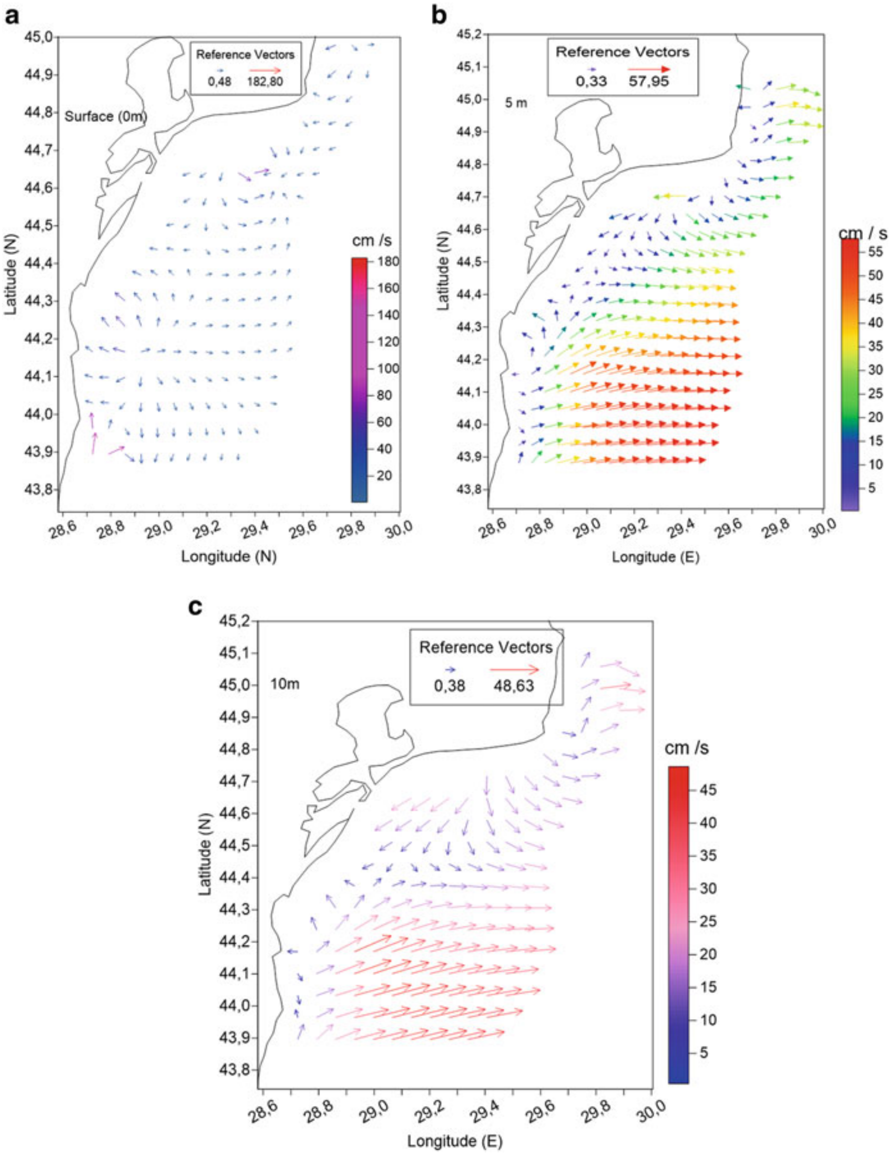

Fig. 13.4 Sea currents distribution on the western Black Sea shelf, February 2010 (NIMRD data)

sediment sample distribution for the ^{40}K radionuclide. We have to notice that the specific activity for the ^{40}K radionuclide is half of that reported by other institutions (UNSCEAR 2008). ^{40}K present high values in concentrations in near-shore areas: at the Danube mouths and in highly commercial routes dynamical zones such as the upwelling events that occur mainly in spring followed by algae bloom (Mihailov et al. 2012). The primary production in the western Black Sea shelf, estimated as

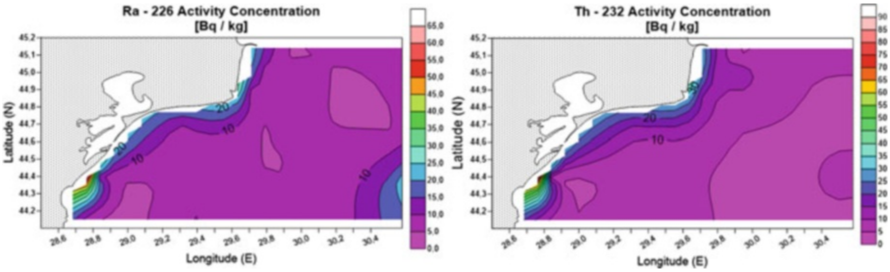

Fig. 13.5 ^{232}Th and ^{226}Ra concentration distribution for the Romanian Black Sea Region

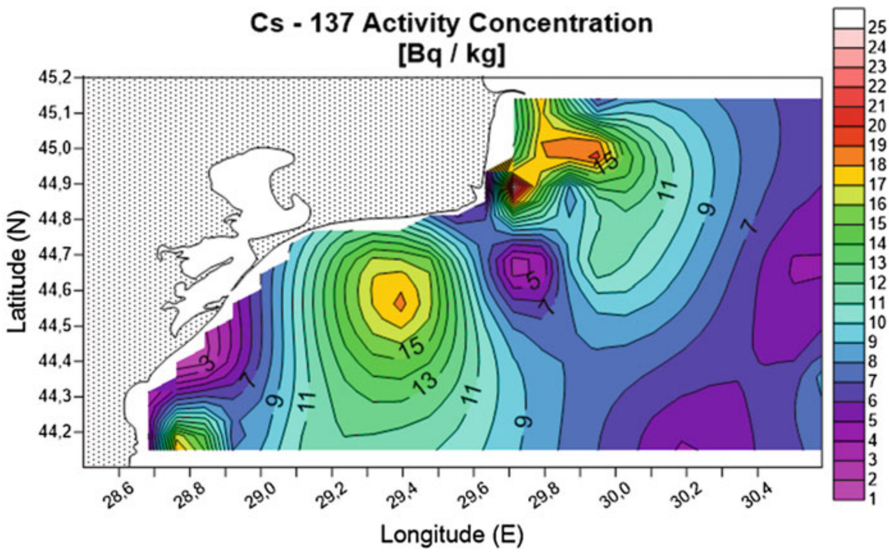

Fig. 13.6 ^{137}Cs Distribution for the Romanian Sector of Black Sea

chlorophyll-a concentration (Fig. 13.8), present high concentration in previously mentioned areas mainly in front of the Danube Mouth due to the nutrient rich waters. Also, in this shallow areas, the sediment transport is very dynamic due to the sea currents and waves. The north-to-south regional depth circulation feature determine at the 20 m isobaths similar values of 200–240 Bq/kg.

Long term radioisotopes like ^{241}Pu with a halflife of 14 years (Boulyga et al. 1997; Sasahara et al. 2004; Rumynin and Nikulenkov 2016) released in large amounts by the Cernobyl event, are responsible, among other processes, for the presence of ^{241}Am that can be traced within our samples.

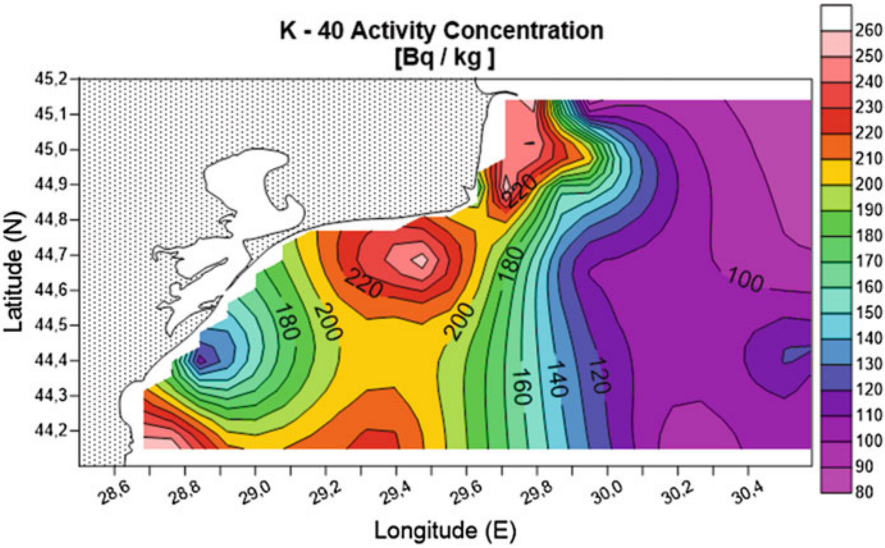

Fig. 13.7 40-K distribution within the Romanian Black Sea Sector

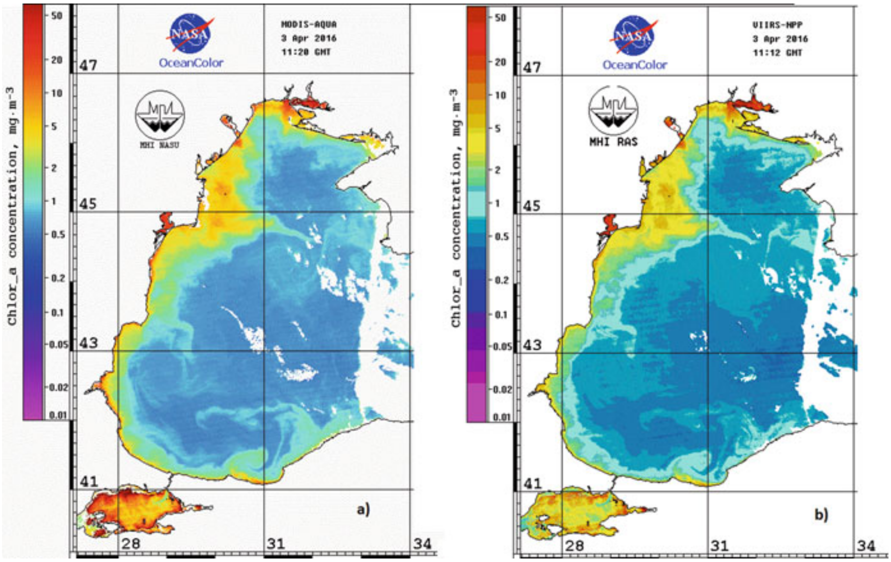

Fig. 13.8 Chlorophyll – a concentration on the western Black Sea shelf, data retrieved from dvs. mhi.ru (Remote Sensing Department 2017): (**a**) Modis-Aqua data on 3 April 2016 (NASA Goddard Space Flight Center 2016), (**b**) VIIRD-HPP data on 3 April 2016

13.5 Conclusion

Radioisotope inventory analysis for the black sea area (at least for Romanian Shore line) can be a valuable tool for contamination analysis but specific techniques have to be developed for such activities. The wide variety of samples and sample type and their densities can raise specific issues while using specialized high resolution spectrometry (using GeHP detectors with standard POPTOP coaxial geometry) and require detector calibration coefficient correction for each sample but, at least for sediment samples can provide lower MDA's and high confidence results.

The case for seawater samples, standard radioisotopes cannot always be determined but in some cases the simple presence of radionuclides like ^{241}Am in the Constanta EST 2 location can be traced to the Chernobyl Event. In this specific case, the higher ^{241}Am is correlated with a high concentration in ^{137}Cs and by its mean we can trace it back to the ^{241}Puradionuclides given by Chernobyl (Muravitsky et al. 2005).

While previous studies focus on air distribution (Nikolaos Evangeliou et al. 2016) for major radionuclides this method applied to sediment samples can use ^{241} Am as a tracer for major nuclear incidents in Europe and the presence of both Black Sea – a semi closed basin – and the Danube (a river running along nearly half of Europe) give an opportunity for an better assessment of the main nuclear incident in Eurasia, the Cernobyl event.

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Chapter 14
Gamma-Ray Radionuclides in Sediments from Mamaia Beach on the Romanian Black Sea Coast

Vasile Pătraşcu, Romul Mircea Mărgineanu, Ana-Maria Blebea-Apostu, Dănuţ I. Diaconeasa, and Mariana Claudia Gomoiu

Abstract Tourist activities on the seaside, but not exclusively, are dependent of the quality of the environmental components from the coastal zone. The water and the substrate are some of the main components. Their importance is supported, on the other hand, by their background role in the marine ecosystem. The surveillance of the radioactive indicator for sediments helps at knowing its distribution in the marine ecosystem and at assessing the risk of exposure to ionizing radiation for people. Setting-up and maintaining a database is necessary both for the present state, as well as to assess trends. A further study may reveal important knowledge in combination with other environmental factors, such as hydrodynamics, chemicals, for example, and their impact on biota. The Navodari – Mamaia area, which is now contained in a plan to rehabilitate the shoreline, was taken as a case study. The samples were collected on seven profiles distributed in that area, all from the sands at terrestrial vegetation limit and up to sediments submerged up to 12 m. The 56 samples were analyzed in IFIN-HH underground laboratory with ultra-low radiation background. The results indicated the presence of artificial radionuclide Cs-137, with values between 0.5 and 10.5 Bq/kg. The natural radionuclide K-40 is also present in the range of 55–494 Bq/kg sediment.

Keywords Marine radioactivity • Sediments • Romanian coastal zone • Black Sea

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V. Pătraşcu (✉) • D.I. Diaconeasa
National Institute for Marine Research and Development "Grigore Antipa", Constanţa, Romania
e-mail: vpatrascu@alpha.rmri.ro

R.M. Mărgineanu • A.-M. Blebea-Apostu • M.C. Gomoiu
Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Bucharest-Magurele, Romania

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14.1 Introduction

Tourist activities on the seaside, but not exclusively, are dependent of the quality of the environmental components from the coastal zone. In marine ecosystem, the basic components are the water and the substrate. This importance is supported, on the other hand, by their role in its life and functionality. Measurements of the radioactivity of sediments give data of distribution in the marine ecosystem and for the risk assessment (Chiosila et al. 2012). Setting-up and maintaining a database is necessary to evaluate the state of the environment quality and its trends. A complex correlation study may reveal new knowledge, considering other environmental factors, such as hydrodynamics, chemicals and their influence on biota (Nicolaev et al. 2015). The Năvodari – Mamaia area was taken as a case study, beeing now involved in a rehabilitation plan of the coast.

Data presented in this paper were obtained in the frame of the BS ERA NET 041 Project, from Black Sea ERA NET Pilot Joint Call 2010/2011, under FP7 European Program.

14.2 Materials and Methods

The samples were taken from Mamaia beaches, central positioned in Romanian littoral at Black Sea. In laboratory the samples were dried (105 Celsius degrees) and weighted. Seven profiles (transects MM1 up to MM7) were chosen along the beach, for each taking a set of samples from the shore and from the water. Those are emerged sediments, from upper beach (limit of vegetation-UB), medium beach (middle beach-MB), interface (front of water-I), and submerged sediments, from 1 m, 3 m, 5 m, 7 m, 10 m and even 12 m. Separately, granulometric measurements of the samples have been performed (Diaconeasa 2017). The parameters used to describe a grain size distribution can be summarised into four main categories, that is: mean, refers to the average grain size; sorting, refers to the uniformity of grain size in a sediment; skewness, that is the degree of asymmetry of a frequency or cumulative curve; kurtosis, that is the degree of peakedness or departure from the "normal" frequency or cumulative curve.

The investigation of the radioactivity was performed by IFIN-HH, coordinator of the "RACE" BS ERA NET 041 Project, using the facilities of Slanic Prahova Low – Background Radiation Laboratory (SPLBRL) (Margineanu et al. 2008). The measurements were performed by a gamma spectrometry system using HPGe detector (FWHM of 1.77 keV/1332.4 keV and a relative efficiency of 22.3%), InSpectorTM 2000 electronic module and GENIE2000 spectrum acquisition and processing software. Gamma spectra were recorded for 85,000 s for samples up to 130 g of sand, sealed in cylindrical plastic boxes (75 mm diameter, 1 mm wall thickness, 40 mm high).

14.3 Results

The results regarding the radioactivity of the sediments are presented in Table 14.1, for Cs137 and Table 14.2, for K40.

The results indicated the presence of artificial radionuclide Cs-137, with values between 0.5 and 10.5 Bq/kg and average 2,1+/−1,5 Bq/kg. The natural radionuclide K-40 is also present in the range of 55–494 Bq/kg sediment, with average 249+/−94 Bq/kg. The relative highest deviation at average activity level of the radionuclides can be explained by small different areas, having some physical and geological peculiarity.

14.4 Discussions

Analyzing the correlation factor for each transect (MM1 to MM7) from Mamaia beach, is identified positive correlation between K40 and Cs137 radionuclides (range between 0,59 and 0,94 for r). One single profile has no correlation (0,11 at MM7; Table 14.3).

Another set of correlation factors can be obtained between Cs and K radionuclides, by zonal layers (coastal, backshore, swash, surf, nearshore; Table 14.4). In nearshore zone, without mixing process, the differentiation of sediments lead to insulation fields and low correlation at zonal level. On the contrary, in areas with good mix, there is a stronger correlation (0,74–0,94).

Analyzing the correlation factors for main granulometry parameters, in case of Cs137, different aspects can be observed (positive or negative correlation, as in Tables 14.5 and Table 14.6). An evident negative correlation of radioactive content is visible with size (mean diameter), the fine grains having good capacity to concentrate it (Tables 14.5 and 14.6).

Water movements influence the transport and segregation of sediment (zonal differences), and their quality (granulometry, content) affecting the fixation of radionuclides (see the dispersion of the average levels of Cs137 and K40 contents). Dams and submerged constructions can influence the local and zonal distribution of sediments, according with the marine currents and wave regime (Diaconeasa 2017).

The external radiological impact of the radioactive content in sand of the Mamaia beach is at low level. Using the dose coefficient from (UNSCEAR 2000), result an average absorbed dose in air of 10,4 nGy/h for K40, under worldwide level. Actually the external exposure rates is reported for Romanian seashore in the Mamaia area at average at 59 nGy/h. This results are confirmed by *in-situ* dose rate measurements (Margineanu et al. 2013).

Table 14.1 Cs137 activity (A) in sediments from Mamaia beach stations (Bq/kg)

Transect	MM1		MM2		MM3		MM4		MM5		MM6		MM7	
Station	A	Uncert	A	Uncert	A	Uncert	A	Uncert	A	Uncert	A	Uncert	A	Uncert
UB	1,2	0,1	2	0,2	2,1	0,3	1,3	0,2	0,9	0,1	1,1	0,1	1,6	0,2
MB	1,2	0,1	2,2	0,3	1,1	0,1	1,3	0,2	0,6	0,1	2	0,2	1,7	0,2
I	1,7	0,2	1,3	0,2	1,2	0,1	0,5	0,1	0,6	0,1	1,5	0,2	1,4	0,2
−1	2,2	0,3	2	0,2	1,6	0,2	1,3	0,2	1,5	0,2	6,4	0,8	1,8	0,2
−3	3,3	0,4	1,5	0,2	1,8	0,2	1,1	0,1	1,3	0,2	10,5	1,3	2,1	0,3
−5	4	0,5	1,9	0,2	1,9	0,2	2,3	0,3	0,9	0,1	1,6	0,2	1,9	0,2
−7	2,7	0,3	2,4	0,3	1,9	0,2	3,1	0,4	1,7	0,2	0,8	0,1	2,3	0,3
−10	4,7	0,6	3,4	0,4			2	0,2	1,5	0,2	1,9	0,2	2,9	0,3
−12							2,1	0,3						

Table 14.2 K40 activity (A) in sediments from Mamaia beach stations (Bq/kg)

Transect	MM1		MM2		MM3		MM4		MM5		MM6		MM7	
Station	A	Uncert	A	Uncert	A	Uncert	A	Uncert	A	Uncert	A	Uncert	A	Uncert
UB	139	14	322	32	332	33	159	16	128	13	135	14	143	14
MB	173	17	259	26	153	15	125	13	64	6	218	22	245	25
I	245	25	245	25	181	18	55	6	71	7	306	31	257	26
−1	376	38	334	33	210	21	193	19	342	34	494	49	252	25
−3	280	28	326	33	225	23	175	18	245	25	425	43	264	26
−5	418	42	336	34	240	24	248	25	211	21	337	34	246	25
−7	273	27	338	34	258	26	319	32	342	34	198	20	114	11
−10	263	26	452	45			258	26	228	23	234	23	283	28
−12							243	24						

Table 14.3 Transect: correlation factors between radionuclides in Mamaia beach (r)

Transect	MM1	MM2	MM3	MM4	MM5	MM6	MM7
Cs137-K40	0,59	0,92	0,8	0,94	0,93	0,77	0,11

Table 14.4 Zonal layers: correlation factors between radionuclides (r)

Coastal zone	Layer	Cs137-K40
Backshore	UB	0,91
	MB	0,92
Swash	I	0,94
Surf	−1	0,82
	−3	0,84
	−5	0,74
Nearshore	−7	0,13
	−10	0,4

Table 14.5 Transect: correlation factors between Cs137 and main statistical parameters in sediments (r)

Transect	Mean	Sorting	Skewness	Kurtois
MM1	−0,71	0,69	−0,89	0,81
MM2	−0,92	−0,84	−0,59	0,9
MM3	−0,4	−0,21	−0,04	0,11
MM4	−0,64	−0,43	−0,08	0,72
MM5	−0,56	−0,84	0,55	0,59
MM6	−0,39	−0,57	−0,18	−0,23
MM7	−0,36	0,03	−0,75	−0,07

Table 14.6 Zonal layers: correlation factors between Cs137 and main statistical parameters in sediments (r)

Coastal zone	Layer	Mean	Sorting	Skewness	Kurtois
Backshore	UB	−0.76	−0.58	−0.24	0.6
	MB	−0.65	0.02	0.6	0.68
Swash	I	−0.59	−0.50	0.83	0.43
Surf	−1	−0.35	0.79	−0.33	0.50
	−3	0.01	0.79	0.14	0.33
	−5	−0.74	0.89	−0.93	0.73
Nearshore	−7	−0.11	0.4	−0.5	0.05
	−10	−0.3	0.81	−0.83	0.77

14.5 Conclusion

The content of Cs137 is between 0.5 and 10.5 Bq/kg, with average level 2,1+/−1,5 Bq/kg.

The content of K40 is between 55 and 494 Bq/kg sediment, with average level 249+/−94 Bq/kg.

Everywhere in Mamaia sector, the two radionuclides, have good positive correlation.

A negative good correlation of radioactive content is with mean diameter, the fine grains of sediment having good capacity for fixing the radionuclides.

Water movements influence the transport and segregation of sediment (zonal differences), and their quality (granulometry, content) affecting the fixation of radionuclides.

The external radiological impact of the radioactive content in sand of the beach is at low level.

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Chapter 15
Radioactive Content in Fish from Black Sea Caches. Its Impact on Population by Food Consumption

Vasile Pătraşcu, Romul Mircea Mărgineanu, Valodia Maximov, Ana-Maria Blebea-Apostu, Mădălina Galaţchi, Claudia Gomoiu, and George Ţiganov

Abstract Marine living resources are a recognized food basis. The exploitation of species with economic value has increased in intensity, along with the sharp global food demand. The Black Sea, as a semi-enclosed sea, has a limited potential in this respect. The stocks have decreased recently and, consequently, restricted limits of fishing are needed in all riparian countries. The catches in the Romanian sector ranged from 568 to 2231 tons during 2011–2014. The dominant species were rapa whelk, sprat, anchovy and turbot. As the amount of fish catches is limited, most of the fish is intended for local consumption. Food quality and safety focus attention on the conditions of consumer acceptance. Among targeted indicators, the level of radioactivity has a special importance. This is particularly substantiated for the Black Sea, as a receiving area of all normal and nuclear activities impact from the continent, besides the scientific interest related to the migration of radionuclides in the aquatic environment. This paper presents the natural and artificial significant radionuclide levels measured in fish and an extrapolation to population exposure through food consumption. Thus, it was found that Cs-137 is present between 0.42 and 0.94 Bq/kg fw and K-40 between 36 and 184 Bq/kg fw. The maximum values were considered in calculating exposure for target groups and the entire resource caught. The results obtained do not show an exceeding of the legal limits and do not constitute a risk by food consumption.

Keywords Marine radioactivity • Doses • Marine fish • Radioecology • Black Sea

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V. Pătraşcu (✉) • V. Maximov • M. Galaţchi • G. Ţiganov
National Institute for Marine Research and Development (NIMRD) "Grigore Antipa", Constanta, Romania
e-mail: vpatrascu@alpha.rmri.ro

R.M. Mărgineanu • Ana-Maria Blebea-Apostu • C. Gomoiu
Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Magurele, Romania

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15.1 Introduction

With the population explosion, the demand of food for the human population has increased substantially. The food resources are under increasing pressure. Diversification of resources and efficiency of consumption are two ways with good solutions in order to reduce these pressures. Parallel operation of multiple dietary sources, not only makes the offer richer and healthier, including in the economic field, but also reduce pressures on main source. Consumption efficiency can have positive effect on the dislocation of living resources and on the economic costs, including production costs. Overall, the approach of the two ways would be beneficial for the protection of ecosystems and biodiversity, and bio waste can be minimized. A noticeable component in the coastal zone, is also the fish. Total catch of marine resource, from the Romanian Black Sea sector, were between 568 and 2231 tones, for the period 2011–2014 (Cardinale et al. 2015; Maximov et al. 2013; Nicolaev et al. 2015; Radu et al. 2012). The interest in sea food increased lately for Rapana, their abundance in catches being remarkable (over 80%). Among the species of fish, the most common were anchovies (*Engraulis encrasicolus*), sprat (*Sprattus sprattus*) and turbot (*Psetta maxima Maeotica*) (Maximov et al. 2013; Nicolaev et al. 2015).

Food quality of living marine resources is appreciated also in terms of content of substances having risk to human health. Therefore, the evaluation of radionuclide contents is also a request to the commercial market. Use of nuclear energy, but especially the knowledge of accidental situations, from the past, require continued close monitoring of the environment and living resources, in this regard (Chiosila et al. 2012). Data from this work were obtained in the frame of the BS ERA NET 041 Project, from Black Sea ERA NET Pilot Joint Call 2010/2011, under FP7 European Program.

15.2 Materials and Methods

The samples were taken from fish catches in Romanian area, weighted, dried and ashed (below 450 Celsius degrees). The investigation of the radioactive content was performed by/IFIN-HH, coordinator in the "RACE" BS ERA NET 041 Project, using the facilities of Slanic Prahova Low – Background Radiation Laboratory (SPLBRL) (Margineanu et al. 2008). The measurements were performed by a gamma spectrometry system using HPGe detector (FWHM of 1.77 keV/ 1332.4 keV and a relative efficiency of 22.3%), InSpectorTM 2000 electronic module, GENIE2000 spectrum acquisition and processing soft. Gamma spectra were recorded for 85,000 s for up to 100 g of fish samples sealed in circular plastic boxes (75 mm diameter, 1 mm wall thickness).

The radiological impact was estimated for individual commitment effective dose by ingestion, E:

$$E\ (Sv/y) = h(g)_{Cs137} \times [\Lambda]_{Cs137} \times Iy \tag{15.1}$$

where:

$h(g)_{Cs137}$ is dosimetric coefficient for a given radionuclide (Sv/Bq) at group g of age (>17 years)
$[\Lambda]_{Cs137}$ is radionuclide concentration in food (Bq/kg wm)
Iy is food ingested rate (kg/year) for:

Individid from Population (P) = 10 kg/y;
Individ from Target Group (TG) = 100 kg/y

and for collective dose:

$$EC(man\ Sv/y) = Pman \times E(Sv/y) \tag{15.2}$$

where Pman is the number of the inhabitants using aquatic food (fish).

15.3 Results

The measurable radioactivity in fish samples is for natural radionuclide K40 and for artificial radionuclide Cs137, with results presented in Table 15.1.

Cs137 is distributed between 0.33 and 1.26 Bq/kg wm, and K40 between 36 and 236 Bq/kg wm, with a mean concentration 0,64+/−0,14 Bq/kg wm, respectively 112.1+/−48.9 Bq/kg wm. In fish samples, the two radionuclides are positively correlated, with $r = 0.68$.

15.4 Discussions

To estimate radiological impact by ingestion, are taken the following data:

- $h(g)_{Cs137}$ = 1.3E-8 Sv/Bq, h(g)K40 = 6.2E-9 Sv/Bq, in condition of an age g > 17 year (Basic Norms 2000);
- Inhabitants/Constanta County =684.082 (taken only 462.439, Age Group: 15–64 years =67,6%) (National Institute of Statistics 2011);
- Inhabitants main cites (70% of populations from county): 477.473 (taken only 322.771, Age Group: 15–64 years =67,6%) (National Institute of Statistics 2011);
- The maximum annual total catch of fish recorded in the period 2011–2014 is 369,514 kg (Nicolaev et al. 2015).

Dose results are presented in Table 15.2.

Table 15.1 Radioactivity contents in fish from Romanian Black Sea sector

No	Sample	Data	Location	Fishing method	Depth (m)	Cs137 Bq/kg	Un certainty	K40 Bq/kg	Uncertainty
1	*Merlangius Merlangius Euxinus*	21.10.11		Trawl	60	0.64	0.1	82.9	9.4
2	*Sprattus sprattus*	30.11.11		Trawl	63	0.78	0.13	90	10.1
3	*Engraulis encrasicolus*	30.05.11	Corbu	Stationary	<5	0.68	0.09	134.6	10.8
4	*Atherina boyeri*	13.07.11	Corbu	Stationary	<5	0.82	0.1	143.1	11.5
5	*Solea vulgaris*	13.07.11	Corbu	Stationary	<5	0.56	0.07	120.6	9.7
6	*Neogobius melanostomus*	13.07.11	Corbu	Stationary	<5	0.75	0.09	140.4	11.2
7	*Engraulis Encrasicolus*	16.06.11	Midia-Hagi	Stationary	<5	0.58	0.07	153.9	12.3
8	*Sprattus Sprattus*	16.06.11	Midia-Hagi	Stationary	<5	0.53	0.06	120.7	9.6
9	*Engraulis Encrasicolus*	30.06.11	Midia-Hagi N	Stationary	<5	0.47	0.05	139.9	11.3
10	*Engraulis Encrasicolus*	30.05.11	Cap Midia-Hagi	Stationary	<5	0.81	0.1	154.3	12.3
11	*Engraulis Encrasicolus*	14.07.11	Vama Veche	Stationary	<5	0.62	0.08	141.8	11.4
12	*Solea Vulgaris*	14.07.11	Vama Veche	Stationary	<5	0.78	0.09	183.9	14.8
13	*Trachurus mediterraneus ponticus*	26.07.11	Olimp	Stationary	<5	1.26	0.15	236.2	18.9
14	*Mullus barbatus Ponticus*	26.07.11	Olimp	Stationary	<5	0.56	0.06	123.1	9.8
15	*Engraulis Encrasicolus*	26.07.11	Olimp	Stationary	<5	0.58	0.06	125.8	10.1
16	*Psetta maxima Maeotica*	30.11.11		Trawl	60	0.83	0.11	75.8	6.1
17	*Sprattus Sprattus*	03.07′12	Vama Veche	Stationary	<5	0.66	0.05	77.7	3.2
18	*Sprattus Sprattus*	24.04′12	Perisor	Stationary	<5	0.42	0.04	42.6	2
19	*Sprattus Sprattus*	02.12′12		Trawl	60	0.33	0.03	35.9	3.8
20	*Merlangius Merlangius Euxinus*	02.12′12		Trawl	60	0.54	0.04	77.2	3.3
21	*Sprattus Sprattus*	24.04′12	Sahalin	Stationary	<5	0.7	0.03	63.8	2
22	*Sprattus Sprattus*	23.04′12	Zaton	Stationary	<5	0.44	0.02	48.2	1.5
23	*Sprattus Sprattus*	03.05′12	Navodari	Stationary	<5	0.48	0.03	66.9	2.2

Table 15.2 Radiological impact for people from individual and collective dose contributions

Radionuclide	EIndP (Sv/y)	EIndTG (Sv/y)	EcolCta (manSv/y)	EcolTGCta (manSv/y)	ECatch (Sv/y)
Cs137	0.83 E-7	0.83 E-6	0.038	0.27	0.003
K40	0.7 E-5	0.7 E-4	3.2	22.6	0.26

Starting for low concentration of radionuclide Cs-137 in fish, is expecting to have also low contribution in radiological impact at human population by ingestion. For individual the annual estimation is 0,08 microSv, but for member from target group is ten times higher, following increased diet. Collective dose in Constanta County is less than 0,038 manSv yearly, but for group eating more fish this is less than 0,27 manSv.

Regarding K40, individual dose contribution is 7 microSv, increased one order for more fish in diet. At county level, the collective dose is less than 3,2 manSv per year, increasing at maximum 22,6 manSv for target group (mainly urban population).

These considerations are based on conservative frame (fish with mean concentration, all weight being ingested, the people eating an equal diet). In reality, the fish catch consumed entirely can not deliver more as 3 mSv throughout one year, for Cs137, respectively maximum 0,26 Sv annually, for K40, to all population.

15.5 Conclusions

Artificial radioactivity content in fish from Romanian Black Sea sector is in decimal units of Bq per kg wet.

The total permissible dose of 1 mSv yearly for a person from population, is not exceeded by ingestion of fish.

Considering (UNSCEAR 1993) that in Romania the population receives, from natural background, 2.27 mSv/year and 0.33 mSv/year by artificial sources, sea fish ingestion has, comparatively, a low contribution at target group doses (individual).

These values are infrequent, because the amounts consumed over possible individual values are lower than the estimated annual values (10 and 100 kg).

The dose evaluation by ingestion of fish catch is more realistic, but the knowledge of the real distributions of consumption and doses are unknown (the consumption of fish is mainly appreciated for locals).

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Chapter 16
Levels of Activity Concentration, Migration and Dose Rates on Biota from Alpha-Radioisotopes of Plutonium in the Black Sea Ecosystem

Nataliya N. Tereshchenko

Abstract The Black Sea received abundant amount of plutonium alpha–emitting radionuclides $^{238,239,240}Pu$ with global fallout after nuclear weapon testing in atmosphere and after accident on the Chernobyl nuclear power plant (ChNPP) in 1986. Distribution of plutonium radionuclides in abiotic (water and bottom sediment) and biotic (algae, mollusks, fish) components of the Black Sea ecosystems was studied during the post–Chernobyl period at different areas as a rule at western and central parts of the sea. This study is devoted to the analysis of a radioecological situation in the Black Sea and concerns the levels of contamination and redistribution of the $^{239,240}Pu$ in the abiotic and biotic components of the sea ecosystem. The long–term accumulation and migration trends of these radionuclides were analyzed concerning abiotic components of the Black Sea after the ChNPP accident. Zones were revealed that have an increased ability to accumulate these radioactive pollutants. The estimations of the fluxes of elimination of the after-accidental plutonium alpha–radionuclides into bottom sediments in open and coastal areas of the sea were obtained. Evaluation of irradiation dose rates formed with alpha–radiation of $^{239,240}Pu$ in Black Sea hydrobionts was carried out. Important quantitative characteristics of plutonium migration in the Black Sea ecosystems were obtained and application of the comparative analysis together with equidosimetric approach to the ecological effects assessment from the $^{239,240}Pu$ doses on hydrobionts in contemporary radiological situation in the Black Sea as well as in different potential radioecological situations in wide range of alpha-emitting plutonium radionuclides concentration activity in seawater was fulfilled.

N.N. Tereshchenko (✉)
The A.O. Kovalevsky Institute of Marine Biological Research of RAS, 2 Nakhimov Avenue, Sevastopol, Russian Federation
e-mail: ntereshchenko@yandex.ru

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16.1 Introduction

Plutonium as an element refers to the group of transuranic elements (TUE), which is a group of radioactive substances almost completely of man–made origin. In nature, the TUE (particularly, plutonium and neptunium) were found in the earth's crust in trace amounts in uranium minerals. Plutonium is formed by the spontaneous fission of uranium nuclei under the influence of neutrons of cosmic radiation (Transuranic elements 1985; Plutonium 2003). With neutron activation of uranium fuel in reactors formed of alpha–emitting radionuclides plutonium ^{238}Pu, ^{239}Pu, ^{240}Pu and in smaller quantities – nuclides of heavier isotopes and elements. Currently, it is known about 20 plutonium isotopes with the mass numbers of 228–247. Among them 15 isotopes are alpha–emitters and only five isotopes (mass numbers 241, 243 and 245–247) are beta–emitters. In the thermonuclear explosions produced all the plutonium isotopes, up to ^{257}Pu. But their life–time is tenths of a second, and explore the many short-lived isotopes of plutonium have not yet succeeded (Plutonium 2003; Morss et al. 2008).

16.1.1 *Nature and Man-Made Plutonium*

The plutonium volatility is low, but still its small number is coming into the environment from emissions during operation of nuclear facilities (Warner and Harrison 1993). The most important industrial and radioecological radioisotope is ^{239}Pu. Its reserves of natural origin in the biosphere at a maximum was estimated at several tens of kilograms (about 50 kg) and the anthropogenic plutonium stocks at the end of the twentieth century, reached 950 tons, including 650 tons already attained in nuclear reactors and approximately 300 tons produced for military purposes (Sources and effects 1996; Plutonium 2003) Current stocks of the man-made plutonium are estimated at 2000 tons.

The majority of plutonium is contained in the isolated from the environment. These are potential sources of environmental contamination, which pose a serious, unresolved problem (Warner and Harrison 1993). One potential source of environmental contamination with TUE radionuclides (including plutonium) is the disposal of radioactive waste, such as dumping it in the sea and oceans. Although the performed monitoring studies indicate that currently environmental releases of radioactive substances are insignificant in locations of dumping, it must be remembered that a large amount of radioactive products is concentrated in these areas (WOMARS 2005).

A certain part of the technogenic plutonium (more than 10 tons) dispersed around the globe as a result of its admission into the environment from various anthropogenic sources (Plutonium 2003). Secondary sources of radioactive long–lived isotopes make their contribution to the contamination of the environment by TUE. The secondary sources of contamination of abiogenic and biogenic components of ecosystems are land and water areas contaminated by radioactive substances of different etymology: oceanic islands and terrestrial polygons, where were performed nuclear tests in the past and now, the surrounding area near the nuclear reprocessing plants (Sellafield (the UK), Hanford (USA) radioactive accidents zones: near Windscale (the UK), Kyshtym (Russia), Chernobyl (Ukraine), Fukushima (Japan) and so on, spacecraft crashes zone ("Kosmos–954", "SNAP-9A"), sunken nuclear boats and others (Transuranic elements 1985; Warner and Harrison 1993; WOMARS 2005; Trapeznikov et al. 2007; Gulin et al. 2013; IAEA 2015). At present, the anthropogenic stock of plutonium radioisotopes exceed tens of thousands of times the natural one, although the history of man–made plutonium has only a little more than half a century (the most important plutonium isotope ^{239}Pu was discovered in 1941) and the number of man–made plutonium continues to increase as a result of the operation of nuclear technologies (Plutonium 2003). Significant rates of the plutonium content increase in the biosphere, its high radiotoxicity (especially alpha–emitting isotopes and, in particular, ^{239}Pu), as well as the further development of the nuclear industry make it necessary to study the behavior of plutonium in the environment, including marine ecosystems and develop approaches for assessing the impact of plutonium radionuclides on hydrobionts.

16.1.2 Features of the Black Sea Ecosystem and Plutonium

The alpha–radioisotopes of plutonium ^{239,240}Pu belong to the technogenic radionuclides along with ^{90}Sr and ^{137}Cs that are the most abundant anthropogenic radioisotopes in the marine environment and the main dose–forming artificial radionuclides in the currently radioecological situation in the Black Sea ecosystems after accident on the Chernobyl nuclear power plant (ChNPP) (Polikarpov et al. 2008).

Alpha–radionuclides of Pu have long half-lives $T_{1/2}$ ($T_{1/2}$ of ^{239}Pu more than 24,000 and $T_{1/2}$ of ^{240}Pu over 6000 years) (Plutonium 2003), so their concentrations in the ecosystem components do not decrease practically due to radioactive decay for hundreds of years and their number increases in the environment from the incident to the incident. Seas serve as a kind of buffer systems which receive radioactive contamination and where many of the radionuclides are accumulated as a result of atmospheric transport and with the river and surface runoff. This effect is pronounced for the so–called "elements–divers" (including plutonium) which are accumulated mainly in the bottom sediment. The Black Sea is at risk of radiation contamination as an inland sea in the catchment area of which there was a major radiation accident at the ChNPP and there are located developed countries using nuclear technologies, in particular nuclear power industry. In 2016 in the Russian Federation 10 nuclear power plants are in operation. Also 4 nuclear power plants operating in Ukraine, located on the territory of the Black Sea basin, 146 nuclear power plants operating in the territory of the European Union, 1 nuclear power plant in Armenia, Turkey is planning to build the first nuclear power plant too (IAEA 2015; World nuclear 2016). At the same time, the Black Sea is an important source of seafood, mining, and also has great recreational resource.

The main global source of technogenic radioisotopes in the Black Sea is fallout from nuclear weapons testing in the atmosphere (maximum of these fallouts related to the 60th years of the twentieth century). The second most important source of radioactive the $^{238,239,240}Pu$ contamination served the accident on ChNPP (with a peak in 1986). The Black Sea received radioactive contamination by anthropogenic radionuclides directly from the atmosphere fallout and indirectly as runoff from rivers: in the case of the Chernobyl accident they were Dnieper, Bug, Dniester and Danube rivers predominantly (Gulin et al. 2002). Total inventory of $^{239,240}Pu$ to the Black Sea from the two main sources was estimated at 35.15 TBq from the global fallout and 4.61 TBq from the Chernobyl fallout (Polikarpov et al. 2008).

Modern levels of $^{239,240}Pu$ contamination in the Black Sea water are relatively low. However, it is important to study distribution and biogeochemical behavior of these radionuclides in marine environment and different biogenic components of sea ecosystems. In addition we can to investigate radioecological regularities of plutonium migration in and through the sea using the radioactive plutonium contamination of the Black Sea as a radioactive tracer of natural biogeochemical processes in marine ecosystem. To identify features of radioecological behavior of plutonium in the Black Sea is significant for the open (because the Black Sea, in contrast to other seas, is characterized by the reduction zone) and especially for coastal areas, which are widely used for the cultivation and production of seafood and recreation, and are limited habitat area for biocenoses of benthonic and other oxibionts as the Black Sea depth waters (deeper than 150–200 m) are contaminated with hydrogen sulfide (Skopintsev 1975; Eremeev and Konovalov 2006). Understanding of plutonium pathways will enable to carry out the forecasting of its migration in the ecosystems, prediction of the state of the Black Sea under different radioecological situations, including emergencies, and development of science–based recommendations for minimization of consequences of different nuclear accidents. It is important to evaluate currently the irradiation dose rates of the $^{239,240}Pu$ on the Black Sea hydrobionts of different trophic levels.

So the aim of our investigation was to study the contamination of the Black Sea ecosystem components (water, bottom sediment and hydrobionts) by plutonium alpha–radionuclides $^{239,240}Pu$, determine and analyze quantitative characteristics of plutonium migration in the Black Sea ecosystems and apple a comparative analysis together with equidosimetric approach to the ecological effects assessment from $^{239,240}Pu$ on hydrobionts in contemporary radiological situation in the Black Sea and in different potential radioecological situations in wide range of alpha–emitting plutonium radionuclides concentration activity in seawater.

16.2 Material and Methods

16.2.1 Place of Sampling and Research Objects

Studies of the radioecological state of the Black Sea ecosystem have been performed in the period between 1986 and 2014. The $^{238,239,240}Pu$ alpha–radionuclides were analyzed in abiotic and biotic components of the Black Sea ecosystems in open and coastal areas mainly from the west, north-western and central part of the sea. To analyze the samples of surface water (2–5 m^3), bottom sediment (total sample height 5 cm and vertical column for cutting layers with 0.25, 0.5, 1 or 2 cm) and hydrobionts were taken. Among the Black Sea hydrobionts following indicators were selected: macroalgae – *Phyllophora crispa* (Hudson) P.S. Dixon, *Cystoseira crinite* Duby, *Ulva rigida* C. Ag., bivalves – *Mytilus galloprovincialis* Lamark, 1819; crab – *Carcinus maenas aestuarii* Nardo, 1847; and fish – *Trachurus mediterraneus ponticus* Aleev, 1956, *Sprattus sprattus phalericus* Risso, 1827 and *Merlangius merlangus euxinus* Nordmann, 1840 (Tereshchenko et al. 2007, 2013, 2014; Polikarpov et al. 2008).

16.2.2 Methods of Investigation

Determination of $^{238,239,240}Pu$ was carried out according to accepted radiochemical techniques (Polikarpov et al. 2008; Tereshchenko et al. 2011). The plutonium alpha-samples were then analyzed with the "EG & G ORTEC OCTETE PC" alpha–spectrometer. The ^{242}Pu was added to the samples, as a radiotracer standard to determine the chemical yield. The total error of the $^{239,240}Pu$ activity concentration determination was not more than 20% but error of the ^{238}Pu determination was more than 50% due to its low levels of concentration activity in the samples.

Quantitative parameters of radioecological processes of plutonium redistribution in the Black Sea ecosystems calculated by well known methods (concentration factor (C_f), factor of radiocapacity (F_r), effective half–life ($T_{1/2ef}$), (Polikarpov and Lasorenko 1992; WOMARS 2005; Polikarpov et al. 2008) and by the techniques developed in the Department of Radiation and Chemical Biology of IMBR (sedimentation rate (SR), sedimentation rate of suspended matter (MAR), sedimentation flux (F_{sed}) (Polikarpov et al. 2008; Gulin et al. 2002, 2012; Egorov et al. 2013).

Absorbed dose rates ($D_{ab}R$, Gy/year) and equivalent dose rates ($H_{eq}R$, Sv/year) for the Black Sea hydrobionts were calculated in accordance with widely accepted procedures (Blaylock et al. 1993; Amiro 1997; Polikarpov et al. 2008). To assess the level of environmental impact of ionizing radiation doses of the plutonium alpha–radionuclides was used Polikarpov's conceptual model of chronic action zonality of ionizing irradiations dose rates in the nature (Polikarpov 1998; Polikarpov et al. 2008) was used. The obtained results were compared with the scale of Polikarpov's zones of chronic dose rates and their effects in the ecosystem, as well as with the limit of safe dose rate of ionizing radiation for hydrobionts (IAEA 1992). For analysis was used our own data and published data.

16.3 Result and Discussion

After the accident on the ChNPP an additional (to the global fallout) contamination has occurred in the Black Sea, including radioactive isotopes of plutonium. Compared to other marine areas, the Black Sea has undergone a severe radioactive contamination due to proximity to a source (CNPP) the sea itself as well as a large part of its catchment area, which includes two major rivers – the Danube River and the Dnieper River. Black Sea fell into one of three zones with a higher density of radioactive Chernobyl fallout – a zone of so–called "southern trace" (Izrael 1990; Chernobyl accident 1995; Polikarpov et al. 2008). Pollution data of the land territory of Ukraine and Crimea by plutonium evidenced input of plutonium in the Black Sea from radioactive atmospheric fallout after the accident on CHNPP. According to these data the deposition zone with a density of plutonium radioisotopes up to 110 Bq m^{-2} reached the part of the Crimean Peninsula and other regions of the Black Sea coast (Chernobyl accident 1995). Already in the first months after the ChNPP accident the plutonium isotopes were recorded as part of the Chernobyl fallout in the surface waters of the Black Sea. As a result of deletions in surface waters were formed the ^{239,240}Pu Chernobyl origin concentration activity in the range 3.5–8.5 and the total (Chernobyl and global origin) concentration – 7–17 mBq m^{-3} (Buesseler and Livingston 1996). The ratio of global ^{239,240}Pu to Chernobyl ^{239,240}Pu was about 1:1. During this period inputs of Chernobyl radioactive contamination in the Black Sea evidenced a relatively high concentration activity of ^{242}Cm, since this radionuclide having a short half–life (163 days), was characterized by a relatively high content of the Chernobyl fallout in the first years after the accident. The TUE maximum concentration activity data in the open western and southern parts of the Black Sea in the surface water in 1986 after the Chernobyl accident are presented in Fig. 16.1 (Polikarpov et al. 1990, 1991; Buesseler and Livingston 1996; Polikarpov et al. 2008).

In the following years in addition to atmospheric radioactive fallout, one of the main sources of income of plutonium isotopes in the Black Sea was the river runoff (Polikarpov et al. 1990, 1991). The main rivers were Dnieper River and Danube River.

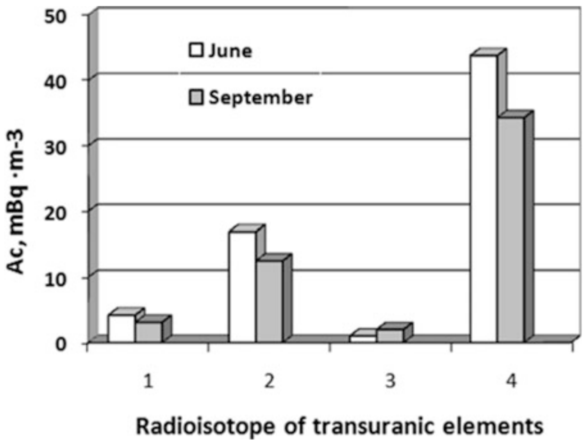


Fig. 16.1 The concentration activity (A_c) of radioisotopes of different transuranic elements in surface water in the Black Sea open area in June and September of 1986, where: *1* – ^{238}Pu, *2* – ^{239,240}Pu, *3* – ^{241}Am, *4* – ^{242}Cm

16.3.1 Alhpa-Radioisotopes of Plutonium in the Black Sea Water

In the 1986–1989 study of ^{238}Pu and ^{239,240}Pu concentration activity in the Black Sea water showed that the activity ratio of ^{238}Pu/^{239,240}Pu was approximately 0.1–0.3 in the central and southern parts of the sea (Polikarpov et al. 1990, 2008; Tereshchenko et al. 2014, 2016). This date indicated that the total concentration activity of plutonium caused by radioisotopes from the Chernobyl fallout as well as from the global fallout, because the activity ratio of ^{238}Pu/^{239,240}Pu were about 0.036 for plutonium isotopes from the global fallout and 0.4–0.5 for plutonium isotopes from the Chernobyl fallout. The activity ratio of these components depended on the history and routes of the Chernobyl radioactive contamination. In general, the plutonium isotopes of the Chernobyl origin accounted for a smaller part of the total contamination.

A different situation was observed in the North–western Black Sea, where the input of radionuclides with river runoff (Dnieper, the Danube, Dniester, Southern Bug rivers and the North Crimean Canal) was significant, along with atmospheric fallout (Polikarpov et al. 1990). In the north–western part of the sea and the estuarine areas ^{239,240}Pu concentration activity was of approximately 0.3–1.1 Bq m^{-3} in 1986–1988 (Fig. 16.2), wherein the ratio of ^{238}Pu/^{239,240}Pu varied in the range 0.4–0.5, indicating that a prevailing share of the Chernobyl plutonium isotopes in their total amount in these areas But even such a relatively high concentration activity of plutonium in the seawater were several orders of magnitude below the permissible concentrations of these radionuclides, and it did not threaten either human health or hydrobionts (NRB-99/2009 2009).

The plutonium input to the Black Sea and its migration from the catchment area led to formation of maximum concentration activity of ^{239,240}Pu in estuarine waters at the north–western part of the sea for the next few years after the accident on ChNPP. But over time the difference of the ^{239,240}Pu concentration activity levels in

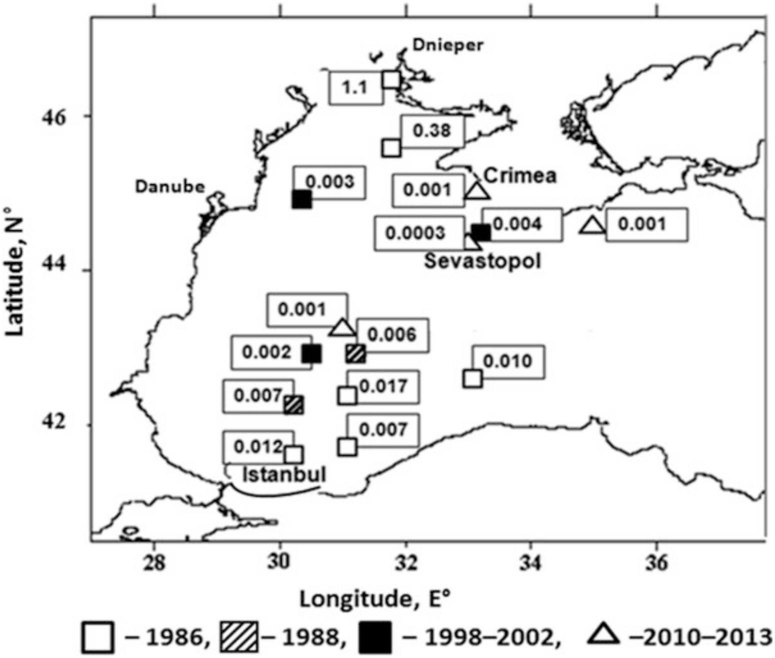


Fig. 16.2 The concentration activity of the ^{239,240}Pu (Bq·m^{-3}) in surface water in different areas of the Black Sea during period after accident on the Chernobyl nuclear power plant

water at near estuaries and the open sea areas have declined markedly (IAEA 2004; Polirarpov et al. 2008).

By the beginning of the 1990s, it was 4.1–6.4 mBq m^{-3} in the deep water area of the central and southern parts of the sea, 7.0–11.0 mBq m^{-3} near the north–eastern coast and by the end of the 1990s it has decreased to 3.0–4.0 mBq m^{-3} in the western parts of the Black Sea, as well as near the Crimean coast (Polikarpov et al. 1991; Sanchez et al. 1991; Buesseler and Livingston, 1996; IAEA 2004; Polikarpov et al. 2008; Tereshchenko et al. 2014, 2016). In subsequent years, the ^{239,240}Pu concentration activity in sea water decreased (Fig. 16.2).

16.3.2 The ^{239,240}Pu Effective Half–Life in the Black Sea Surface Waters

Consideration of changes in the plutonium concentration activity in the aftermath of the Chernobyl accident showed that in that period the concentration activity of ^{239,240}Pu was characterized by an exponential decrease in time in surface waters of the Black Sea (Fig. 16.3).

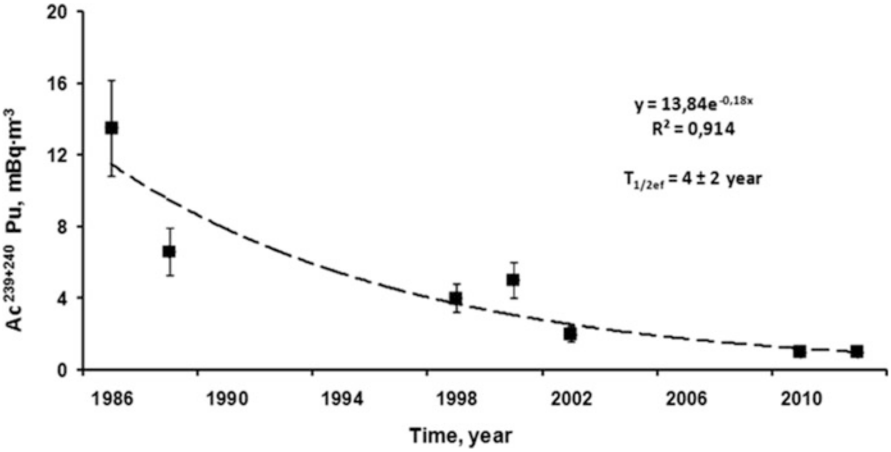


Fig. 16.3 Time trend of the concentration activity of ^{239,240}Pu in surface water of the Black Sea in open area during period after accident on the Chernobyl nuclear power plant in 1986–2013, where: points are data of natural observations, the approximation curve and the equation that describes the approximation curve

The analysis of the equation that describes the approximation curve is reflecting the reduction of the concentration activity of ^{239,240}Pu in the surface water, allowed to estimate the rate of elimination of ^{239,240}Pu from the Black Sea surface water (Tereshchenko et al. 2014, 2016). It was found that the time of reducing the concentration activity of ^{239,240}Pu in 2 times in surface waters (called the effective half–life of radionuclide in surface waters – $T_{1/2ef}$) was 4 ± 2 years (Tereshchenko et al. 2016). Consequently, for the radionuclides plutonium ^{239,240}Pu $T_{1/2ef}$ is lower than that obtained by a similar method for ^{137}Cs (7 years) in the Black Sea water. Also, $T_{1/2ef}$ of ^{239,240}Pu in the Black Sea is about two times less than that one of the ocean waters, which is the average for surface waters of the Pacific – 7.4 ± 1.1, Indian – 9.0 ± 1.7, the Atlantic – 9.1 ± 0.5 years (WOMARS 2005).

16.3.3 Influence of Properties of the Sea Water and Pu on Its Migration

More rapid elimination of plutonium from the Black Sea surface water can be explained by the properties of plutonium and special conditions of the sea that affect the intensity of the biogeochemical processes that are specific to the Black Sea (Table 16.1). (Skopintsev 1975; Zalogin and Kosarev 2000; Ivanov and Belokopytov 2011; Finenko et al. 2011; Egorov et al. 2013).

Pu as a polyvalent element with high sorption activity has an ability to strongly bind to the particles of suspended matter and this connection under reducing conditions is enhanced (Plutonium 2003; Morss et al. 2008) and decreases Pu

Table 16.1 Comparative characteristic of some properties of the Black and Mediterranean seas

Property of the sea	Black Sea	Mediterranean Sea
Area	0.41×10^6 km^2	2.5×10^6 km^2
Catchment area	2.3×10^6 km^2	6.2×10^6 km^2
Specific catchments (A/C.ar)	5.6	2.5
Runoff	350 km^3·year^{-1}	420 km^3·year^{-1}
Volume	536 000 km^3	3600 000 km^3
Specific runoff (R/V)	6.5×10^{-4}	1.2×10^{-4}
Transparency of water (open area)	20–25 m	50–60 m
Concentration of Chl "a" (open area)	0.5–3.0	0.1–0.3
Trophic level (open area)	Mesotrophic	Oligotrophic
Redox conditions	Oxidizing (0–150 m), reducing (200–2200 m)	Oxidizing

remobilization in the reduction hydrogen sulphide zone of the Black Sea. A more rapid Pu settling to the bottom sediment with suspended matter promote redox conditions in the transition redox zone of the sea, where the change of the oxidizing conditions on the reducing in the water causes the Pu co–precipitation with iron and manganese, which are transformed under these conditions from dissolved to the suspended form (Morss et al. 2008). Mesotrophic status of waters in the open sea and a large runoff of extensive Black Sea catchment basin lead to increase in the number of suspended matter of biogenic and terrigenous origin. There are two factors: increased adsorption on the particles and increasing the number of suspended matter provide more strong plutonium flux with the biogeochemical sedimentation in the bottom sediment and short time of plutonium stay in the surface waters in the Black Sea as compared with the Mediterranean waters. In Table 16.1 are some properties of the seas that led to more amount of particulate matter in the Black Sea compared with the Mediterranean Sea.

Dynamics of the percentage of suspended plutonium with depth in the Black Sea water confirmed these biogeochemical processes (Table 16.2.)

On the one hand, the contribution of the trophic level of water and the redox properties of the Black Sea waters and on the other hand, the physical–chemical properties of plutonium can be traced by comparing the quantitative parameters of the migration of Pu and Cs in the Black and Mediterranean Sea.

The plutonium and cesium residence time in the surface waters of the Mediterranean Sea is longer than in the Black Sea waters, as indicated by the value of the effective half–lives of these radionuclides (Table 16.3). In the Mediterranean Sea, with oligotrophic waters (Table 16.1), which is characterized by a smaller amount of suspensions, plutonium and cesium as the binding element with particulate matter, are staying for a longer period in the surface waters. In the post–Chernobyl period $T_{1/2ef}$ Pu = $T_{1/2ef}$ Cs = 13 years as well as in period before accident on ChNPP when it was equal to 11 years (WOMARS 2005). Some increase in $T_{1/2ef}$ of

Table 16.2 Influence of the redox Black Sea conditions on the biogeochemical Pu behavior in the sea water

The Black Sea			
Zone of the sea	Depth of water, m	Part of the ^{239,240}Pu on suspended matter, %[a]	Main features of biogeochemical Pu behavior
Oxidizing zone	5	70–73	Associating of Pu with a suspension and remobilization in the water masses as a result of suspended matter oxidation.
	50	1–40	
	70	20–29	
Redox zone	110	76–100	Co–precipitation of plutonium with iron and manganese, transition of plutonium in the suspended form
	150	59–93	
Reducing zone	800	63–92	Stable link reduced forms of plutonium with a suspension and inhibition of suspended matter oxidation in reducing conditions: decrease of Pu remobilization in the water.
	1800	73–100	

[a]The calculation is performed according to the published data (Sanchez et al. 1991)

the radionuclides in the post-Chernobyl period may be linked to the duration of receipt of Chernobyl contamination.

The degree of cesium sorption by particulate matter can affect the availability of its chemical analogue – potassium in seawater. However, this factor is present in Black Sea and in the Mediterranean Sea, where potassium is contained in a sufficient amount and is about 0.03 and 0.05% by weight, respectively. On the Cs lower sorption activity indicates also lower the Cs accumulation concerning to bottom sediments and suspended matter (Table 16.3). The Cs larger $T_{1/2ef}$ compared to the Pu $T_{1/2ef}$ in the Black Sea is obviously connected with the physical–chemical properties of this element. Though it is chemically very active, but it has one degree of oxidation. So, Cs is not affected by the redox conditions in the Black Sea, experienced by plutonium. The experimental study results of the cesium accumulation by bottom sediment in different redox conditions have shown that the latter have little effect on the cesium sorption by bottom sediment (Polikarpov and Lazorenko 1992). The difference between physical–chemical properties of plutonium and cesium and the presence of specific redox conditions in the Black Sea led to the fact that the difference of the Pu $T_{1/2ef}$ in surface waters for the compared seas 3 years exceeds the difference of the Cs $T_{1/2ef}$ in surface waters in the Mediterranean and Black Sea (Table.16.3), which amounts to 33%. Perhaps this is the percentage that gives an estimate the impact of specific physical–chemical characteristics of the Black Sea waters and plutonium properties on its redistribution processes in the ecosystems of the seas.

The intensity of the plutonium elimination determines the rate of self–purification of the Black Sea surface water by biogeochemical processes of ecosystem functioning, including some biotic components (in particular, the production processes that serve as an indicator of trophic level of water) and physical–chemical transformations, which led to the formation of more powerful biogeochemical sedimentation plutonium fluxes into bottom sediment.

Table 16.3 Characteristics of plutonium and cesium migration properties in the Black and Mediterranean Sea, where: $T_{1/2ef,}$ – effective half–lives of radionuclide in surface water, C_f – concentration factor of radionuclide

Name of sea	$T_{1/2ef,}$ year (%)		C_f of sediments		C_f of suspended matter	
	$^{239+240}Pu$	^{137}Cs	$^{239+240}Pu$	^{137}Cs	$^{239+240}Pu$	^{137}Cs
Mediterranean Sea	13 (100)	13 (100)				
Black Sea	4 (31)	7 (54)	$n \times 10^4$–10^5	$n \times 10^2$	$n \times 10^4$–10^6	$n \times 10^3$

A lower value of the Pu $T_{1/2ef}$ in the Black Sea (4 years) indicates the higher (respectively, more than 3 times) rate of self–purification of the Black Sea surface water against Pu than in the Mediterranean Sea due to the more intense process of sedimentation. This process contributes to the Pu accumulation in sediment and should cause a difference in the plutonium redistribution in the seas ecosystems. The field investigations of the specific activity of water and bottom sediment regards to Pu in the Mediterranean (Papucci et al. 1996; Choppin and Pamela 1998) and the Black Sea (Baloga 1994; Strezov et al. 1996; IAEA 2004; Tereshchenko and Polikarpov 2007; Tereshchenko et al. 2014, 2016) and evaluation, based on them, plutonium inventory in the water column and bottom sediment, confirmed that the high rate of self–purification of the Black Sea water masses led to a significant Pu redistribution difference between water and sediment in the compared seas (Tereshchenko and Polikarpov 2007). Only about 11% of $^{239,240}Pu$ in the Black Sea is concentrated in the water column and in the sediment – 89%, whereas in the Mediterranean sea in open area the prevailing amount of plutonium is in the water column – about 95% and in bottom sediment – only 5% (Papucci et al. 1996; Tereshchenko and Polikarpov 2007).

Therefore, in the Mediterranean Sea plutonium exhibits hydrotropic type of biogeochemical behavior, as the prevailing part of it is concentrated in the water masses (Papucci et al. 1996; WOMARS 2005). In the Black Sea plutonium concentrates in sediments and shows pedotropic type of biogeochemical behavior. As a result, different types of biogeochemical behavior of plutonium in these seas and high speed self–purification of surface waters in the Black Sea against plutonium it becomes possible to change the direction of the resultant plutonium flow between the seas.

16.3.4 The $^{239+240}Pu$ Flows Through the Bosphorus Strait

As it is known, the movement of water through the Bosphorus Strait comes from the Black Sea by upper course and into the Black Sea – by lower course of the sea water. According to data of different authors on the water exchange through the Strait annual volumes of water passing through the Bosporus vary several times (Ivanov and Belokopytov 2011). Therefore, average annual volumes of seawater flowers were used by us in the calculations from the Black Sea by upper

Table 16.4 The $^{239+240}Pu$ flows through the Bosphorus Strait in the post–Chernobyl period

Period of investigation, year	The $^{239+240}Pu$ flow through the Bosphorus Strait, GBq·year^{-1}		
	Outflow from the Black Sea by upper course	Input into the Black Sea by lower course	The resultant $^{239+240}Pu$ flow into the Black Sea
1986	4.34	2.90	−1.44
1990	2.79	2.31	−0.48
1992	1.88	2.06	+0.42
1994	1.27	1.81	+0.54
2002–2003	0.62	1.29	+0.67
2012–2014	0.18	0.58	+0.40

course – 362 km^3·year^{-1} and into the Black Sea by lower course – 145 km^3·year^{-1}. Estimates of the $^{239+240}Pu$ fluxes in different periods after the accident on the ChNPP through the Bosporus Strait were made on the basis of data on the $^{239+240}Pu$ concentration activity in marine surface waters in the Black Sea (Tereshchenko et al. 2014, 2016) and Mediterranean Sea (WOMARS 2005; Tereshchenko et al. 2011) are presented in Table 16.4.

As can be seen from the above data, immediately after the Chernobyl fallout in 1986, the resulting average annual $^{239+240}Pu$ flow with Bosphorus waters was directed to the Mediterranean Sea. The $^{239+240}Pu$ outflow through the Bosporus exceeded its entry into the Black Sea (Table 16.4). After a few years as a result of biogeochemical processes the $^{239+240}Pu$ redistribution in the ecosystems of these seas was occurred. The $^{239+240}Pu$ input into the Black Sea through the Bosporus began to exceed its outflow, although the volume of entering water by the Bosporus lower course 2 times less than that one by the Bosphorus upper course. This was due to the fact that the self–purification surface waters from plutonium in the Black Sea occurred more intensively, and the $^{239+240}Pu$ concentration activity in the Black Sea waters decreased more rapidly than that one in Mediterranean waters (Table 16.3). By 2002, the number of the removing $^{239+240}Pu$ from the Black Sea has decreased by more than 7 times, and the incoming $^{239+240}Pu$ in the Black Sea by the Mediterranean waters decreased only 2.2 times (Table 16.4). As a result of these changes the Mediterranean waters in 2012–2014 continued to be a source of the $^{239+240}Pu$ contamination of the Black Sea water.

Therefore, without being attached to the accuracy of the absolute values of input of plutonium radioisotopes into the Black Sea by the Mediterranean waters, given the inaccuracy of quantitative estimates of water exchange through the Bosporus Strait (Ivanov and Belokopytov 2011), as well as the possible influence of other factors on these processes, we can conclude that, depending on the ratio of the level of $^{239+240}Pu$ concentration activity in the water of the seas and the volume of water passing through the Bosphorus by the upper and the lower Bosphorus course the direction of $^{239+240}Pu$ transport between the seas was changed.

The Mediterranean Sea at a certain phase in the period after the accident on the ChNPP acted as a source of the entering $^{239+240}Pu$ into the Black Sea, although this sea is more distant from the source of contamination (ChNPP). The Black Sea, on the contrary, served as a biogeochemical barrier on the way of the Chernobyl plutonium migration from the Black Sea catchment area into the Mediterranean Sea basin. So, it appears the plutonium pedotropic type of biogeochemical behavior in the Black Sea ecosystem and the high rate of self–purification of surface waters against $^{239+240}$Pu in the Black Sea on the plutonium flows and their direction between the seas.

16.3.5 Alhpa-Radioisotopes of Plutonium in the Black Sea Bottom Sediments

The study of the spatial distribution of $^{239+240}$Pu in the Black Sea sediments showed that, as the distribution in water, it was of patchy (Fig. 16.4) (Strezov et al. 1996; IAEA 2004; Tereshchenko et al. 2013; Tereshchenko et al. 2014, 2016). On the one hand, this is due to the composition of bottom sediment, and on the other hand – with a history of the $^{239+240}$Pu input and, in particular, proximity to the Dnieper–Bug estuary, as well as to the Danube and North Crimean channel mouth, and hence with the levels of concentration activity of water in relation to $^{239+240}$Pu and with the rate of the sedimentation fluxes of particulate matter (Tereshchenko et al. 2013, 2016).

16.3.6 Sedimentation $^{239+240}$Pu Fluxes into Bottom Sediment

Application of radiotracer technologies using man–made radioactive isotopes, input into the Black Sea ecosystem due to nuclear events (Gulin et al. 2002, 2012; Polikarpov et al. 2008), allowed values of sedimentation rate (SR), the particulate matter accumulation rate (MAR) and the $^{239+240}$Pu sedimentation fluxes. The obtained results showed that the plutonium fluxes depends on both the $^{239+240}$Pu concentration activity in the water and on the rate of sedimentation processes, trophic level of seawater area and the distance from sources of terrigenous suspended matter. In general, in the areas of open sea SR was 0.4–0.9, on the continental slope – about 2.2, in nearshore areas – from 2.4 to 11.5 mm/year. The highest values of SR confined to the estuarine areas of the Danube, the Dnieper and the Bug (Gulin et al. 2002; Polikarpov et al. 2008).

Decrease of the $^{239+240}$Pu in water with time (Fig. 16.2 and 16.3) led to lower plutonium sediments fluxes in bottom sediment and falling asleep sediment with high content of $^{239+240}$Pu the cleaner bottom sediment. This is confirmed by data on the vertical distribution of the $^{239+240}$Pu concentration activity of sediment (Fig. 16.5) (Tereshchenko et al. 2016).

Method of geochronological dating of sediment made it possible to determine the depth of the maximum of the Chernobyl and global fallout and calculate the

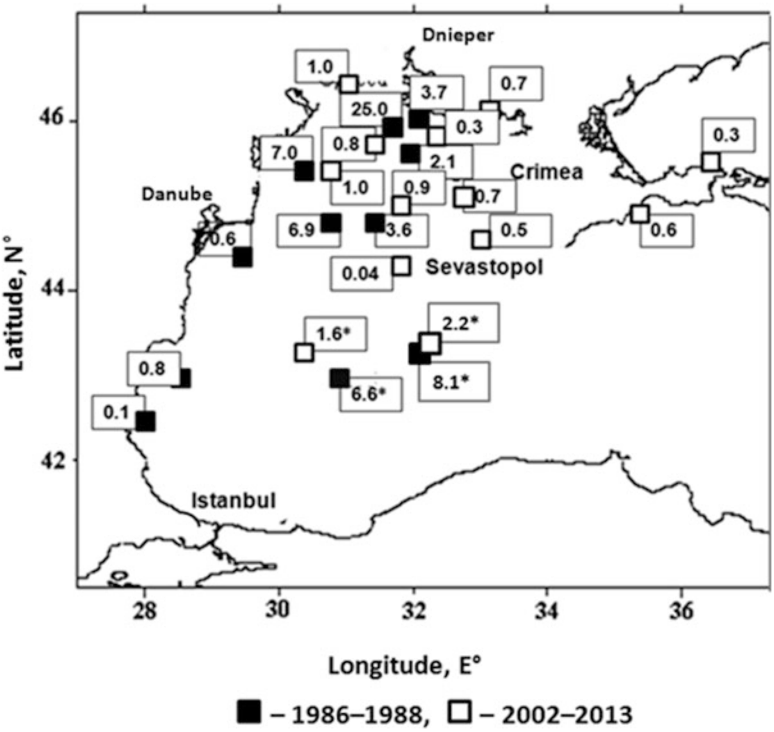
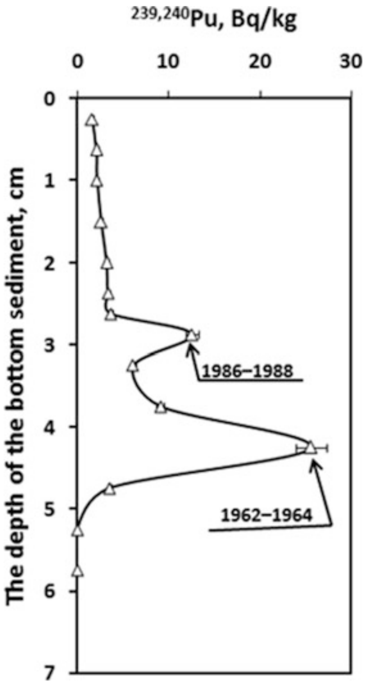


Fig. 16.4 The concentration activity of the ^{239,240}Pu, Bq·kg^{-1} d.w. in surface layer of bottom sediment (0–5 cm) in the Black Sea during period after accident on the Chernobyl nuclear power plant: *– surface layer 0–1 cm

average plutonium fluxes in different period before and after the Chernobyl accident (Gulin et al. 2002; Tereshchenko et al. 2012, 2016; Egorov et al. 2013) In open area in the Western Black Sea annual average fluxes of $^{239+240}$Pu ranged from 0.53 to 6.07 Bq·m^{-2}·year^{-1}. In 1962–1963 – maximum of the global fallout was 6.07, in 1986–1988 – maximum of the Chernobyl fallout – 3.16 and now – 0.53–0.55 Bq m^{-2} year^{-1}. So, the density of the maximum of Chernobyl fallout was less 2 times compared with the maximum of global fallout in the open area of the Western Black Sea. In this layer the ratio of ^{238}Pu/$^{239+240}$Pu was equal 0.34 and it exceeded the global ratio 19 times. The rest of the plutonium amount replenished radioactive contamination from the global fallout. After the peak of receipt of the Chernobyl contamination in the next time–point the ratio of ^{238}Pu/$^{239+240}$Pu decreased to 0.03–0.04, and the proportion of Chernobyl plutonium also fell to 2–5%. Thus, the basic amount of plutonium Chernobyl origin arrived in the deep zone of the Black Sea primarily through atmospheric transport in the first period after the accident on the Chernobyl nuclear power plant but the main source of Pu contamination of the Black Sea is the global fallout (Fig. 16.5).

Fig. 16.5 Depth distribution of the $^{239,240}Pu$ concentration activity of the Black Sea bottom sediment in open area and maximum of the global (1962–1963) and Chernobyl (1986–1988) fallout

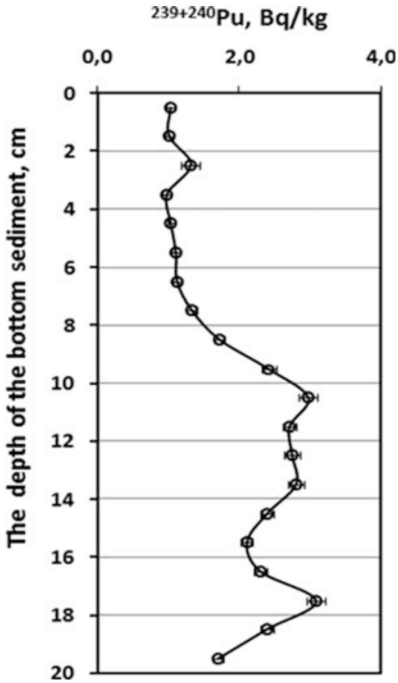


The density of radioactive fallout was varied in different area of the Black Sea and in coastal area the $^{239+240}Pu$ average fluxes ranged from 1.08 to 3.813 Bq m^{-2} year^{-1}. It depended on the $^{239+240}Pu$ concentration activity in the water and SR which ranged from 2 to 6 mm year^{-1} in Sevastopol sea area and that was significantly higher than SR in open area. The depth distribution of the $^{239,240}Pu$ concentration activity of the Black Sea bottom sediment in Sevastopol sea area is presented in Fig. 16.6 (Tereshchenko et al. 2016). The maximum of the Chernobyl fallout was on depth about 7–8 cm, it was deeper than in open area 2.7 times and the $^{239+240}Pu$ fluxes in that time were 2.27 Bq m^{-2} year^{-1} for maximum of the Chernobyl fallout. In this layer the ratio of $^{238}Pu/^{239+240}Pu$ was equal 0.036 that exceeded this ratio in global fallout only about 2 times. In period of maximum of the Chernobyl and global radioactive fallout the $^{239,240}Pu$ concentration activity of the Black Sea bottom sediment in open area was higher than in coastal area, but the contaminated layers are lower several times.

16.3.7 Plutonium Radiocapacity Factor of Bottom Sediment

Integral characteristic to evaluate a role of bottom sediment in the redistribution of the radionuclide in the water ecosystems is radiocapacity, as a measure of the ability of sediment to accumulate and retain radioactive substances, originally

Fig. 16.6 Depth distribution of the $^{239,240}Pu$ concentration activity of the Black Sea bottom sediment in nearshore zone



input into the water environment. As a quantitative measure of radiocapacity used the radiocapacity factor (F_r, %) (Polikarpov and Lasorenko 1992; Tereshchenko et al. 2012; 2016). As a relative value, it refers to the proportion of the radionuclide, which accumulates by sediment from the water column, and depends on the accumulative ability of sediment, as well as the depth of the water and the thickness of the accumulating layer of sediment. The values of the radiocapacity factor for Black Sea bottom sediment against Pu were calculated on the basis of field observations and expressed as a percentage, are shown in Fig. 16.7 (Tereshchenko 2011; Tereshchenko et al. 2014).

If we compare F_r of Pu with those of cesium and strontium, it is becoming obviously the differences between the biogeochemical Pu behavior and Cs, Sr behavior (Fig. 16.7). As it is well known, strontium refers to hydrotropic radionuclides (Polikarpov and Lasorenko 1992). It remains in the water and moves with the water masses (including outside of the Black Sea), and the sediment accumulates it very little (Polikarpov et al. 2008), so the F_r of Sr equals to the thousandths of a percent. Although cesium in freshwater ecosystems refers to pedotropic radionuclides (Polikarpov and Lasorenko 1992), but its accumulation in sediment greatly affect the redistribution of the system "water – bottom sediments" only on the shelf of the Black Sea (Fig. 16.7), Cs soon shows properties of equitropic element, it more evenly distributed between the main components of the aquatic ecosystem: water – bottom sediment – biota. The bottom sediments of the continental slope and the Black Sea deep basin accumulate Cs in a less degree, the principal amount of

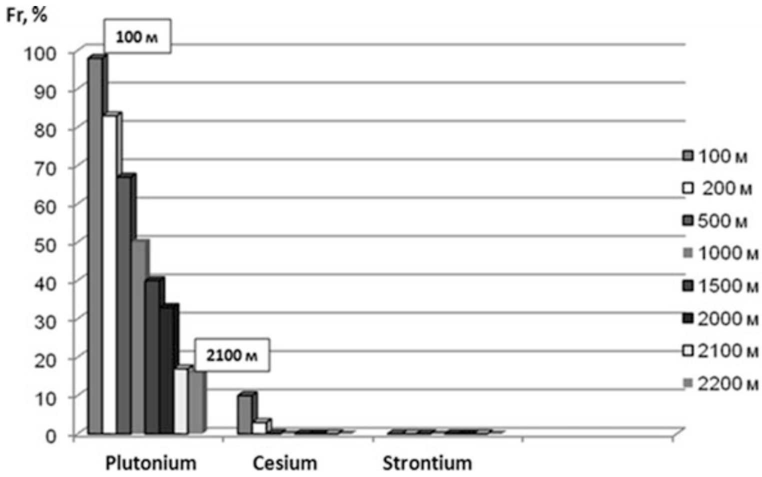


Fig. 16.7 Comparative characteristics of radiocapacity factor (F_r,%) of the Black Sea silt bottom sediment against radionuclides of $^{239+240}$Pu (Tereshchenko 2011; Tereshchenko et al. 2012; 2016), ^{137}Cs and ^{90}Sr (Polikarpov and Lasorenko 1992; Polikarpov et al. 2008)

which remains in the body of water and can migrate outside the sea. Plutonium has the highest F_r of Pu both on the shelf and in the regions of the continental slope and the Black Sea deep basin. At depths of 100–200 m silt bottom sediment can accumulate about 98% of the radionuclide and at great depths – from 14 to 30% against to the Pu inventory in the water column (Tereshchenko et al. 2012). The high F_r of Pu defines a relatively rapid depletion it of the Black Sea water masses and reduction of its outflow outside the Black sea with water masses.

16.3.8 Alhpa–Radioisotopes of Plutonium in the Black Sea Hydrobionts

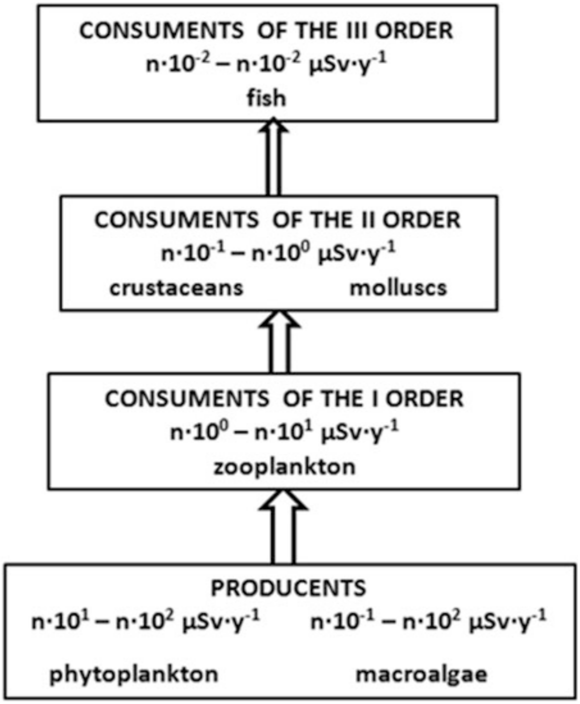
Results of the analysis of ^{239,240} Pu concentration activities (mBq kg^{-1} ww) in the Black Sea hydrobionts were shown that the activity levels were relatively low. The concentration in brown algae *Cystoseira crinita* and *C.barbata* varied from 1.0 to 13.6, in green algae *Ulva rigida* it did not exceed 1.2, in bivalve *Mytilus galloprovincialis* it ranged from 0.8 to 2.4 mBq kg^{-1} ww, and in fish *Merlangius merlangus euxinus, Sprattus sprattus phalericus* and *Trachurus mediterramium ponticus* it ranged from 0.3 to 1.8 mBq kg^{-1} (Polikarpov et al. 2008; Tereshchenko 2005, 2013). The concentration of ^{239,240} Pu in *Phyllophora crispa* from different areas of the Black Sea varied from 53 ± 2 2 to 95 ± 10 mBq kg^{-1} ww. But biogenic components – bottom sediment of the Black Sea ecosystems accumulated plutonium intensively and some taxonomic groups of the Black Sea biota were characterized with high values of plutonium concentration factor (C_f) (Tereshchenko et al.

2007; Tereshchenko 2013). The Black Sea studied hydrobionts can be placed in the following order with a decrease in accumulative ability for radionuclides ^{239,240} Pu according to the value of the plutonium^{239,240}Pu concentration factor (C_f (Pu)): phytoplankton (1×10^4–10^5) > macroalgae (1×10^2–10^4) > zooplankton (1×10^3) > bivalves (5×10^2) > crab (1×10^2) > fish (1×10^2). However the C_f (Pu) of the Black Sea sediment of 2–3 orders of magnitude higher than the C_f (Pu) of hydrobionts, besides the biomass of marine organisms is little significant part in the sea ecosystem, so unlike the shallow freshwater highly productive ecosystem, where biomass is an important part of the ecosystem marine organisms in the Black Sea do not play a significant role in deposition of plutonium, but increase the flux of plutonium up the food chain to the person consuming sea products as plutonium concentration activities in hydrobionts by 2-3-5 orders of magnitude higher than in the sea water. Therefore the Black sea hydrobionts suffer the increased radiation exposure from alpha–radiation of the incorporated Pu radionuclides.

16.3.9 Internal Exposure Doses from Alpha–Radiation of Plutonium on the Black Sea Hydrobionts

Based on our own results and the published data on the levels of anthropogenic plutonium contamination of marine organisms, the internal exposure doses of biogenic components of the Black Sea ecosystem from these radioisotopes have been determined. The contemporary radioecological situation in the Black Sea after the Chernobyl accident is safe (Polikarpov et al. 2008; Tereshchenko et al. 2014). The range of absorbed dose rates of internal exposure from alpha–radiation of ^{239,240}Pu that incorporated into Black Sea hydrobionts was 0.01–4.94 μGy year^{-1}, and equivalent dose rates was 0.24–98.84 μSv year^{-1}. The maximum radiation exposures observed for the Black Sea organisms were for phytoplankton and red macroalgae *Ph. crispa*. In general, the observed equivalent dose rates for the Black Sea hydrobionts were 4–7 orders of magnitudes lower than the limit of safe dose rate of 4 Sv·year^{-1}, and were not a threat to the Black Sea hydrobionts. The average annual equivalent dose rate ($H_{eq}R$) of $^{239+240}$Pu on the Black Sea hydrobionts varied range by $n \cdot 10^{-2}$ to the $n \cdot 10^2$ Sv year^{-1} (Fig. 16.8). The highest radiation doses from plutonium alpha radionuclides for the Black Sea aquatic organisms of different trophic levels observed in members of the lower links of the food chain. In general, in the transition from the lower to the higher trophic level of amplification degree of plutonium migration is reduced by about an order of magnitude (Fig. 16.8).

Fig. 16.8 The level of equivalent doses rate of the $^{239+240}Pu$ for the Black Sea hydrobionts of different trophic levels



16.3.10 Radioecological Effects of Chronic Ionizing Radiation Dose Rate from Alpha–Radiation of ^{239,240}Pu on Hydrobionts

The Polikarpov's conceptual model of ecological zones, radioecological effects of chronic ionizing radiation dose rate levels was originally proposed for ecological risk assessment of ionising radiation (Polikarpov 1998; Tereshchenko and Polikarpov 2007; Polikarpov et al. 2008). This model categorises responses of organisms, populations and ecosystems to all the existing and possible dose rates in the environment as follows:

1. the "Uncertainty zone" – (below the lowest natural ionising radiation background level),
2. the radiation "Well-being zone" (natural ionising radiation background range),
3. the "Physiological masking zone" (0.005–0.1 Sv·year^{-1}),
4. the "Ecological masking zone" (0.1–4 Sv·year^{-1}),
5. the "Zone of damage to communities/ecosystems" (>>4 Sv·year^{-1}),
6. the "Zone of lethality to the whole biosphere (>>M Sv·year^{-1}) (Polikarpov 1998; Polikarpov et al. 2008).

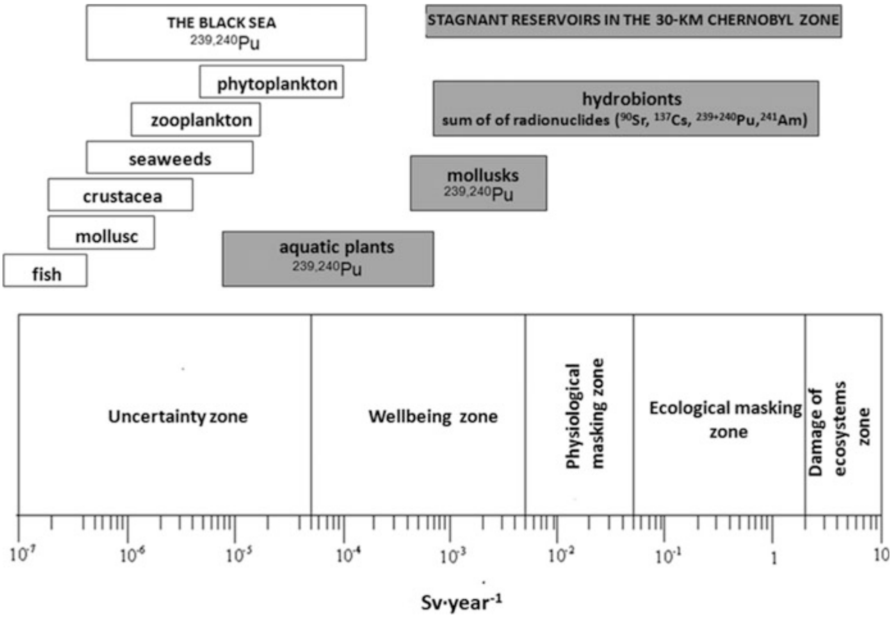


Fig. 16.9 The levels of currently ecological impact of radiation dose rates from $^{239+240}$Pu to different taxonomic groups of the Black Sea hydrobionts and the $^{239+240}$Pu dose rates and the sum of the main man–made radionuclides dose rates to aquatic organisms in reservoirs of the ChNPP 30–km zone

According to Polikarpov's conceptual model of ecological zones, radioecological effects of chronic ionizing radiation dose rate levels from alpha-radiation of ^{239,240}Pu for the Black Sea hydrobionts are specific for the "Well-being zone" and "Uncertainty zone" (Tereshchenko and Polikarpov 2007; Tereshchenko et al. 2014) and in the ChNPP 30–km zone the dose rates from man–made radionuclides were significant higher and reached the "Physiological masking zone", the "Ecological masking zone, "and even the "Zone of damage to ecosystems" (Fig. 16.9).

16.3.11 Forward–Looking Estimating the Limiting $^{239+240}$Pu Concentration Activity in Seawater

Staying on for hundreds of years, by a recorded environmental radiation factor that creates chronic radiation exposure on marine life, contemporary content of plutonium in the Black Sea does not have a damaging effect on biological components of the sea ecosystem. But radioecologycal situation can be changed. So, based on field observations and model calculations as well as on the conceptual model of chronic action zonality of ionizing radiations dose rates in the nature (Polikarpov 1998;

Table 16.5 The forward–looking estimating the limiting $^{239+240}$Pu concentration activity in seawater for each zone of radiochemoecological chronic action of ionizing radiation on marine organisms

Hydrobiont	The limiting $^{239+240}$Pu concentrations in seawater for every zone of radioecological effects of chronic ionizing radiation dose rate on hydrobionts, $Bq{\cdot}L^{-1}$				
	Uncertainty zone	Well-being zone	Physiological masking zone	Ecological masking zone	Zone of damage to ecosystems
Phytoplankton	$3.84{\cdot}10^{-10}$	$1.53{\cdot}10^{-7}$	$1.92{\cdot}10^{-5}$	$1.92{\cdot}10^{-4}$	$1.40{\cdot}10^{-2}$
Red algae	$6.41{\cdot}10^{-9}$	$2.56{\cdot}10^{-6}$	$3.21{\cdot}10^{-4}$	$3.21{\cdot}10^{-3}$	$2.34{\cdot}10^{-1}$
Zooplankton	$3.84{\cdot}10^{-8}$	$1.53{\cdot}10^{-5}$	$1.92{\cdot}10^{-3}$	$1.92{\cdot}10^{-2}$	$1.40{\cdot}10^{0}$
Brown algae	$7.12{\cdot}10^{-8}$	$2.85{\cdot}10^{-5}$	$3.56{\cdot}10^{-3}$	$3.56{\cdot}10^{-2}$	$2.60{\cdot}10^{0}$
Mollusks	$2.18{\cdot}10^{-7}$	$8.73{\cdot}10^{-5}$	$1.01{\cdot}10^{-2}$	$1.01{\cdot}10^{-1}$	$7.97{\cdot}10^{0}$
Crustacea	$3.37{\cdot}10^{-7}$	$1.35{\cdot}10^{-4}$	$1.69{\cdot}10^{-2}$	$1.69{\cdot}10^{-1}$	$1.23{\cdot}10^{1}$
Green algae	$3.63{\cdot}10^{-7}$	$1.45{\cdot}10^{-4}$	$1.81{\cdot}10^{-2}$	$1.81{\cdot}10^{-1}$	$1.32{\cdot}10^{1}$
Fish	$1.28{\cdot}10^{-6}$	$5.13{\cdot}10^{-4}$	$6.41{\cdot}10^{-2}$	$6.41{\cdot}10^{-1}$	$4.68{\cdot}10^{1}$

Polikarpov et al. 2008), $H_{eq}R$ for marine organisms in the wide range of radionuclides concentrations in seawater and the average critical level of the ^{239,240}Pu concentration activity in marine environment for each group of hydrobionts have been determined. The limiting plutonium concentration activity in sea water was also calculated for each Polikarpov's zone for each group of hydrobionts with their accumulation ability to show wide range of water concentration activity in sea water caused the same ecological effect of ionizing radiation $H_{eq}R$ according to the Polikarpov's conceptual model on different group of hydrobionts. They varied for "Damage to ecosystems zone" from 1×10^{-2} to 5×10 ^{239,240}Pu $Bq{\cdot}L^{-1}$ in sea water (Table 16.5) (Tereshchenko 2013).

Depending on the accumulative ability of marine organisms against ^{239,240}Pu, the limiting concentration activity of these radionuclides in seawater varied in the range of 3 orders of magnitude for different groups of the studied Black Sea hydrobionts.

Since species radiosensitivity, being characterized by LD_{50} (the dose causing 50% death rate of organisms), within each taxonomic group. It is known to vary in a range from 1 to 3 orders of magnitude (Polikarpov et al. 2008), then for radioresistant species, being able to tolerate higher radiation doses, the limiting radionuclides concentration activity in seawater will be accordingly higher by 1–3 orders of magnitude. Thus, the expected ecological effect of the radiation is determined by the level of ^{239,240}Pu concentration activity in sea water, the value of accumulative ability of marine species and radiosensitivity of hydrobionts.

16.4 Conclusion

The studies revealed radiological regularities of the Pu behavior in the Black Sea ecosystem. Quantitative parameters of biogeochemical processes of plutonium migration: Concentration factor against $^{239+240}$Pu by biota and abiotic components, factor of radiocapacity of bottom sediment, the average annual fluxes of $^{239+240}$Pu in different parts of the sea, the effective half–life of $^{239+240}$Pu in the Black Sea surface waters, the levels of its concentration activity in ecosystem components.

It was noted an increase in the ability of the Black Sea surface water to self–purification, compared to other seas, particularly the Mediterranean Sea. The revealed features of redistribution of $^{239+240}$Pu in the Black Sea are connected with both conditions, formed in the sea, in particular, the presence of a reducing hydrogen sulfide zone in the sea as well as the properties of plutonium, which determined the silty bottom sediments as the main long–term depot of plutonium. The obtained results allowed characterizing the role of shelf areas and the deep zone in plutonium migration and deposition.

It was recommended the sea algae, as a link in the food chain with the maximum accumulative capacity in respect of plutonium among biotic components and defined the critical habitat – silty bottom sediment as the main place of deposit of the prevailing part of the plutonium incoming into the sea, curried out a quantitative assessment of pedotropic type of biogeochemical behavior of plutonium in the Black Sea ecosystems.

Thus, the study of the radoiecological regularities and quantitative characteristics of the redistribution of $^{239+240}$Pu in the Black Sea make it possible to form a scientific basis for the characteristics of plutonium redistribution trends in the Black Sea ecosystem in different spatial and temporal scales, to evaluate and predict the radioecological state of waters at different possible concentration activities of the Black Sea waters against plutonium radionuclides using quantitative parameters of biogeochemical migration of plutonium in the Black Sea ecosystem.

Thus, the expected ecological effect of the radiation was determined by the level of ^{239,240}Pu concentration activity in sea water and its connection with the value of accumulative ability of marine species and its radiosensitivity. In after ChNPP accident period the levels of dose rates were formed from plutonium did not exceed the levels typical for the “Well-being zone”. Therefore, the contemporary levels of plutonium concentration in the Black Sea, have no a noticeable negative effect on the Black Sea hydrobionts. The Black Sea hydrobionts are exposed to the action of the concentrations of different contaminators in the water environment, and they also have an increased accumulative ability. They are capable of accumulating contaminators (in particular ^{239,240}Pu) to levels exceeding tens and tens thousands times their concentration activity in the water, and thus the risk is increased many times of the negative influence of radioactive contamination on biological systems and objects. In connection with this, the radioecological monitoring investigations must include the determinations of the radionuclides concentration activity, both in the sea water and bottom sediment and in the indicated species of hydrobionts too.

It has been shown that the Black Sea macrophytes (in particular, multiyear algae *Phyllophora crispa and Cystoseira crinite*) and the mollusks (sedentary filter feeders mussels – *Mytilus galloprovincialis*) can be the indicated species for estimation of the radioecological state of coastal water areas. So, radioecologycal monitoring for successful solve the ecological problems should include the investigation of three aspects: of concentration, migration regularity and dose estimation.

Radiological study the quantitative characteristics of the Black Sea hydrobionts describing the features of biotic migration of plutonium in the sea-ecosystem may serve as the basis for assessment of the radioecological situation in the Black Sea and its forecast for a wide range of concentration activity of plutonium in the sea water.

Such a comparative analysis with the use of the Polikarpov's conceptual model and radioecologycal monitoring observations in natural ecosystems may be applied for the evaluation and prediction of the environmental situation in the different aquatic reservoirs.

The developed analytical approaches can serve as a basis for evaluating current radioecological situation in the Black Sea ecosystems against radionuclides of plutonium and other radioisotopes. These approaches can be used for prognosis radioecologycal state of sea area in a wide range of expected concentrations of radionuclides in the water environment.

The result of research biogeochemical process in the Black Sea ecosystems with using man-made radionuclides in complex together with natural radioisotopes as radio tracers of these process and allows us not only receive information about currently situation in the sea, but investigate regularities of radionuclide behavior in the Black Sea itself and in Mediterranean basin. This new knowledge of radioecologycal regularities of migration and redistribution of radioisotopes of plutonium and quantities parameter of them make possible evaluation of radioecologycal state of different Black Sea areas and its forecast and make deeper our understanding of many process of functioning of the sea ecosystems and mechanisms of these process. It is important not only for radioecology but also for molismology and hydrobiology in general.

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Chapter 17
Radionuclides ^{137}Cs and ^{90}Sr in Components of the Black Sea Ecosystems: Contemporary Status and Prognosis

Natalya Yu. Mirzoyeva, Viktor N. Egorov, and Sergey B. Gulin

Abstract Over the period from 1986 to 2016 the data for the ^{90}Sr and ^{137}Cs horizontal and vertical distribution in the surface water and in the water column of the Black Sea, accordingly, were analyzed. The results of full-profile measurements of ^{137}Cs in the deep water column were obtained in 2015 for the first time for the whole post-Chernobyl period. The time constants of exponential functions were determined and the forecast of ^{90}Sr and ^{137}Cs concentrations reduction to the pre-accident levels in the components of the ecosystem of the Sevastopol bay was made. The estimations of the balance components of these radionuclides in the Black Sea were obtained. It is shown that to the present time the steady-state equilibrium between entry and elimination of ^{90}Sr and ^{137}Cs in the oxygen zone of the Black Sea was formed, at the same time their accumulation in the hydrogen-sulphidous zone has been increasing. By 2013 the ^{90}Sr and ^{137}Cs content in the Black Sea was evaluated as 1670 and 2843 TBq, respectively, that was in 3.6–6.4 and in 1.2–1.6 times higher, than the content of these radionuclides at the sea in 2000. At the same time 66% of ^{137}Cs and 67% of ^{90}Sr of the total content of radionuclides in the whole water column was in the hydrogen-sulphidous zone of the Black Sea. The period of circulation of ^{137}Cs and ^{90}Sr in the oxygen and hydrogen-sulphidous zones of the Black Sea is about 14 and 94 years, respectively.

17.1 Introduction

A significant amount of long-lived radionuclides entered into the Black Sea after the Chernobyl Nuclear Power Plant (ChNPP) accident, which happened in 1986. In subsequent years, they migrated along whole water area of the sea, gradually penetrating into the depth of the water column and bottom sediments. At that there was a problem of the assessment and prediction of the ecological hazard, as

N.Y. Mirzoyeva (✉) • V.N. Egorov • S.B. Gulin
Radiation and Chemical Biology Department, FSBIS Institute of marine biological research RAS (IMBR), 2, Nakhimov Av., Sevastopol 299011, Russian Federation
e-mail: natmirz@mail.ru

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well as the scopes of radiological response time of the Black Sea on the radioactive contamination of its waters (Polikarpov et al. 2008). The monitoring, which has been carried out since 1986 has allowed to evaluate the risk of influence of the post-accidental ^{90}Sr and ^{137}Cs on the living organisms from the Black Sea ecosystems (Polikarpov et al. 2008). On the other hand, the study of the migration of radionuclides in the marine environment has made it possible to use them as tracers of large-scale vertical circulation of the Black Sea waters (Egorov et al. 2001; Gulin et al. 2011).

However, until recently these studies, particularly with respect ^{137}Cs, were made only at the upper 200 m, less commonly for the 500 m layer of the water column of the Black Sea (Egorov et al. 2001). This was due to the lack of reliable at that time (or available) methods of ^{137}Cs concentrations measurements in relatively small volumes of water, and the sampling of the required sample volume (1000 l or more) for this procedure at that time from great depths of sea water was quite a challenge. Recently, this problem is solved by using the new radioanalytical methods, which allow to significantly reduce the volume of samples to measure the content of ^{137}Cs, for example, by precipitating with ammonium phosphomolybdate with followed beta radiometry or the concentration of samples by classic high sorption method and with using the high-performance gamma- and liquid-scintillation spectrometry (Gulin et al. 2015). In the latter case, in the same sample of water can simultaneously identify and ^{137}Cs, and ^{90}Sr, without using expensive cesium tracers for its radiochemical yield, which greatly improves the performance of sampling and measurement. This method allowed for the first time for the entire period since the ChNPP accident, to get a full profile of the vertical distribution of ^{137}Cs in the deep thickness of the Black Sea (Gulin et al. 2015). Previously, such measurements were performed only once and only in before Chernobyl period (Vakulovsky et al. 1980).

The purpose of this study was to analyze the contemporary radioecological state of the Black Sea concerning of the contamination of ^{90}Sr and ^{137}Cs after the ChNPP accident, to make a forecasting of the period of time for achieve of concentrations of these artificial radionuclides till or less of the pre-accident levels in the balance, abiotic and biotic components of the Black Sea ecosystems, determination of the rate of self-purification of the coastal and deep-water areas of the Black Sea from ^{90}Sr and ^{137}Cs after the ChNPP accident.

In accordance with the proposed purpose the following tasks were solved:

– to analyze the presented in the literature and own obtained results on the pollution of the ^{90}Sr and ^{137}Cs of water, hydrobionts and bottom sediments of the different areas of the Black Sea,
– to describe the new data on concentrations of ^{90}Sr and ^{137}Cs in the deep waters of the Black Sea (the data on the content of ^{137}Cs in the deep water (1500 m) in the eastern part of the Black Sea for the first time was obtained in 2013),
– to fulfill the assessment of the balance components: the entrance, content and elimination of ^{90}Sr and ^{137}Cs in the coastal, aerobic and anaerobic water column of the Black Sea as a result of studying of the dynamics of the vertical

distribution of radionuclides in the water column during the entire period after the ChNPP accident taking into account the new data about the above-mentioned distribution ^{137}Cs in the deep layers of sea.
– to make the forecast of the time of the decreasing till levels of concentrations of artificial radionuclides ^{90}Sr и ^{137}Cs in the balance components, abiotic and biotic components of the Black Sea ecosystem, which were in them before the ChNPP accident,
– to get the new data about the speed of the self-purification of coastal and deep-water areas of the Black Sea from ^{90}Sr and ^{137}Cs radionuclides after the ChNPP accident.

17.2 Materials and Methods

17.2.1 Analysis of Sample Sites and Samples

In this investigation the results of the radioanalytical measurements obtained by us with the usage of standard methods in the framework of the radiation monitoring 1986–2016 years were applied (Polikarpov et al. 2008), as well as the data on the vertical distribution of ^{90}Sr and ^{137}Cs in the water column of the Black Sea deep-water zone, obtained in 2013 and 2015 years (Gulin et al. 2015) were used. Material for investigations was taken during the sea trips (Polikarpov et al. 2008) on scientific research vessels (SRV) of the Institute of Biology of the Southern Seas (IBSS) NAS of Ukraine (now it is Institute of Marine Biological Research AS of Russia (IMBR)) such as "Professor Vodyanitskiy" (including the material from its 88 cruise in September 2016) and "Academician Kovalevskiy", as well as in coastal areas on small vessels during the shore expeditions, (Fig. 17.1).

To determine the concentrations of ^{90}Sr and ^{137}Cs after the ChNPP accident the following indicator species of hydrobionts were selected. The main object of study among the Black Sea mollusks was the *Mytilus galloprovincialis* (Lam.), among the seaweed it was brown algae *Cystoseira crinita* (Duby).

17.2.2 Sampling

The sampling of surface water (volume 20–2000 l) was realized with using pumps "Azovets", "Malish" and with using the deck's turbine pump. The "Sartorius" Peristaltic Pumps, vacuum pumps and turbine pump "Flotec-F360-5 ACMP" were used for filtration of sea water samples and sorption of contaminants or suspended matter. Water samples from various horizons were taken with using the bathometers of the Niskin system (10 and 20 l volumes), the 140 l Bodmen bathometer, as well as cassettes of bathometers STD probe "Istok-3" (6 × 10 l),

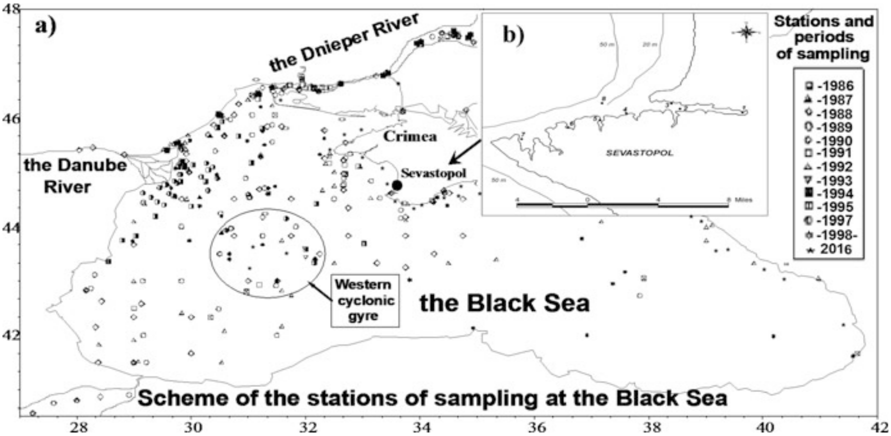


Fig. 17.1 Scheme of location of the sampling stations in the open (**a**) and coastal areas (**b**) of the Black Sea

system Knudsen and "Neil Brown Mark III" (12 × 10 l), type "Go-Flo". The precipitation of pollutants from the water samples was carried out in plastic containers and cubes of organic glass volume 50 and 100 l, as well as in flexible polyethylene containers 20–25 l. The high-capacity cylindrical membrane filters "CUNO" (United States), type "MICRO-WYND-II", mark DPPPZ (0.5 μm) or DPPPY, DCCPY (1 μm) and "AQUA" (Italy) generally were used for separation of suspended matter in the water samples up to 5000 l for determining in them the radionuclides of cesium or plutonium. The cylindrical high-performance membrane filters FVKN-0.2-0.25 with pore diameter 0.2 μm, filters "Blue Ribbon" and the Petryanov filter cloth were used also.

Sampling of the bottom sediments was carried out by corer"Ocean-0.25" (0.25 m disclosure area), the "BC-0.025", Reineck (Germany) and box corer design firm slung Shelf" (United States), which was used mainly in offshore areas. The modernized tube sampler in diameter of 210 mm, equipped with sphincteric locks (production of the Woods Hole Oceanographic Institution, United States) and multicorer "Bowers & Connelly Mark-II-400" (United Kingdom) were used for the precise sampling of the columns of the bottom sediments. Using of the multicorer was allowed to receive at the same time the four soft sediment columns at a diameter of 9 cm with a maximum undamaged state of levels. Sampling of bottom sediments from the above equipments was made by barking with fixed of thickness and square of the surface layer.

Sampling of mollusks and macroalgae was realized in the coastal biotopes and the deep water zone of the Black Sea by the Sigsbee bottom trawl and fish-fish-traditional gear.

During the research was carried out more than 3330 definitions of ^{90}Sr, ^{137}Cs (Table 17.1).

Table 17.1 Summary data on the number of determinations of ^{90}Sr and ^{137}Cs in the objects of the Black Sea ecosystem in the 1986–2016 yrs

	Objects of investigations				
Radionuclides	Water	Bottom sediments	Water plants	Mollusks	Region of investigations
^{137}Cs	390	530	138	105	North-West, West and Central regions, the coastal part of the Crimea, range of depth of research 6–2000 m
^{90}Sr	1210	490	311	162	
Total	1600	1020	449	267	

17.2.3 Methods of Determination of the ^{90}Sr and ^{137}Cs Concentration in Natural Objects

The method of ^{90}Sr determination in hydrobionts, water and bottom sediments was based on: carrying out of radiochemical procedure of the strontium preconcentration, then purification from interfering elements, measuring of the ^{90}Y (the daughter product) activity on Cerenkov's radiation and subsequent mathematical data processing (Harvey et al. 1989; Instrument description 1989, «Quantulus 1220»). Analysis was carried out with the use of the low background liquid-scintillation counter (LSC) LKB "Quantulus 1220". The lower limit of detection (LLD) was 0.01–0.04 Bq kg^{-1} (for hydrobionts and bottom sediments) and Bq m^{-3} (for water samples). Recoveries are calculated from Sr-stable recovery by flame photometry for the ^{90}Sr and then gravimetrically from yttrium oxalate for ^{90}Y (Harvey et al. 1989; Instrument description «Quantulus 1220», Polikarpov et al. 2008). Each result is reported as the mean of the values activity of parallel repeatability samples, which were measured separately. Total relative error of the each result does not exceed 20%.

The sorption method of determination of radioisotopes of caesium of ^{137}Cs in water ecosystems is based on principle of carrying out of their gamma-spectrometric measuring after collection of pollutant on the filters for the separation of the suspended matter in fibrous or powder sorbents (Buesseler et al. 1990; Polikarpov et al. 2008). On carrying out of investigations besides the highly productive cylindrical winding filters, a fibrous cationite "Mtilon-T" or powder "Anfesh", K_4 [Fe $(CN)_6$] in the form of 15% solution, $CuSO_4$ in the form of 5% solution was used. The preparation of the sorbent material was carried out through the standard methods, the losses of cesium did not exceed 10% (Buesseler et al. 1990; Polikarpov et al. 2008). The volume of sea water was not less than 3000–5000 l. Maximum speed and the volume of the pumped water was determined experimentally (Buesseler et al. 1990). After the ashing the samples were gone on the gamma-spectrometric measurements. The measurements in the sorbents, hydrobionts and bottom sediments were carried out on the scintillation NaI (Tl) detectors (№ 1, 2) with lead shield and with the ORTEC 855 Dual Spec AMP amplifiers, Canberra AMP 2026, and also on the end ultra-pure germanium detector Canberra-Packard XtRa GX2019 with relative efficiency of measuring about 23% and with resolution 0.66 kev at energy of radiation of radionuclide 1.46 Mev. The analysis of obtained gamma-spectra was carried out with using of the Analyzer MCA, S100, System 100. The data obtained were statistically treated according to commonly accepted techniques (Polikarpov et al. 2008).

In cruise 2013, as mentioned above, the original method of ^{137}Cs determination from relatively small volumes of water was applied, which allowed for the first time after the ChNPP accident to get full information about vertical distribution of ^{137}Cs in the deep-layers basin of the Black Sea.

The quality control of the analytical methods and the reliability of the results for ^{90}Sr and for radionuclides of ^{137}Cs and $^{239, 240}Pu$ were supported from the constant participation in international intercalibrations during 1990–2004 under the aegis of the IAEA (Vienna, Austria), (Polikarpov et al. 2008).

Adjustment of the periods of the exchange water in the oxidation and reduction zones of the Black Sea was conducted using a model of the large-scale radioisotopic, salt and water balance of the sea (Stokozov 2004). For parameterization of this model the data on changes in the profiles of the vertical distribution of ^{137}Cs and ^{90}Sr in the water during the post-Chernobyl period were used. The components of the water balance, including river flow, evaporation, precipitation, and water exchange through the Black Sea straits, were determined by the results of long-term meteorological observations (Voitsekhovitch et al. 1998), and averaged profiles of the vertical distribution of water salinity were evaluated on numerous data of hydrological surveys.

It was found, that the dynamics of the concentrations of the after-accident radionuclides in the Black Sea ecosystem are described adequately by an exponential function. Estimation of the forecast of time for ^{90}Sr and ^{137}Cs concentrations decrease in the components of the Black Sea ecosystems to the before-accident levels were fulfilled by method of an extrapolation of the approximating line of the exponential function (Mirzoyeva 2008; Mirzoyeva et al. 2013).

17.3 ^{90}Sr and ^{137}Cs in the Black Sea Ecosystems. Results

17.3.1 Sea Water

Chronological trends of the horizontal distribution of the average concentrations of ^{90}Sr and ^{137}Cs in the surface layer of sea water of the North-Western part and the region of the Crimean coast of the Black Sea are summarized and presented in Table 17.2 (IAEA 2004; Database ORChB IMBR 2006; Polikarpov et al. 2008.; Gulin et al., 2013, Tereschenko et al. 2014).

Comparative distribution of modern concentrations of ^{90}Sr and ^{137}Cs in the surface layer of water of the Black Sea in 2011 and 2014–2016 years (2 years before and during the period after the termination of the water supply from the North-Crimean canal (NCC) on the territory of Crimea, respectively) is shown in

Table 17.2 Average concentrations of ^{137}Cs and ^{90}Sr (Bq m^{-3}) in seawater of the North-Western part of the Black Sea region and the Crimean coast in the period before and after the ChNPP accident

Date, year	Concentration	
	^{137}Cs	^{90}Sr
Before 26th of April 1986	14–15	15
After 26th of April 1986	143 ± 43	28–53
1987	84 ± 25	22 ± 3
1988	79 ± 24	24 ± 6
1989	76 ± 1.3	21 ± 1
1989	76 ± 1.3	21 ± 1
1990	69 ± 21	23 ± 2
1991	31 ± 9	No data
1992	36 ± 11	20 ± 1
1993	36 ± 11	22.0
1994	27.7	27.3
1995	28 ± 8	15.0
1998	24 ± 6	20 ± 4
2000	24 ± 2	19 ± 4
2011	14.9 – 56.1	6.7–32.1
2013	17.1 ± 0.9	12.5 – 24.8
2014	13.8 ± 1.2[a]	7.1 ± 1.3[a]
2015	14.4 ± 1.3[a]	8.2 ± 1.3[a]
2016	16.1 ± 2.4[a]	7.2 ± 1.3[a]

[a]The results were obtained in the period after the closure of the North-Crimean canal (Ukraine builds dam..., 2014)

Figs. 17.2 and 17.3. Analysis of the results (Table 17.2 and Fig. 17.2) has shown, that the concentration of ^{90}Sr and ^{137}Cs in the surface layer of the Black Sea water varied in the range of 6.7–32.1 Bq $m^{-3}$and 14.9–56.1 Bq m^{-3}, respectively, in August 2011.

Excess the concentrations of ^{90}Sr and ^{137}Cs of the pre-accident levels in the surface water of the Black Sea in areas of the Dnieper-Bug estuary, Kerch region and along the coast of the Crimea showed the secondary inflow of these radionuclides into the Black Sea with the waters of the Dnieper River through the NCC (Gulin et al. 2013).

The period of decrease in twice (T_{05}) was determined and forecast of the all period of reduction of the ^{90}Sr concentration in water of the investigated sea area till pre-accident levels was made (Mirzoyeva et al. 2013) based on retrospective analysis (Database ORChB IMBR 2006; Polikarpov et al. 2008) and values of ^{90}Sr concentrations in the water of the Dnieper-Bug estuary of the Black Sea obtained in 2011 (Fig. 17.4).

The forecasted period (T_{05}) for ^{90}Sr concentration in water for this region was determined as 7.6 years, and period of complete reduction to the pre-accident levels was assessed as 32 years (by 2018). These periods were in 3.8 and 4.7 times, respectively, less than the periods of the physical half-life decay and five periods of the radionuclide decay. A tendency to decrease of the concentration of radionuclides in the area of the Crimean coast to the pre-accident levels and below was

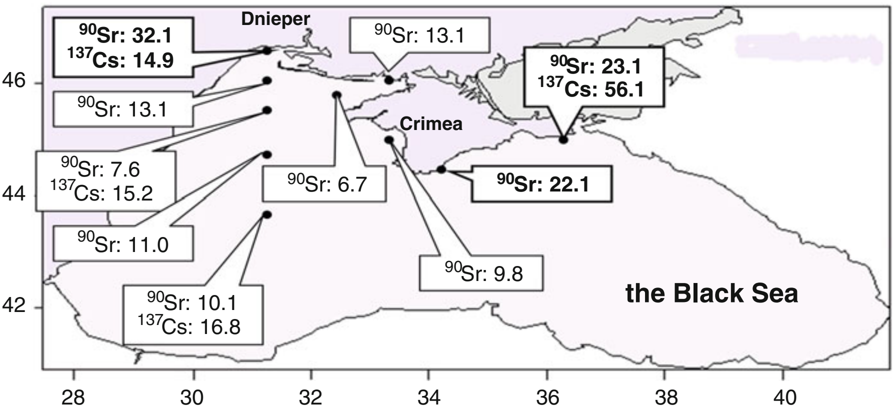


Fig. 17.2 Distribution of ^{90}Sr in surface water of the Black Sea (August 2011) (Gulin et al. 2013; Mirzoyeva et al. 2013)

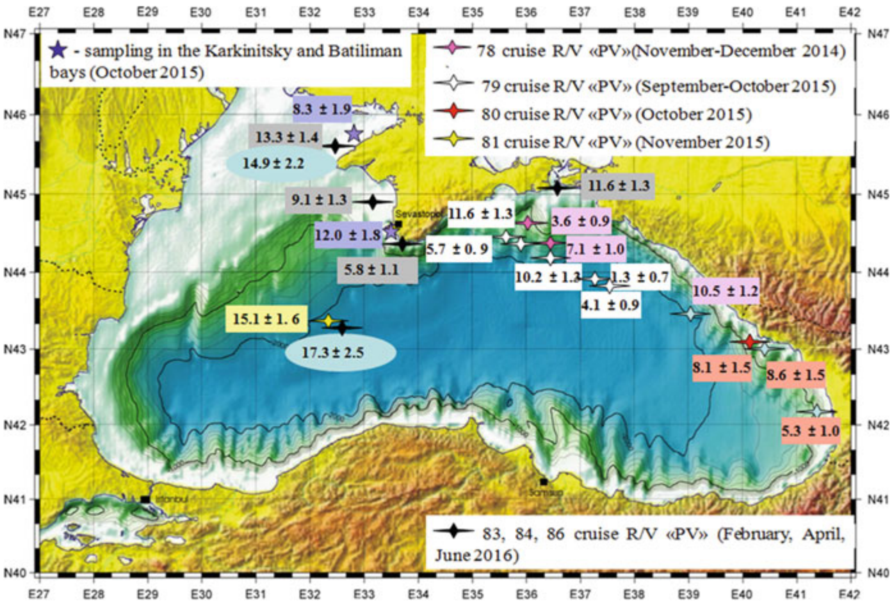


Fig. 17.3 Distribution of ^{90}Sr (rectangles) and ^{137}Cs (ovals) in the surface water of the Black Sea in the 2014–2016 period (the period after overlapping the water supply in Crimea in North-Crimean canal) (note: Cs data presented for April 2016)

shown according to results of the distribution of ^{90}Sr and ^{137}Cs concentrations in the surface layer of water of the Black Sea in the period after a stopping of the filing of the Dnieper water through the NCC in the region of Crimea (2014–2016.)

Note that the concentrations of ^{90}Sr and ^{137}Cs in the central part of western cyclonic gyre were slightly higher than content of these radionuclides in

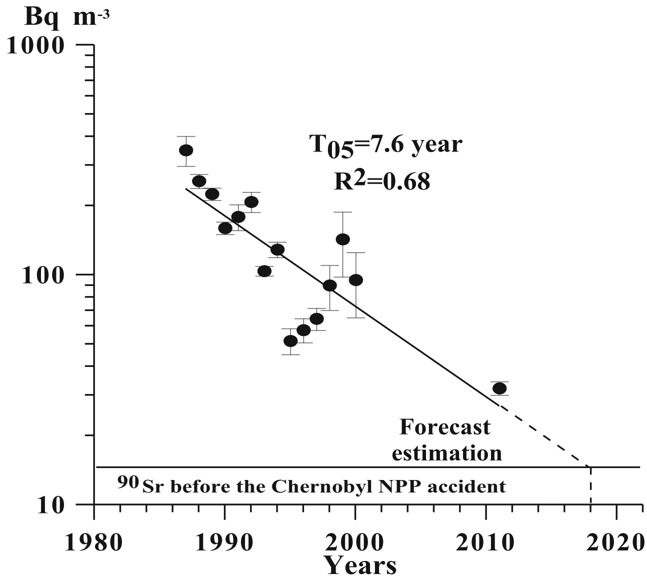


Fig. 17.4 The Dynamics and forecasting estimation of the annual change of the average ^{90}Sr concentration in water of the Dnieper-Bugs estuary of the Black Sea (Mirzoyeva et al. 2013)

Karkinitsky Bay of the Black Sea (Fig. 17.3). Perhaps this is due to post-accident transport the dissolved radionuclides by the Black Sea current from the area of the Dnieper-Bug estuary, to which the NCC waters now resets, to the central area of the Black Sea.

The components of ^{137}Cs and ^{90}Sr balance in the Black Sea before and after the ChNPP accident (Fig. 17.5), obtained on base analysis of the primary data and published materials (Buesseler et al. 1990; Gudiksen et al. 1991; Voitsekhovich et al. 1997; Chudinovskikh et al. 2004; Database ORChB IMBR 2006; Polikarpov et al. 2008) are presented.

Study of the radiological response of the Black Sea on the ChNPP accident showed that the main factors of the formation of radioactive contamination fields were: atmospheric fallout on the surface of the sea, inflow of the radionuclides in the oxygen zone with the runoff of the rivers and their transport through the straits, migration into deep zone and removal by sedimentation into the thickness of bottom sediments (Fig. 17.5). Inflow of ^{90}Sr with atmospheric fallout on the Black Sea water area in 1986 was 100–300 TBq and for 137Cs –1700–2400 TBq. For the period 1986–2000 years the 160 ± 28 TBq of ^{90}Sr and 22.6 ± 5.4 TBq ^{137}Cs had realized at sea with the runoff of the largest Rivers (the Dnieper and the Danube) of the Black Sea (Polikarpov et al. 2008). Thus, the total flow of ^{90}Sr into the Black Sea from 1986 to 2000 can be estimated as 260–460 TBq and ^{137}Cs – 1723–2423 TBq. By 2000, the sedimentary depositing of ^{90}Sr into the thickness of the bottom sediments of the Black Sea amounted to only 0.4 TBq, or 0.09–0.15% of

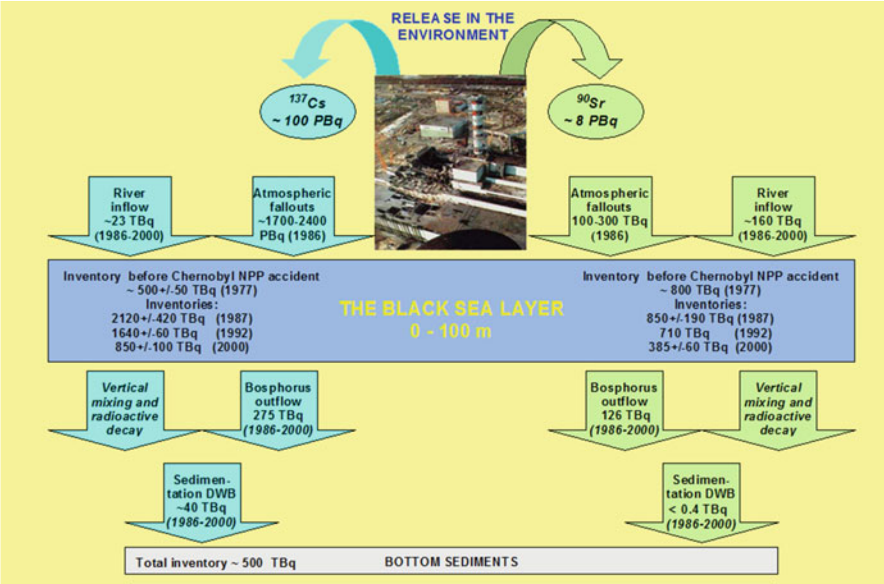


Fig. 17.5 Inventories ^{90}Sr and ^{137}Cs in the 0–100 m layer of the Black Sea before Chernobyl NPP accident, in the period 1987–2000 and balance components (Polikarpov et al. 2008)

the total entrance of this radionuclide in the sea during this period, and ^{137}Cs – 40 TBq, or 1.6–2.3%, respectively (Gudiksen et al. 1989; Gulin et al. 2011). These estimates imply that the deposition of ^{90}Sr and ^{137}Cs in the thickness of the bottom sediments was insignificant compared with the content of these radionuclides in the oxygen and hydrogen-sulphidous zone of the Black Sea. Therefore, we can consider the water mass of these areas, especially hydrogen-sulphidous as the main depot for the post-Chernobyl ^{90}Sr and ^{137}Cs.

It was obtained (Stokozov 2004; Mirzoyeva 2008; Polikarpov et al. 2008), that in the period after the ChNPP accident the reduction of the ^{90}Sr and ^{137}Cs concentrations in the surface water of the Black Sea was determined by stirring in a layer of 0–50 m and a vertical migration of ^{90}Sr and ^{137}Cs in deep waters mostly in the 0–200 m layer, since 1986 (Fig. 17.6).

The results of studies of the vertical distribution of ^{90}Sr and ^{137}Cs in the area of western cyclonic gyre of the Black Sea, obtained in 2013 and 2015 are shown in Figs. 17.7 and 17.8, Table 17.3.

They allowed to traced the dynamics of the content of radionuclides in the water column of the Black Sea for the entire post-Chernobyl period, and to assess their distribution in the oxygen and hydrogen-sulphidous zones. It is shown (Figs. 17.7 and 17.8, Table 17.3), that by 2015 the system of biogeochemical conditioning ^{90}Sr and ^{137}Cs content in the upper 100-m water column of the Black Sea is almost reached the stationary level, i.e. entrance streams of these radionuclides in the

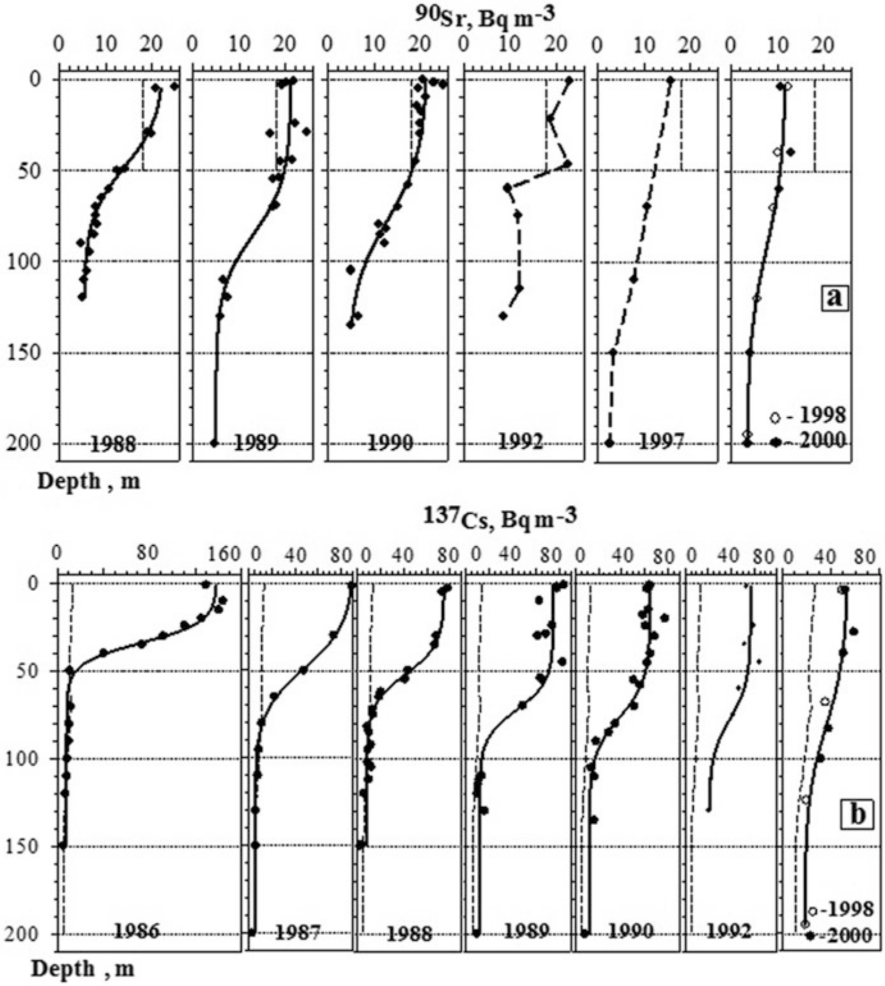


Fig. 17.6 Profiles of vertical distributions of ^{90}Sr (**a**) and ^{137}Cs (**b**) in the Black Sea Central Basin in the period 1986–2000 (*circles*), their approximations (*solid lines*) and levels of ^{90}Sr and ^{137}Cs concentrations in the 0–50 and 0–200 m layers before the ChNPP accident (*dashed lines*) (Egorov et al. 1993, 2001)

surface layers of the sea are now balanced by their radioactive decay and migration in depth layers.

It is determined that the dynamics of penetration was not dependent on concentrations of ^{90}Sr and ^{137}Cs, and in general, coincide for both radionuclides. This reflects the impact of a large-scale vertical circulation of the water masses in the deep basin of the Black Sea. Moreover, the maximum intensity of vertical mixing of water corresponded to a layer of water of 0–50 m, and its decrease was observed in the layer of seasonal pycnocline with a further decrease on the lower limit of the

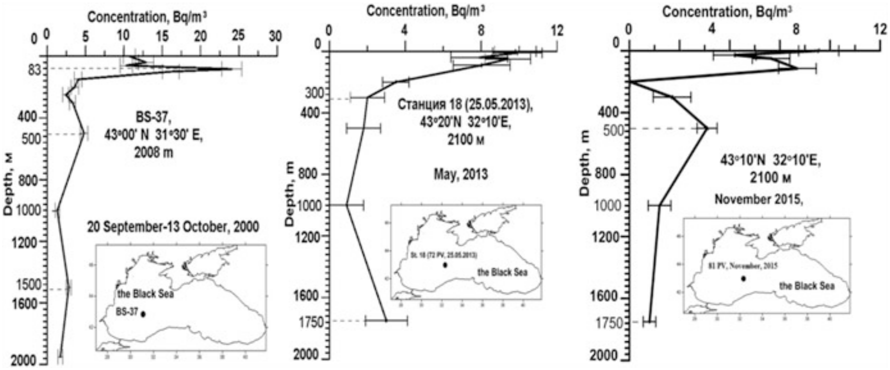
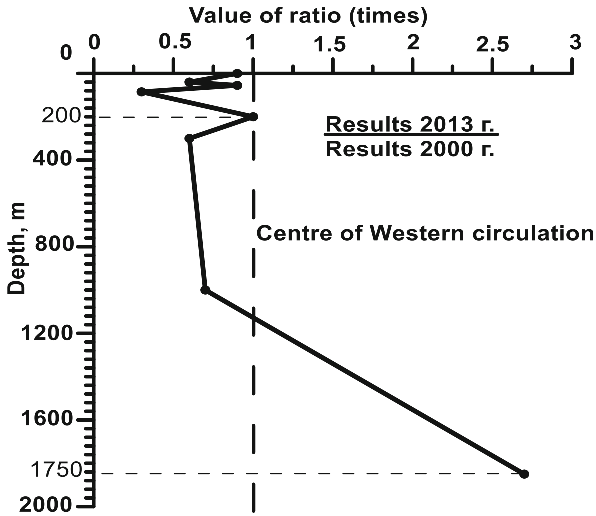


Fig. 17.7 Profiles of the vertical distribution of ^{90}Sr in the water of the center of western circulation of the Black Sea in 2000, 2013 and 2015 (published for the first time)

Fig. 17.8 The ratio of the concentrations vertical distribution of ^{90}Sr in water of the center of the western circulation of the Black Sea in 2000 and 2013 (published for the first time)



oxygen zone of the Black Sea. Similar results were obtained for the zone of the Main Black Sea stream, flowing around the periphery of the Black Sea deep-water basin (Polikarpov et al. 2008). On results of these studies found that the period of the vertical circulation of the Black Sea waters in the layer of 0–50 m can be estimated at 5 years, a period of complete renewal of water in the bottom of the pycnocline in 15–25 years, and the entire volume of the sea in 140 years (Egorov et al. 1999).

With an area of 423 thousand. km^2 and a maximum depth of 2212 m the volume of water of the Black Sea is 547015 km^3, of which 475890 km^3 (87%) of its relate to hydrogen-sulphidous zone. However, about 90% of the water hydrogen-sulphidous zone of the Black Sea, on average corresponds to a depth of over 200 m, and the area of their upper boundary is about 312 thousand. km^2 (Goncharov et al. 1965;

Table 17.3 Vertical distribution of ^{90}Sr and ^{137}Cs in the water column of the deep-water area of the Black Sea (district of western cyclonic gyre, May 2013)

Depth, m	^{90}Sr		^{137}Cs	
	Bq/m^3	±1σ	Bq/m^3	±1σ
0	9.75	1.10	17.26	2.69
10	9.94	1.27	10.66	1.64
40	7.94	1.48	11.56	1.79
50	9.41	1.20	10.37	1.60
90	8.02	1.49	8.03	1.27
200	3.54	0.66	4.03	0.68
300	2.02	0.85	2.00	0.48
500	1.83	0.87	1.72	0.70
1000	0.91	0.87	4.41	0.76
1750	3.03	1.08	1.29	0.68

Zaitsev 1998). The calculated indexes of large-scale circulation of water of oxygen and hydrogen-sulphidous zones of the Black Sea (Table 17.3) suggest that as a result of complex influence of hydrodynamic processes the water flow through the border of oxygen and hydrogen-sulphidous zones of the sea in large-scale averaging can vary from 3120 to 10,920 km^3/year.

At the same time the period of water exchange of the oxidation zone can be estimated at 6.5–23 years, and for hydrogen sulfide zone – in 43–152 years, which is generally correspond to the previously published integral estimates of rate of the vertical circulation water of the Black Sea water rate (Vodyanitskiy 1948; Bogdanova 1959; Skopincev 1975). Calculations made using data from Table 17.4, was showed that in the Black Sea in 2013 contained 1670 TBq of ^{90}Sr, of which 547.7 TBq were in his oxygen, and 1123.3 TBq in the hydrogen-sulphidous zones.

Comparison of these data with the quantity of ^{90}Sr, entered at the period from 1986 to 2000 (260–460 TBq) showed that by 2013 the content of this radionuclide increased 3.6–6.4 times due to its accumulation in the hydrogen-sulphidous zone of the Black Sea. Similar calculations show that by 2013 the concentration of ^{137}Cs in the Black Sea waters increased 1.2–1.6 times (up to 2843 TBq), of which 953 TBq was deposited in an oxygen zone and 1890 TBq in the hydrogen-sulphidous zone of the sea. Thus, an analysis of the shown data revealed a higher rate of pollution by ^{90}Sr and ^{137}Cs of the deep waters of the Black Sea, that, apparently, caused by significant entrance of these radionuclides by runoff of rivers.

17.3.2 Bottom Sediments

The distribution of ^{137}Cs in the surface layer of bottom sediments of the north-western and western (NW-W) part of the Black Sea, received by the results of more than 150 measurements of ^{137}Cs concentration in sediments sampled in 1990–1994 in different areas of the shelf, continental slope and in the deep part of the sea is

Table 17.4 Indicators of large-scale circulation of water oxygen and hydrogen sulphide zone of the Black Sea

Oxygen zone					
Interval depths, m	**The surface area of the lower boundary zone, km²**	**Volume, km³**	**Water exchange with the underlying layers**		**Period of water exchange $T_{exch.}$ through the lower boundary, years**
			m/year	**$T_{exch.}$, km³/year**	
0–200	423,000	71,110	10–35	3120–10,920	6.5–23.0
				5050.1[a]	14.1[a]
Hydrogen-sulphidous zones					
Interval depths,m	**The surface area of the upper boundary zone, km²**	**Volume, km³**	**Water exchange with the water of the oxidizing layer**		**Period of water exchange $T_{exch.}$ hydro-gen-sulphidous zone, years**
			m/year	**km³/year**	
200–2212	312,000	475,890	10–35	3120–10,920	43.0–152.0
				5051[a]	94.2[a]

[a]– estimate obtained by the results of simulation (Egorov et al. 1993); $T_{exch.}$ – period of water exchange

shown on Fig. 17.9 (Gulin et al. 2002; Polikarpov et al. 2008). Inventories of ^{137}Cs in bottom sediments at the selected sites of the NW-W part of the Black Sea (Stokozov 2004; Polikarpov et al. 2008) are shown on Fig. 17.10. The most contaminated bottom sediments were in the delta of the Danube and the Dnieper-Bug estuary. This reflected the relatively large entrance of the Chernobyl ^{137}Cs with flow of the north-western rivers into the Black Sea for a 4–8 year period that has elapsed since the Chernobyl NPP accident to the moment of sampling. The increased concentrations of ^{137}Cs were found, also, at Cape Tarkhankut, in the north-western part of the Crimean peninsula. This could be the result of active irrigation of this region of the Dnieper water entering the North-Crimean Canal (NCC). It is known, that the annual consumption of water in the NCC is about 9.5 km^3, which is comparable, for example, with the annual runoff of the Dniester River. It should also be noted that the components of irrigated land ecosystems accumulated up to 65–70% of the ^{137}Cs activity, entering to the NCC.

In addition, the increased concentration of ^{137}Cs in the surface layer of bottom sediments of the area may be related to the sedimentation of suspended matter at the circulation of water masses along the coast with a complex shoreline. Thus, sedimentation of the terrigenous suspended matters in estuarine areas was very high, and the sedimentation flow of the deposition of the radionuclides in these areas of the sea could be main factor of self-purification of water.

Thus, the general regularity of the change of cumulative ^{137}Cs in bottom sediments of the Black Sea after the ChNPP accident was that the maximum stock of this radionuclide was found in estuarine areas of the Danube and the Dnieper Rivers and it was an order of magnitude higher than those in the tiefensprung of the northwestern part near the isobath of 100 m and in two orders

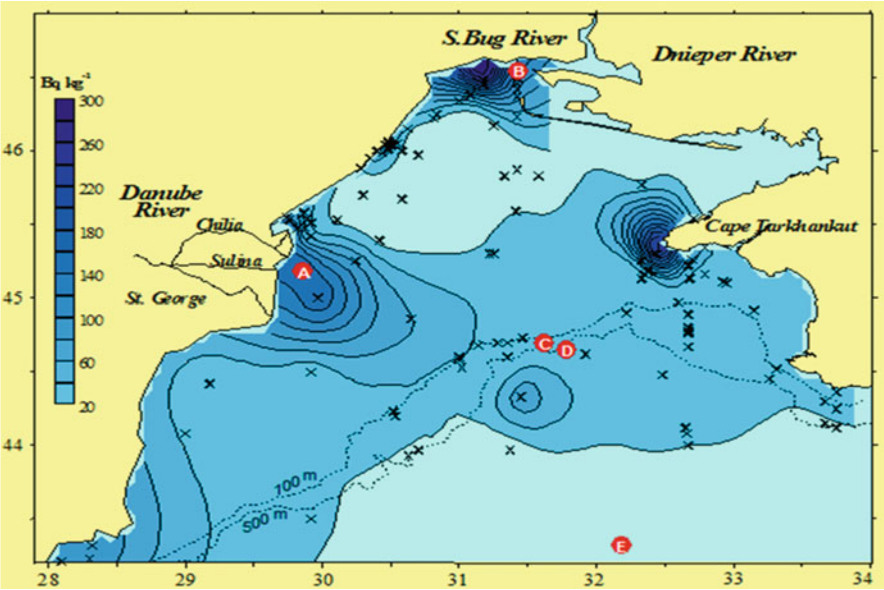


Fig. 17.9 Distribution of ^{137}Cs activity in the upper 5-cm layer of bottom sediments of the NW-W part of the Black Sea in 1992–1994 years (x – samples sites of surface sediments: *A–E* – sample sites of sediments cores) (Gulin et al. 2002; Polikarpov et al. 2008)

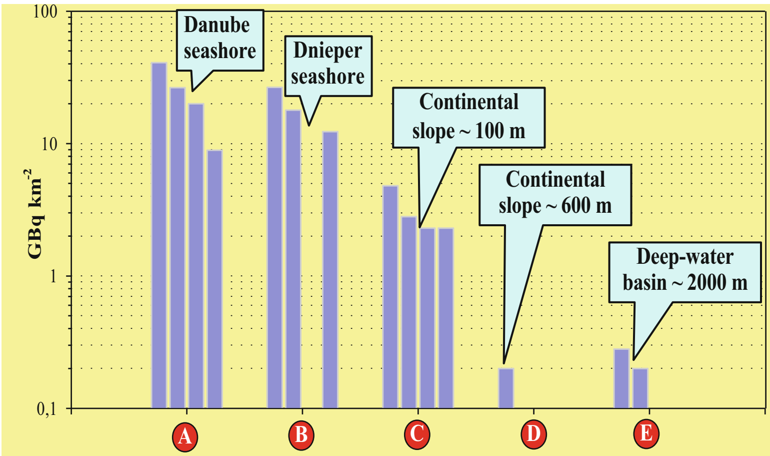


Fig. 17.10 Inventories of ^{137}Cs in bottom sediments at the selected sites of the NW-W part of the Black Sea (Stokozov 2004; Polikarpov et al. 2008)

of magnitude, than stock of this radionuclide in deep water anoxic bottom sediments, Fig. 17.10 (Stokozov 2004). The relation of ^{137}Cs inventories under the unit of area of the water column to the ^{137}Cs inventories in the unit square of the bottom ranged from 0.01 to 0.04 in the estuarine areas of the Danube and the Dnieper to 1.3–2.2, at the tiefensprung and up to 25–100 in the deep part of the sea. These evaluations confirmed that the role of sedimentation factor ^{137}Cs migration in the Black Sea could be relevant only in the local estuarine areas of rivers.

The scheme of redistribution of the average concentrations of ^{90}Sr (Bq kg^{-1} dw) in bottom sediments (0–5 cm layer) of the Black Sea in 1986–2015 are presented on Fig. 17.11. They show that in 1986, ^{90}Sr concentration in the sediments ranged from 0.4 to 46.4 Bq kg^{-1} dry weight. ^{90}Sr distribution depended both on the depth of the sediment, and the remoteness of the area from the sources of income of the radionuclide in the Black Sea – the Dnieper and the Danube Rivers. In the western deep-water part of the Black Sea at a depth of ~ 2000 m (Fig. 17.11), the concentration of ^{90}Sr in 1988 was 0.3 Bq kg^{-1} dry weight, which corresponded to the levels defined in the Black Sea to the ChNPP accident (Barannik 1974; Database ORChB IMBR 2006). ^{90}Sr concentration in the sediments of the estuary of the Chorokh River (south-eastern part of the sea) was also small, and in 2000 was 0.5 Bq kg^{-1} dry weight. The most contaminated by 90Sr areas were estuarine zone of the Dnieper, the Dniester and the Danube, partly area Tarkhankut peninsula, south-eastern part of Crimea (Feodosia district). The association of elevated concentrations of ^{90}Sr to these areas not only persisted over time (until 2015), but also the process of increasing of the concentration of radionuclides in bottom sediments in studied regions was observed.

17.3.3 Forecast Assessments

The forecast assessments of the time periods to reach to the pre-accident levels of ^{90} Sr and ^{137}Cs concentrations in the balance, abiotic and biotic components of the Black Sea ecosystems are presented in Table 17.5. The periods of time of the decreasing in twice and total periods of decreasing concentrations of these artificial radionuclides to pre-accident levels were determined for the balance components, biotic and abiotic components of the Sevastopol bays of the Black Sea. It was found that the biogeochemical processes occurring in the Black Sea, in average decrease in 2–6 times the residence of the post-accident ^{90}Sr and ^{137}Cs in comparison with the physical half-lives, and five periods of decay of investigated radionuclides.

17.4 Conclusion

It was determined, that the main factors of the formation of radioactive pollution in the Black Sea are: atmospheric fallout on the surface of the sea, entry of the radionuclides into the oxygen zone with runoff of the rivers, removal of radionuclides through the straits, migration into the deep zone, removal into the thickness of bottom sediments, radioactive decay.

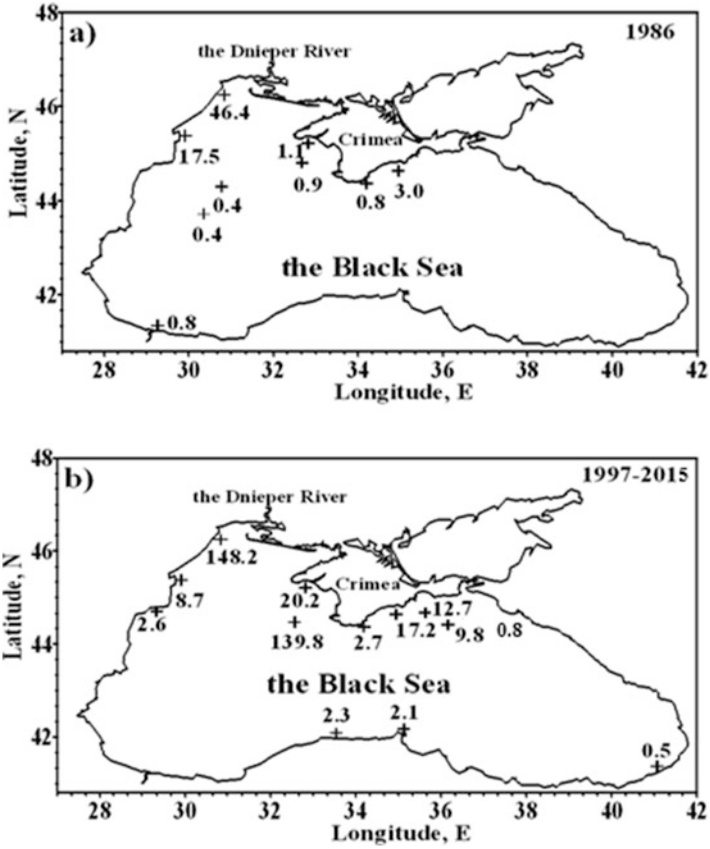


Fig. 17.11 The maps of contamination of the Black Sea bottom sediments (in a layer 0–5 cm) by ^{90}Sr for the after accidental period 1986–2015

As a result of the contemporary forecast estimates it was obtained that a decrease of the 90Sr concentration in the water of the Dnieper-Bug estuary (northern area of the north-western part of the Black Sea) to the pre-accident levels will occur up 2018, rather than before 2025, as assumed previously (Mirzoyeva 2008). The hydrological and biogeochemical processes, occurring in the study area of the sea, reduce the time of presence of post-accident radionuclides in the marine environment in the 2–6 times.

To the present time the stationary equilibrium is formed between entrance and elimination of ^{90}Sr and ^{137}Cs in the oxygen zone of the Black Sea, while the content of radionuclides in the hydrogen-sulphidous zone of the sea has been increasing.

By 2013 the content of ^{90}Sr and ^{137}Cs was evaluated in the Black Sea as 1670 TBq and 2843 TBq, respectively, that in 3.6–6.4 and in 1.2–1.6 times was higher than the content of the radionuclides in the 2000. Herewith 66% and 67%

Table 17.5 Half–lives ($T_{0.5}$) and complete times of responses ($T = 5\ T_{0.5}$) for main balance components and some ecosystems of the Black Sea Basin to the pollution with ^{90}Sr and ^{137}Cs after the ChNPP accident (years)

Components	^{90}Sr		^{137}Cs	
	$T_{0.5}$	T	$T_{0.5}$	T
Inflow from the Dnieper River (since 1987)	7.0	36.0	2.0	11.0
Inflow from the Danube River (since 1987)	14.4	73.0	6.9	35.5
Outflow through the Bosporus Strait (since 1987)	9.5	47.5	6.4	32
Surface waters near the Dnieper estuary (since 1989)	9.6	52.0	–	–
Surface waters of the Central Western Black Sea (since 1986)	9.9	49.5	6.1	30.5
Danube Delta marine bottom sediments (since 1991)	–	–	14.4	77.0
Region of the Sevastopol Bay:				
Surface waters (since 1987)	8.8	45.0	6.1	30.5
Brown seaweed *Cystoseira crinita* (since 1987)	4.9	25.0	4.7	24.0
Mollusc Mytilis galloprovincialis *(since 1986)*	6.7	33.5	7.6	38

Note:–Including period before an exponential decreasing

^{137}Cs ^{90}Sr of the total content of radionuclides in the water was in the hydrogen-sulphidous zone of the Black Sea.

The period of the cycle of ^{90}Sr and ^{137}Cs in the oxygen and hydrogen-sulphidous zones of the Black Sea is about 14 and 94 years, respectively. In the latter case, this value is three times the half-life of ^{90}Sr and ^{137}Cs, so the hydrogen-sulphidous zone of the water column of the Black Sea can be seen as a depot for these radionuclides.

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Chapter 18
Radioecology of the Black Sea

Aleksandr Strezov

18.1 Introduction

Radioecology is a modern science dealing with the behavior of radionuclides in the environment. The studies of marine ecosystems, biodiversity and biota interactions, including reliable evaluation of radionuclide and heavy metal impact on soils, sediments and algae is a major task in studying the risk of environmental pollution and effects on humans. Creation of data bases for long term environmental management of pollution; evaluation of ecological impact of human activities and management of sustainable environment – coastal zone and continental shelf, including assessment and forecasting techniques, is needed to understand the impacts of various activities on ecosystems, to contribute to protect the ecosystems from pollution and to develop long-term models for management of the coastal zone.

18.1.1 The Black Sea Marine Ecosystem

The pollution of marine ecosystems by nuclides and heavy metals has been a worldwide problem in the last decades. The Black Sea ecosystem and ecological status has been damaged mainly as a result of chemical pollution. Much of the pollutants come from major rivers and from smaller sources in all Black Sea coastal countries. The Black Sea water column is heavily impacted by a great number of pollutants

A. Strezov (✉)
Bulgarian Academy of Sciences, Institute for Nuclear Research and Nuclear Energy, Blv Tzarigradsko shosse 72, Sofia 1874, Bulgaria
e-mail: astrezov@abv.bg

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originating from different sources of direct and indirect discharge of land based sources – sewage, fallout etc. from economies of coastal states.

The Black sea is a half-enclosed sea, with 40°27′N-46°32′N latitude and 27°27′E–41°42′E longitude. Together with Azov Sea, it covers an area of 462,000 km^2. Its east to west dimension is 1150 km and from north to south is 610 km. In the Black sea main basin, the depth of water approaches 2200 m, and the western shelf zone is comparatively shallow. The Black sea is surrounded by six countries and is linked with the Mediterranean Sea through the Bosphorus, and the Azov Sea to the north.

The Black Sea has experienced the worst environmental degradation of all of the world's oceans. The situation has become so severe that it has affected the health and standard of living of the people in the immediate area. Most of the six coastal countries – Bulgaria, Georgia, Romania, Russia, Turkey, and Ukraine – have unstable or collapsed economies. About 160 million people live in the Black Sea catchment basin, including 80 million only in the Danube River basin. Although international agreements, strategic plans, and national environmental programs are in place, the severe economic problems have significantly slowed environmental monitoring, remediation, and restoration efforts. The environmental crisis and subsequent dramatic changes in the Black Sea's ecosystem and resources are a direct effect of both natural and anthropogenic causes: an enormous increase in the nutrient and pollutant load from three major rivers, the Danube, Dnyestr, and Dnyepr; from industrial and municipal wastewater pollution sources along the coast; and from dumping on the open sea. The Bosphorus is essentially a narrow elongated shallow channel approximately 31 km long, with a width varying between 0.7–3.5 km and a depth of 39–100 m. The main rivers: Rioni, Kodori and Inguri Chorokh, Kyzyl-Irmak, Eshil-Irmak, Sakarya, Kuban, Dnister and Southern Bug also flow into the Black Sea.

The seabed is divided into the shelf, the continental slope and the deep-sea depression. The shelf occupies a large area in the north-western part of the Black Sea, where it is over 200 km wide and has a depth ranging from 0 to 160 m. In other parts of the sea it has a depth of less than 100 m and a width of 2.2 to 15 km.

The Black Sea encloses the largest body of permanently anoxic water in the world: some 90% of the sea's 5.37×10^5 km^3 total volume is deprived of oxygen and rich in hydrogen sulphide. Only a thin upper layer of marine water (up to 150 m) supports the unique biological life in the Black Sea ecosystem. The deeper and more dense water layers are saturated with hydrogen sulfide, that over thousands years, accumulated from decaying organic matter in the Black Sea. Due to this unique geomorphological structure and specific hydro-chemical conditions, specific organisms, basically on the level of protozoa, bacteria, and some multicellular invertebrates inhabit the deep-sea waters. The coastal industries discharge wastes directly into the sea with little or no treatment. The countries of the Black sea basin do their efforts to protect the nature of the sea by formulating international rules for the cleaning of water areas from oil and wastes. Nuclides and heavy metals in the marine environment constitute a potential risk to the flora and fauna species, including humans through food chains. Furthermore, there is increasing evidence that presence of nuclides and heavy metals is linked to the exacerbation of some microbial diseases in aquatic organisms.

At sufficiently high concentrations, heavy metals are toxic to the organism, and so, it is important their concentrations to be monitored especially when increased above the normal levels in the environment before the effects on marine organisms.

The Black Sea drains a surface of land five times larger than its own area, shared by 17 countries and inhabited by over 160 million people. Rivers, notably the Danube, Dnieper, Don, Kuban and Bug, bring in about 80% of the pollutants (50% from the Danube alone). They include agrochemicals, poorly treated industrial liquid effluents, and domestic wastewater. Atmospheric transport, predominantly from Europe, and coastal sources, such as direct industrial waste and sewage discharges or dump sites, account for the remaining 20%. Riverine input of nutrients, heavy metals, radionuclides, organic compounds and oil is a severe problem.

The concentrations of rivers pollutants (domestic and industrial discharges) provide useful information about the sources that have the potential to lead to local pollution problems along the Black sea coast. The shallow, biologically productive layer of the Black sea receives water from a waste drainage basin of about 17 countries. Pollutants, transported by rivers, forms the main source of pollution in the Black sea.

According to Zaitzev (1992) the estimation of land based sources, the sea annually receives big amounts of mineral nitrogen, mineral and organic phosphorus, as well oil and oil products, detergents, zinc, lead, mercury, copper, arsenic, chromium.

Man-made eutrophication of coastal waters and shelf zones has been the most harmful impact on the sea. The area most affected by eutrophication is the north-western part of the sea, where the three largest rivers, the Danube, Dniester and Dnieper are inflowing.

Increase in nutrients in the river discharge triggered the mass development of phytoplankon and an expansion in the area of its blooms. This phenomenon has been thoroughly studied by Ukrainian, Romanian and Bulgarian scientists. A large algal biomass provides good feeding conditions for plant-eating animal plankton (zooplankton) and a sharp increase in the numbers of some zooplankton species occurred in the 1970s and 1980s.

Aquatic organisms, especially macroalgae, are widely used as bioindicators for the study of marine Nuclides and heavy metals are the most harmful elemental pollutants and are of particular concern because of their toxicities to humans. They include both essential elements like iron and toxic metals like cadmium and mercury. Most of them show significant affinity to sulphur and disrupt enzyme function by forming bonds with sulphur groups in enzymes. Cadmium, copper, lead and mercury ions bind to the cell membranes hindering the transport processes through the cell wall. Some of the metalloids, elements on the borderline between metals and nonmetals, are significant water pollutants (Manahan 1999).

Radionuclides occur naturally in the environment but recently some artificial radionuclides have been introduced. In the past there have been several accidents, at nuclear plants, with satellites, aircraft and nuclear submarines, in which radioactive material has been dispersed (or could be dispersed in the future) into the marine environment. The most important was the Chernobyl accident which caused world-wide distribution of some of the radionuclides released (e.g. ^{137}Cs). Other nuclear accidents which have occurred in coastal sea areas (e.g. in Vladivostok Bay) or inland (e.g. at Chelyabinsk) have had only regional effects on the radionuclide concentrations of the marine environment.

One of the most widespread is the ^{137}Cs isotope. Its major sources come from the atmospheric deposition of debris from atmospheric nuclear explosions that occurred in the 50 and 60’s and in the northern hemisphere from nuclear accidents in particular.

18.1.2 Radionuclides in the Black Sea Marine Environment

Since 1945 there has been a continuous release of technogenic radionuclides to the environment, leading to their accumulation in the seas and oceans, the main source of contamination being nuclear weapons tests in the atmosphere, on land and in water. The Danube was the main contributor for nuclides in the Black Sea region before 1986 mainly ^{90}Sr and ^{137}C) Polikarpov (1966), Kulebakina and Zesenko (1984), Sokolova (1975), while the Dnyepr took second place.

After the Chernobyl accident a considerable increase occurred in nuclides quantity in the environment (Buesseler et al. 1987; Kulebakina et al. 1988; Kulebakina and Polikarpov 1989; Baumann et al. 1989; Broberg 1989; Hadderingh and Kema 1989). The Black Sea being near to the reactor accepted great quantity direct atmospheric radionuclide fallout. Additionally Chernobyl nuclides entered and continued to enter the environment carried by the big rivers – Danube, Dnyepr, Dnester.

A major part of the distribution and migration of long lived nuclide contaminants (mainly ^{137}Cs, ^{90}Sr) are not only the hydrophysical processes but also the biosedimentation and sorption on bottom sediments and concentration by biota. It is known that ^{137}Cs and ^{90}Sr fallout before 1986 are found in sea water mainly in soluble forms (Shvedov et al. (1962), and are weakly affected by biological migration (contrary to other nuclides as ^{141}Ce, ^{144}Ce, ^{103}Ru, ^{95}Zr etc.). Chernobyl radionuclides are characterized by a higher content of nonsoluble forms (even “hot” particles) which are part of the reactor fuel. These peculiarities affect the behavior of the Chernobyl nuclides in sediments and their accumulation in biota. The contamination of sea bed sediments by ^{137}Cs and ^{90}Sr had a “spot” character which was due to the way Cs entered the environment at the beginning – mainly airborne on different particles.

Cesium penetrated rather quickly the water depths – in 1987 Cs was measured up to 120 m, while in 1988 it reached 200–250 m. The observed phenomenon of “self decontamination” of Black Sea waters was due to the radioactivity spots dilution and secondly to interaction of dissolved Cs with the bottom sediments (Polikarpov 1987; Kulebakina et al. 1988; Kulebakina and Polikarpov 1989).

The natural nuclides members of uranium 238 and thorium 232 also enter the environment be several pathways and are also accumulated in biota.

So it is necessary to assess scientifically the impacts of discharges on humans and to identify the most important critical 'pathways' or 'groups' and the risks involved also attempt to consider multiple exposure routes. It can indeed be argued that radioactive pollution control is more successful in producing a mature methodology which is unifying in respect of all radioactive substances and there are only a few cases where conventional pollutants are successfully ranked against each other – such as in considering their relative importance as 'greenhouse' gases or the relative toxicity of certain similar organic compounds. However, in conventional pollution control, one further step is taken after risk assessment, one which is absent from radioactive pollution control – namely, the information generated in the earlier stages is used to produce 'environmental quality standards' against which absolute concentrations, trends and the effectiveness of pollution control at source can be clearly measured. Thus, if instead of considering, e.g. plutonium or technetium in units of 'concentration', we consider them as contributors to the overall 'dose', we cease to treat them as 'substances' in their own right and simultaneously regard the world as a 'brown-field site' already 'contaminated'. However, ecological toxicology (ecotoxicology) is required for predicting real world effects and for site-specific assessments. Ecotoxicology and ecology have shown similar developmental patterns over time; closer cooperation between ecologists and toxicologists would benefit both disciplines. Ecology can be incorporated into toxicology either extrinsically (separately, e.g., providing information on pre-selected test species) or intrinsically (e.g., as part of test species selection) – the latter is preferable. General guidelines for acute and chronic testing and criteria for species selection differ for ecotoxicology and environmental toxicology, and are outlined.

Radionuclides are a part of anthropogenic pollutants in the Black sea marine ecosystems. Massive amounts of industrial effluents are transported by the big rivers that enter the Black sea (Danube, Dnyeper, Dnester etc.). The change in the radiation situation in the Black Sea after the Chernobyl accident stimulated multiple studies of radionuclide accumulation processes in biota as the Black sea received a great amount of radionuclides, due to its geographical position. The complex analysis of pollutants is a major task for modern ecology in obtaining reliable information about the type and quantities of substances entering the marine environment. The analysis of environmental matrixes, such as water/sediments/algae, provides a picture of the total contaminant load in a given ecosystem.

The contamination of Black sea littoral zone is a powerful factor affecting the phytobentos dynamics. The technogenic and natural nuclide releases due to human activities in the marine ecosystems lead to a change in contaminant content and may affect the composition of species in the marine environment (Bologa et al. 1996; Guven et al. 1993). The complex analysis of pollutant concentrations in the marine environment gives reliable information for the types and quantities of contaminants that enter the hydrosphere. The change in the radiation situation of the Black sea after the Chernobyl accident was the reason for multiple studies on radionuclide accumulation processes in biota. The Black sea received a great amount of radionuclide impact due to its geographical position as the closest marine basin to the accident site. The technogenic radionuclides got into the marine ecosystems through atmospheric fallout and through the big rivers Danube, Dnieper and Dnester that enter the northwest Black sea corner. For this reason, the level of anthropogenic nuclides should be monitored to evaluate the radioactivity transfer along the trophic chain and assess the radiation risk for biota in the marine ecosystem.

Since 1945 there has been a continuous release of technogenic radionuclides to the environment started, leading to their accumulation in the seas and oceans, the main source of contamination being nuclear weapons tests in the atmosphere, on land and in water. The Bulgarian Black Sea coast received a great amount of radionuclide impact during nuclear tests in 1960s and after 1986 being close to Chernobyl NPP, a considerable direct atmospheric radionuclide fallout occurred in the environment, Additionally, Chernobyl nuclides entered the marine environment mostly in the northwest corner of the Black Sea carried by the big rivers – Dnyepr, Dnester, Danube (Keondjan et al. 1990) plus pollutant emissions carried by the local rivers (Tuncer et al. 1998).

Marine sediments are widely used for environmental control because of their ability to accumulate various pollutants. Macroalgae are another important medium for nuclide accumulation in marine ecosystems. Radionuclides affect the living organisms both as heavy metals and by their radiation. They participate in radionuclide and heavy metal transfer to the biosphere and man as elements of the food chain of marine biota. Many authors have investigated migration of radionuclides as well as biological effects of ionizing radiation in the Black sea environment.

18.2 Radioecological Studies of Black Sea Ecosystems

18.2.1 Romanian Marine Research

A semi-enclosed tideless basin bordering six countries, the Black Sea is still considered a **"unicum hidrobiologicum"** because of its physical, chemical, and biological peculiarities; unlike any other sea. The Black Sea is permanently deficient in oxygen, or anoxic below a depth of 150–200 m (Bologa 1994). Major factors contributing to the deterioration of the Black Sea environment are pollution and improper use of natural resources (Osvath et al. 1998). The Black Sea is a unique marine environment, one especially exposed to anthropogenic impact. Almost landlocked, besides the link with the shallow inland Azov Sea, its only exchange of water with the World Ocean is through the narrow Bosporus Strait.

As to radioactive contamination, different IAEA programmes showed that concentration of anthropogenic radionuclides in the Black sea environment, although considerably higher than in other parts of the World Ocean, are such that no significant radiological consequences can be expected for the public.

Fallout from atmospheric weapon tests and from Chernobyl accident provided excellent radiotracers for the Black Sea, such as ^{90}Sr, ^{137}Cs and plutonium isotopes (Osvath et al. 1998). The main input occurred through direct deposition on the sea surface. For ^{90}Sr, the Dnieper river became a significant source after the nuclear accident.

Various radiotracers can be used to trace water mixing and circulation, as time markers to provide sediment deposition chronologies, to provide information on fluxes of particles and particle-reactive pollutants, and in planktonic primary production estimates by, ^{14}C (relevant to eutrophication).

For the Romanian Black Sea sector such work has carried particular importance. The need for monitoring radioactivity level's is mainly explained by the continuing existence of fallout, by the than its own area, shared by 17 countries and inhabited by over 160 milion people. Rivers, notably the Danube, Dnieper, Don, Kuban and Bug, bring in about 80% of the pollutants (50% from the Danube alone). They include agrochemicals, poorly treated industrial liquid effluents, and domestic wastewater. Atmospheric transport, predominantly from Europe, and coastal sources, such as direct industrial waste and sewage discharges or dump sites, account for the remaining 20%. Riverine input of nutrients, heavy metals, radionuclides, organic compounds and oil is a severe problem (Osvath et al. 1998). The Black Sea's radioactivity levels have been the subject of rigorous research in the riparian countries and among organizations participating in various international oceanographic cruises. After the Chernobyl accident interest in radiological research of the Black Sea increased. Studies have included both radioactivity surveys on abiotic and biotic compounds, and experiments on the biokinetics of radionuclides in the marine environment.

The main research tasks have included completion of the database on marine radioactive levels. Data have been also used for studies of distribution coefficients (Kds) for marine sediments and seawater and of concentration factors (CFs) for relevant local species. Assessment of external and internal individual and collective doses from marine radioactivity due to immersion in seawater and/or sea food consumption is also being made (Patrascu and Bologa 1990).

The monitoring is being done for a number of reasons. One objective was to define the levels of radioactivity in the marine environment as a baseline before the new NPP started operating. Another objective was the identification of bioindicators for studying radiocontamination of the marine ecosystem, and experimentally determining possible levels of accumulation of critical radionuclides in marine biota and biological systems having direct or indirect influences on the environment and human health.

Studies of radioactivity in environmental components in the Romanian marine sector date back in 1962. Beginning in 1976, the Romanian Marine Research Institute (RMRI, later National Institute for Marine Research and Development **"Grigore Antipa" –** NIMRD) initiated the country's systematic study of marine radioactivity using a network of permanent stations located between the Danube mouths, the southern extremity of the Romanian littoral, and occasionally offshore up to 90 nautical miles (Bologa 1994; Bologa et al. 1995). The monitoring programme has resulted in a fairly extensive database covering the last 20 years. A network of stations including the whole area between the Danube mouths (Sulina) and the southern limit (Mangalia), from the shoreline to 90 n.m. offshore has been used for radioactivity monitoring in the Romanian Black Sea sector.

Romanian studies thus particularly focused on computing the concentration of ^{137}Cs and ^{90}Sr for sediment and seawater in the pre-Danubian sector of the Black Sea. Gamma spectrometry was used for analyzing emerged and submerged sediments, seawater, macroalgae, invertebrates and fish of marine origin (Bologa et al. 1991).

The highest content of artificial gamma emitters was noticed in 1986, followed by its subsequent decrease in all components, excepting submerged sediments that are a sink for the isotopes. Environmental CFs for ^{137}Cs and ^{90}Sr in different Black Sea biota were also estimated (Fig. 18.1). The radiometric investigations of the coastal marine ecosystem showed the presence of the long-lived anthropogenic radionuclides ^{90}Sr and ^{137}Cs (Table 18.1). Significant ^{90}Sr activities (0.53–8.6 Bq. kg dry weight (d.w.) were found in the submerged sediments collected from seven profiles between the northern and southern limits of the Romanian littoral (Table 18.1). The maximum values were recorded at the pre-Danubian zone, in good generally correlation with quality and origin of the sediments. For 1998 the ^{90}Sr level ranged from 2.1 to 7.8 Bq.kg^{-1} d.w. in 1999 from 3.1 to 8.3 Bq.kg^{-1} d.w. Emerged sediments were under lower limit of detection ($<$1.8 Bq.kg^{-1} d.w.), emphasizing small influence of the aquatic environment and their processes.

The continued monitoring of marine radioactivity is necessary either for avoiding of any nuclear risk and for comparative radio-metric studies in the coastal zone (Patrascu and Bologa 1990; Bologa and Patrascu 1998; Bologa et al. 1998). The knowledge and conservation of the environmental factor quality can be supported only by concrete results (Fig. 18.2).

Romanian monitoring data of the annual concentrations of gamma emitting radionuclides were used in the IAEA and national data bases.

18.2.2 Ukrainian Marine Research

The Black Sea is one of the most contaminated marine basins in the Northern Hemisphere; since the 26 April 1986 Chernobyl disaster, the Black Sea has been a sink for Chernobyl-associated radionuclides. It has been estimated that ~2 PBq of ^{137}Cs were directly deposited by the atmosphere onto the water surface of the Black Sea.

Most previous papers investigating fluvial transport of Chernobyl debris into the Black Sea have focused on ^{137}Cs and ^{90}Sr. Also associated with direct atmospheric fallout as well as fluvial transport, however, are nonvolatile radionuclides from fuel particles, including transuranium elements (Np, Pu, Am, Cm).

Fig. 18.1 The Black Sea countries

Table 18.1 Results on radioactivity level for marine components (1992–1997)

Component	N	Gross beta	^{90}Sr	^{137}Cs
Sediment				
Emerged	141	30–1300	<1.8	1.1 -:- 11
Submerged	154	95 -:- 1470	0.53 -:- 8.6	3.7 -:- 257
(Bq/kg dry.w.)				
Seawater	62	3300 -:- 7500	10.9 -:- 26	0.1 -:- 120
(Bq/m^3)				
Macroalgae	52	39 -:- 683	<0.16 -:- 12.3	0.2 -:- 81.4
(Bq/kg d.w.)				
Molluscs	41	12 -:- 192	<0.13 -:- 0.7	0.4 -:- 2.6
(Bq/kg d.w.)				
Fish	42	17 -:- 251	<0.15 -:- 1.1	1.2 -:- 7.2
(Bq/kg d.w.)				

In a 2002 study, Gulin et al. investigated the ^{137}Cs, ^{238}Pu, ^{239} + ^{240}Pu, and ^{241}Am activity profiles in sediments collected from the Danube and Dnieper Deltas. In surface sediments (0–5 cm), a distinct enhancement of ^{137}Cs was evident in the vicinities of the river mouths, with activities diminishing *vs* distance; ^{137}Cs inventories were 1–2 orders of magnitude higher in the deltas *vs* remote locations. Gulin et al.'s Danube core revealed a ^{137}Cs activity peak associated with 1963 stratospheric fallout, as well as a more recent, higher-activity peak associated with Chernobyl. The ^{238}Pu and $^{239+240}Pu$ activity profiles exhibited similar features, dated as 1991 and 1993 from hydrologic data. The presence of high ^{241}Am activities, $^{241}Am/^{239+240}Pu$ activity ratios of ~1, and $^{238}Pu/^{239}$ + ^{240}Pu exceeding

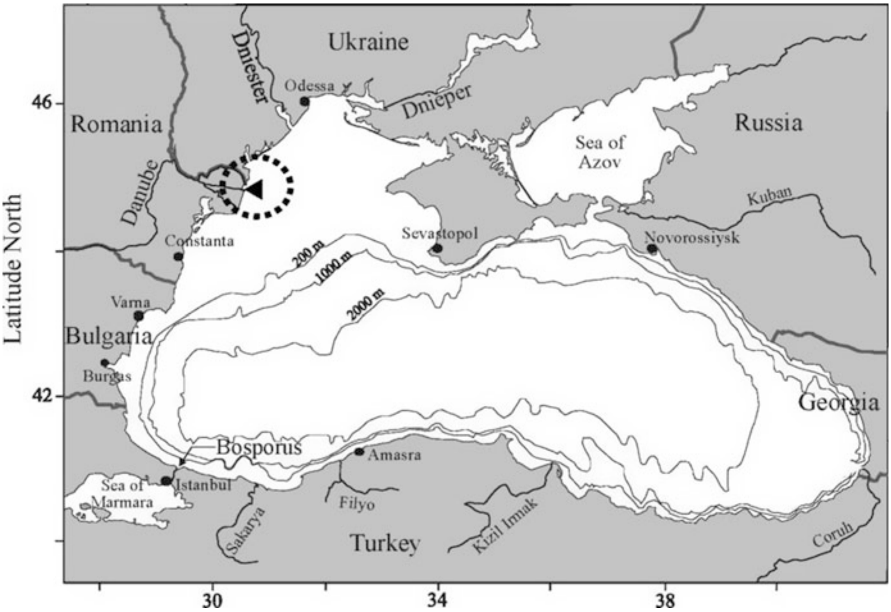


Fig. 18.2 Rivers flowing in the Black Sea

stratospheric fallout ratios all supported the finding that Chernobyl-derived Pu was being transported in an episodic fashion into the Black Sea (Table 18.2).

Valuable Pu fingerprinting information can also be ascertained using ^{240}Pu/^{39}Pu atom ratios. Since Pu is almost exclusively of synthetic origin, its isotope composition reflects the neutron flux conditions present during its production. The main sources of Pu in the Earth's surface environment have been releases from Pu production reactors (i.e., Hanford), power reactor accidents (e.g., Chernobyl), and fallout from the large-scale atmospheric tests of nuclear weapons that commenced in the early 1950s.

Compared to stratospheric fallout, Chernobyl debris exhibits much higher ^{240}Pu/^{239}Pu; Muramatsu et al. (2000) studied soils from the 30 km exclusion zone near the reactor vast majority of Th and U.

Pu fractions were analyzed by sector field ICPMS using a VG Axiom MC system equipped with a CETAC U-5000AT ultrasonic nebulizer. The ICPMS instrument was operated in the single collector, electron multiplier mode. The low-resolution mode (m/Am ~400 at 10% height) was used. A tuning solution containing 0.05 pg/L U was used to adjust and optimize the experimental conditions before analysis. Solutions were supplied to the ultrasonic nebulizer by means of a peristaltic pump operating at an uptake rate of 400–500 pL/min. Ion intensities were collected at a single point at the summit of each mass spectral peak with a dwell time of 10 ms; ions monitored were ^{238}U+, ^{239}Pu+, ^{240}Pu+, and ^{242}Pu+. The E-scan (electrostatic sector scanning) mode was used to cycle repeatedly between these ions for three to five sequential 90 s integrations. A $^{238}U^{1}H^{+}/^{238}U^{+}$ ratio of 0.00003 was measured,

Table 18.2 Interannual changes of average ^{90}Sr and ^{137}Cs concentrations in the sea water of the North-western Black Sea before and after the Chernobyl nuclear power plant (ChNPP) accident

Period, year	Concentration ^{137}Cs Bq m^{-3}	^{90}Sr Concentration Bq m^{-3}
Before 26th of April 1986	14–15	15
After 26th of April 1986	143 ± 43	28–53
1987	84 ± 25	22 ± 3
1988	79 ± 24	24 ± 6
1989	476 ± 24	21 ± 1
1989	76 ± 1.3	21 ± 1
1990	69 ± 21	23 ± 2
1991	31 ± 9	No data
1992	36 ± 11	20 ± 1
1993	36 ± 11	22.0
1994	27.7	27.3
1995	28 ± 8	15.0
1998	24 ± 6	20 ± 4
2000	24 ± 2	19 ± 4
2011	14.9–16.8	6.7–32

and the $^{238}U^{+}$ intensity was used with this correction factor to subtract the UH^{+} contribution on ^{239}Pu+, the correction amounting to <2% of the total m/z 239 signal. Mass discrimination was 0.7–0.8% per m/z, and corrections were performed using a factor determined based upon $^{238}U/^{235}U$ measured externally for a natural U standard ($^{38}U/^{235}U$ = 137.88). The UH+ and mass-discrimination corrected ICPMS data were used to calculate $^{239+240}$Pu activities and $^{240}Pu/^{239}Pu$ atom ratios.

The accuracy of the ICPMS-based $^{239+240}$Pu activity measurements were assessed through preparation and analyses of two standard reference materials produced from the US National Institute of Standards and Technology (NIST). Seven aliquots of 1.0 g nominal mass were prepared for each of these materials through the course of the study. For NIST 4353 (Rocky Flats Soil-1), a ^{239} + ^{240}Pu activity of 8.3 ± 1.4 Bq/kg was found; for NIST 4357 (Ocean Sediment), a ^{239} + ^{240} Pu activity of 10.7 ± 0.9 Bq/kg was obtained. These compare well *vs* the certified activities of 8.03 ± 0.60 and 10.4 ± 0.2 Bq/kg, respectively. Though these materials are not certified for any Pu atom ratios, the $^{240}Pu/^{239}Pu$ results obtained (0.061 ± 0.003 and 0.227 ± 0.010 for 4353 and 4357, respectively) are concordant with expected $^{240}Pu/^{239}Pu$ in materials containing weapons-grade Pu (NIST 4353) and Pu from latter Sellafield discharges (NIST 4357).

Monitoring of the radiochemoecological state of the Black Sea ecosystem was carried out after the Chernobyl accident in the period between 1986 and 2011. Materials for investigation were taken during expeditions as a rule on scientific research vessels such as “Professor Vodyanitskiy” and “Academician Kovalevskiy”, IBSS. Sampling of the bottom sediments was carried out by box corers. Concentrations of the radionuclides of ^{90}Sr and ^{137}Cs were analyzed in the following marine macrophytes: *Ceramium virgatum, Cladophora spp., Cystoseira* *crinita, Padina pavonica, Phyllophora crispa, Ulva rigida C. Ulva linza* and *Zostera marina.* Alpha-radionuclides of $^{239,240}Pu$ were analyzed in water, bottom sediments and the following hydrobionts: macroalgae – C. *crinita, U. rigida, Ph. crispa;*bivalves – *Mytilus galloprovincialis* and fish – *Trachurus mediterraneus ponticus*, *Sprattus sprattus phalericus, Merlangius merlangus.*

Research was done for Pu content and it showed that the 1963 stratospheric fallout deposition maximum is present at a depth of 18–20 cm. Several lines of evidence support the 1963 interpretation of this maximum: (i) the Pu ratios in this depth range agrees with the isotopic composition of stratospheric fallout; (ii) a ^{238} Pu activity peak is also observed at this depth; (iii) the $^{238}Pu/^{239+240}Pu$ activity ratios in this portion of the sediment core are close to the Northern Hemisphere stratospheric fallout activity ratio of 0.04; and (iv) the ^{239} + ^{240}Pu activity peaks also coincide with a ^{137}Cs activity maximum found in earlier studies. The seven ICPMS-analyzed intervals between 14–16 cm and 26–28 cm, inclusive, have $^{240}Pu/^{239}$ Pu $= 0.187 \pm 0.005$ (1 SD), which coincides with the range of 0.180 ± 0.014. In the same depth range of the core, the ten intervals between 14–15 and 24–25 cm analyzed by alpha spectrometry have $^{238}Pu/^{239}$ + $^{240}Pu = 0.038 \pm 0.005$ (1 SD).

The upper portion of the sediment core, commencing at about 12 cm, clearly shows systematic changes stemming from an additional input of non-stratospheric fallout Pu. The vertical profiles of ^{238}Pu and $^{239+240}Pu$ both show double peaks above 12 cm. Associated with these peaks are $^{238}Pu/^{239+240}Pu$ activity ratios and ^{240} $Pu/^{239}Pu$ atom ratios that are significantly higher than stratospheric fallout; the highest $^{240}Pu/^{39}Pu$ ratio of 0.307 ± 0.014 was found in the 4–6 cm depth interval. It follows that the near-surface double peaks stem from fluvial transport of Chernobyl-associated radionuclides *via* the Danube River, as these peaks exhibit $^{238}Pu/^{239+240}Pu$ and $^{240}Pu/^{239}Pu$ signatures consistent with mixing of Chernobyl debris with stratospheric fallout. As a result of the Chernobyl accident, both volatile fission products (e.g. ^{137}Cs) and nonvolatile actinides (U, Pu) were distributed over a widespread area of Eurasia. The non-volatile actinides, along with nonvolatile fission products are contained in individual "hot" fuel particles of 1–10 pm aerodynamic diameter; these particles have been previously identified in Poland and in Finland. The transport of "hot" fuel particles over distances of up to ~1000 km is evident in these previous studies. Deposition of non-volatile Chernobyl particles into the Danube watershed occurred during the course of the accident; over subsequent years, material has been eroding from the catchment basin, entering the Danube River, and is thereafter transported towards the Black Sea.

An initial study of the Chernobyl disaster and its environmental effects was conducted in 1988 by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The USCEAR report depicts the behavior of the plumes released during the course of the accident.

It was demonstrated using $^{240}Pu/^{239}Pu$ atom ratios measured by SF-ICPMS, that Chernobyl-derived Pu is present in the Black Sea's Danube Delta sediments. The ^{40} $Pu/^{239}Pu$ ratios in the upper portions of a core collected in 1997 indicate mixing between stratospheric fallout ($^{240}Pu/^{239}Pu = 0.180$) and Chernobyl debris ($^{240}Pu/$ $^{239}Pu = 0.403$). The elevated $^{240}Pu/^{239}Pu$ ratios are observed in two early 1990s pulses that coincide with similar features in ^{238}Pu, ^{241}Am, ^{137}Cs, and ^{238}Pu/$^{239+240}$Pu profiles reported previously. The Chernobyl-derived Pu in the Danube Delta sediments evidently originates from non-volatile actinides deposited into the Danube catchment basin during April–May 1986, followed by erosion and fluvial transport to the Black Sea.

18.2.3 Turkish Marine Research

The radionuclide content in the Black Sea was studies by several Turkish scientists – Ugur, Topcuoglu, Guven, Varinglioglu etc. The Chernobyl fallout radionuclides were determined in a considerable amount of the anthropogenic radionuclides entered in Turkish coast of the Black Sea after Chernobyl.

The ^{137}Cs, ^{238}U, ^{232}Th and ^{40}K contents in sediment trap material are given in Table 18.1. ^{137}Cs specific activities range from 0.04 ± 0.01 to 0.10 ± 0.02 Bq.g^{-1} dry weight. The highest activity concentration of ^{137}Cs was found during Autumn 2003. Earlier, the range of the ^{137}Cs concentration was found to be 0.5–1.9 Bq˙g^{-1} dry weight.

Integrated studies were conducted by the Radioecology Laboratory of Qekmece Nuclear Research and Training Center (QNAEM) in Turkey. The Laboratory has gained considerable experience over the years, including through its collaboration since 1970 with the IAEA’s Marine Environment Laboratory (MEL) in Monaco. Agency technical cooperation projects and research programmes additionally have benefited the laboratory. This article highlights selected Turkish studies of the Black Sea related to both radioactive and chemical pollution.

Following the Chernobyl accident in 1986, the fallout radionuclides in Black Sea fish samples were determined weekly and monthly for 3 years. The fish samples were selected from both the pelagic and benthic species that can become products for human consumption. High levels of total gamma activity (^{131}I, ^{106}Ru, ^{134}Cs and ^{137}Cs) in fish samples were found in the range of 37–65 Bq/kg during May 1986. The total radioactivity levels in the fish samples gradually decreased during the first 3 months. Thereafter, except for ^{137}Cs, radionuclides attributed to the Chernobyl accident were not detected studies of the Black Sea related to both radioactive and chemical pollution.

The Chernobyl radionuclides were also investigated in mussel, sea snail and macro-algae species after the accident. The highest activities found for ^{134}Cs and ^{137}Cs were 142 Bq/kg and 289 Bq/kg dry weight in soft tissues of mussels during May and June 1986, respectively. The ^{110m}Ag radionuclide was detected at low levels in sea snails during 1986 and 1987. ^{90}Sr activity was found to be below 0.1 Bq/kg dry weight in all samples. The results showed that the western part of the Black Sea’s Turkish region was less contaminated than its eastern part. Turkish specialists have been working on the determination of anthropogenic radionuclides namely, ^{210}Po, ^{210}Pb, ^{238}U, ^{232}Th and ^{40}K in biota and sediment samples from seven stations in the Black Sea since 1997. Studies of anthropogenic ^{137}Cs also have been conducted.

The results showed that the ^{238}U and ^{210}Po concentrations in anchovy were within the ranges of 38–101 Bq/kg and 94–112 Bq/kg dry weight, respectively. These results confirm that the dominant contribution to radioactive contamination in fish comes from natural radionuclides, and the contribution of anthropogenic ^{137} Cs (from atmospheric nuclear-weapons testing and the Chernobyl accident) is negligible.

Biokinetics of ^{241}Am, ^{110m} Ag and ^{137}Cs were also investigated in mussel, limpet, sea snail and macro-algae species in the Black Sea water under laboratory conditions. In addition, ^{137}Cs in mussel and macroalgae species was investigated under contaminated Black Sea conditions after the Chernobyl accident. The biological halflives of the ^{137}Cs in mussel and macro-algae were found to be 63 days and 19 to 29 months, respectively (Tables 18.3 and 18.4).

18.2.4 Radionuclide Accumulation in Sediments, Algae and Biota in Bulgarian Black Sea Marine Ecosystems

The implementation of advanced methods and technology in the field of marine ecosystems studies is important to assess the impact of pollutants on marine ecosystems and biodiversity and biota interactions, including reliable study of radionuclide and heavy metal content in soils, sediments and algae. Creation of data bases for long term environmental management of pollution; evaluation of ecological impact of human activities and management of sustainable environment – coastal zone and continental shelf, including assessment and forecasting techniques, is needed to understand the impacts of various activities on ecosystems, to contribute to protect the ecosystems from pollution and to develop long-term models for management of the coastal zone.

Improved knowledge of marine processes, ecosystems and interactions will facilitate the basis of new ecological status, the sustainable use of the marine environment and resources, while fully respecting ecosystem integrity and functioning, and to promote the development of new, integrated management concepts.

That is why the determining of variations of ecosystem functioning; concepts for a safe and environmentally responsible use of the seafloor and sub-seafloor resources; management models of transport pathways and impacts of pollutants, key elements and nutrients in marine environments is the main task of modern marine radioecology.

Another target is to develop a predictive capability for variations in ecosystem functioning and structure for better assessment of naturally occurring mechanisms of ecosystem behaviour. Research activities will address the effects of environmental factors and interactions at sea boundaries and interfaces in relation to ecosystem functioning and alteration, distinguish natural from anthropogenic variability, assess the role of extreme environments and their communities. The

Table 18.3 Metal content in biota & sediments from the Black Sea 1997–98

Metal	Macroalgae	Mussel	Sea snail	Anchovy fish	Other fish	Sediment
Cadmium	0.5–2.7	1.8–6.4	0.4–2.2	0.1–0.2	0.1–0.2	0.6–0.9
Cobalt	<0.05–6.5	1.8–2.9	0.2–0.3	0.2–0.3	0.2–0.4	5.2–17.2
Chromium	<0.05	2.2–7.6	0.5–0.6	0.3–0.8	0.2–0.3	22–122
Nickel	2.3–83.8	4.0–4.1	<0.01	<0.01	<0.01	2.2–69.1
Zinc	59–96	256–512	41–45	30–40	26–30	57–127
Iron	106–1095	355–597	27–98	37–44	30–32	2.6–4.9
Manganese	23–296	10.1–22.8	1.9–3.5	1.8–2.5	0.5–0.7	354–902
Lead	<0.1–10.8	0.3–2.6	<0.01	<0.01	0.3–1.4	11–30
Copper	3.5–16.5	7.3–8.0	17–35	2.2–2.8	1.0–1.3	23–75

Table 18.4 Radionuclides in Turkish Black Sea, 1997–98 (in Bq/kg d.w.)

	Polonium-210	Uranium-238	Thorium-232	Cesium-137
Macroalgae	9–55	<13–744	<7–305	<3–25
Mussel (soft part)	100–162	140–240	<7	<3–20
Sea snail (soft part)	76–141	31–179	<7	<3–22
Anchovy fish	94–112	38–101	<7	<3–10
Other fish species	2–7	<13–198	<7	<3–25
Sediment	5–216	<13–63	12–36	<3–138

obtained results will facilitate the assessment of sedimentary systems for the sustainable management and use of the sea shelf.

Transport pathways and impacts of pollutants, key elements and nutrients in the marine environment will support the implementation and further development promote the advancement of relevant conventions for the reduction of nutrient and pollutant loads of the sea. Research activities should address the transport, cycling, coupling and accumulation of nuclide and heavy metal pollutants. The impact of pollutants should be addressed, their uptake by organisms, their ecotoxicological effects and the synergistic effects of multiple pollutants upon the marine ecosystems.

Another important task is the reducing the anthropogenic impact on biodiversity and the sustainable functioning of marine ecosystems, facilitating the development of safe, economic and sustainable exploitation technologies requiring safe and economic (yet sustainable) exploitation of marine resources by improving the scientific basis of sustainability.

Complex monitoring of Global changes and marine ecosystems for modelling and adequate management for sustainable environment have to include the foremost requirement to better characterize, observe and monitor the marine environment.

The objective is to stimulate "clean" technological developments for oceanic environments, to develop integrated coastal management concepts, including cost-benefit assessments, to alleviate pollution, flooding and erosion, in particular of fragile coastlines, and to ensure sustainable resource utilization. Anticipated deliverables are integrated management tools and concepts for the coastal zone ecosystem; long-term predictions of coastal zone changes; reliable, economic and environmentally compatible coastal protection measures against flooding and erosion; effective monitoring in coastal, shelf and slope areas.

Emphasis should be put on efficiency, speed, reliability, environmental friendliness and safety. In parallel, attention will be given to the improvement of sample collection and handling (including samples from sea drilling), the exploitation of distributed sample collections, and inter-calibration exercises, networking and joint experiments. Special attention will be given to the problems of coastal inlets (tidal basins, estuaries, lagoons, arias, brachial zones).

A monitoring program for measuring technogenic and natural radionuclides in marine environmental samples from the Bulgarian Black sea coast has been utilized since 1991.

The radionuclide content dependency of on the season, location, type of sediment and type of algae and the comparison of radionuclide content in bottom sediments and algae from one and the same sampling location gives information for the mechanisms of radionuclide transfer from the sediments to biota as well as the trend of the potential hazard for the marine ecosystems.

18.2.4.1 Radionuclides in Bulgarian Black Sea Sediments

A major part of the distribution and migration of long lived nuclide contaminants (mainly ^{137}Cs, ^{90}Sr) are not only the hydrophysical processes but also the biosedimentation and sorption on bottom sediments and concentration by biota. It is known that ^{137}Cs and ^{90}Sr fallout are found in sea water mainly in soluble forms and are weakly affected by biological migration (contrary to other nuclides as ^{141}Ce, ^{144}Ce, ^{103}Ru, ^{95}Zr etc.). Chernobyl radionuclides are characterised by a higher content of nonsoluble forms (even “hot” particles) which are part of the reactor fuel. These peculiarities affect the behaviour of the Chernobyl nuclides in sediments and in their accumulation in biota. The contamination of sea bed sediments by ^{137}Cs and ^{90}Sr had a “spot” character which was due to the way Cs entered the environment at the beginning – mainly airborne on different particles.

Cesium penetrated rather quickly the water depths – in 1987 Cs was measured up to 120 m, while in 1988 it reached 200–250 m. The observed phenomenon of “self decontamination” of Black Sea waters was due to the radioactivity spots dilution and secondly to interaction of dissolved Cs with the bottom sediments.

The association of radionuclides with sediments in coastal and estuary areas makes the sediments a large reservoir for radionuclides affecting significantly specific marine ecosystems. As the sea water is constantly in contact with organic and inorganic matter from sea bed sediments, the first necessary step in the estimation of radionuclide migration is the measurement of radionuclide content in sea bed sediments (as a first stage in food chain towards man) and set up a data base for radioisotope content in the Black Sea.

The measurement of technogenic and natural radionuclides in sea bed sediments was carried out in each season of every year after 1991 – spring, summer and autumn, because in this way the estimation of concentration variations of the contaminants, their accumulation and influence on marine ecosystems can be followed. The intercomparisson between the data for the technogenic and natural radionuclides gives the whole picture of isotope impact at a chosen reference point.

Many authors – Russian and Ukrainian scientists, (Polikarpov et al. 1988, 1989), Turkish – Topcuoglu et al. (2001a, b), Guven et al. (1992), Bulgarian (Strezov et al. 1996, 1998, 1999), Romanian – Bologa and Patrascu (1996) have performed measurements in the Black Sea. The impact of Chernobyl on marine ecosystems was intensively studied and much data were published in recent years. Many authors investigated the distribution of Chernobyl radionuclides and their accumulation in lake sediments as well as in sea bed sediments.

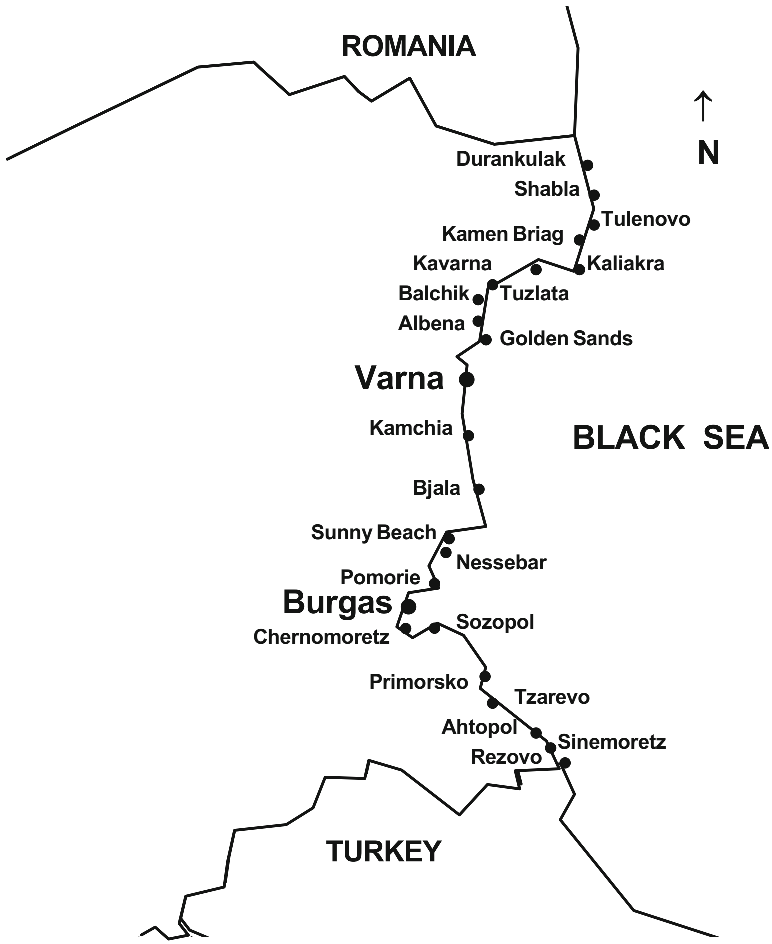


Fig. 18.3 Scheme of sampling locations along the Bulgarian Black Sea coast

The coast of Bulgaria, extending 270 km is mainly soft sedimentary limestone or sandstone, overlaid in many areas with beach or wind-blown sand. In the north, suspended material from the Danube delta has settled, carrying a lot of intertidal mud. The association of radionuclides with sediments in coastal and estuary areas makes sediments a large reservoir for radionuclides affecting significantly specific marine ecosystems. As the seawater is constantly in contact with organic and inorganic matter from sea shelf, the first necessary step in the estimation of radionuclide migration is the measurement of radionuclide content in sea bed sediments and setting up a radioecological data base. Receiving relevant information for radionuclide concentrations in coastal waters and sediments is an important stage in realization of monitoring and control of marine ecosystems at the coast (Fig. 18.3).

The main method for measuring the nuclide content in sediments and algae was the high resolution gamma spectroscopy performed on large high purity Ge semiconductor detectors with nuclear electronic tracts using sophisticated software.

The upper layer of sediments was collected from approximately 1 m^2 of the bottom acquiring about 2–3 kg of solid phase plus several liters of aqueous phase. The depth of the sample layer was maximal 3 cm to evaluate radionuclide content on the surface of the sea bed. In this way the potential seasonal variations could be estimated. The sample collection was performed by experienced scuba divers who carefully selected the sample site to avoid or minimize the differences of samples in particle size, depth and distance from shore, so that the comparison of the sea bed samples of different seasons could be done with greater level of confidence, reliability and accuracy.

Samples were also collected and data obtained for the main Black Sea resorts – Albena, Golden sands, Sunny Beach etc. as well as for some of the main cities along the Bulgarian Black Sea coast. These data were compared with samples taken from definitely clean areas. The contribution of the inflowing rivers for radioisotope content in the Black Sea was also studied sampling river's estuaries and comparing them with the inland sections of the same rivers. So the influence of the river on the adjacent area was compared with that of the sea.

The obtained results (Fig. 18.4) for Black Sea sediment samples show that radionuclide concentrations strongly depend on the nature of the sea bed sediments, because the data obtained for sand sediments are within a close range while those for silt and slime ones are higher and vary to a much greater extent.

The beach matrix from the near shore sediments at these locations is mainly sand and ^{137}Cs data are within a close range: Sunny Beach – 3.2 – 5.6 Bq/kg, Golden Sands – 1.8 – 6.9 Bq/kg, Albena – 3.4 – 7.3 Bq/kg, Tulenovo 4.0–7.1 Bq/kg, Kamen Briag – 4.4–6.6 Bq/kg, Balchik – 4.6 – 7.8 Bq/kg, Primorsko 4.0–5.6 Bq/kg, Sinemoretz – 3.6 – 7.8 Bq/kg. It should be noted that all sand sediment data fall within 8 Bq/kg level except Albena, Golden sands, Ravda, Burgas and Sozopol where nuclide content is higher.

The highest measured cesium content (Fig. 18.4) on the Bulgarian Black Sea coast is at the north locations with slime sediments – Kaliakra (mean 89 Bq/kg), Kavarna (mean 30 Bq/kg) and central Ravda2 (mean 65 Bq/kg). This fact can be attributed to the influence of the big rivers Danube, Dnyepr, Dnester, entering the northwest part of the Black Sea.

The increase in ^{137}Cs concentration in slime sediments and sorption on fine particles leads to cesium scavenging and occurrence at greater depths, which is due to physico-chemical interaction processes of the soluble Cs forms with the surrounding media. In sand and sandy sediments Cs content does not change greatly while the process of ^{137}Cs accumulation is observed in slime and silt sediments. Due to such a process, sea bottom sediments play a major role in radionuclide redistribution between different components in the ecosystems, which change the concentration of ^{137}Cs in the water as it is accumulated more in the sediments.

The observed dependence of radionuclide content on sediment type is valid also for the natural nuclides in sediments. The lowest concentrations of natural nuclides

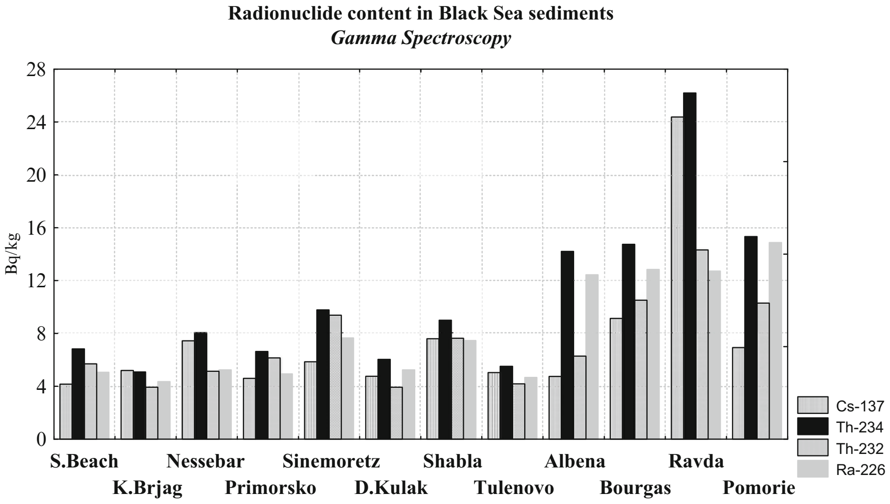


Fig. 18.4 Nuclide content in sand sediments along the Bulgarian coast

is in the sand sediments from the north locations – Duran Kulak, Shabla, Tulenovo, Kamen briag and the measured natural nuclide concentrations are: ^{238}U (4.0–10) Bq/kg, ^{232}Th (3.4–10) Bq/kg, ^{226}Ra (3.6–9) Bq/kg. Low content was obtained at Sunny beach, Nessebar and Primorsko: ^{238}U (3–8) Bq/kg, ^{232}Th (4.4–8) Bq/kg, ^{226}Ra (3.5–6.2) Bq/kg (Figs. 18.5, 18.7 and 18.8).

The obtained mean values for silt sediments are between sand and slime ones with exception of Bjala, whose values for ^{238}U are in the range14–77 Bq/kg.

^{232}Th 12–110 Bq/kg; ^{226}Ra 10–77 Bq/kg and are the highest measured at the silt and slime locations (Figs. 18.6 and 18.7). The data on Fig. 18.5 show that all natural nuclide content in slime sediments varies around 30 Bq/kg, (except ^{232}Th at Kavarna, ^{238}U at Maslen nos and Chernomoretz), showing some uniformity of natural nuclide concentrations along the whole coast.

The highest values for natural nuclides content (similarly to Cs) are obtained for the slime sediments – the obtained results for ^{238}U vary in the different years in the range 5–50 Bq/kg, ^{232}Th – 4.0–35 Bq/kg and ^{226}Ra – 9–50 Bq/kg. The mean values of ^{238}U, ^{232}Th and ^{226}Ra specific activities for slime sampling locations are presented on Fig. 18.3 and these values show the maximum natural nuclide content at the Bulgarian Black Sea coast. The obtained results show that there is a similarity between the accumulation of ^{238}U and ^{232}Th in Black Sea bed sediments. The measured U and Th values are within the range of the cited in the literature meaning that there is no serious contamination with U and Th at the Black Sea coast. ^{226}Ra content generally follows the pattern of U and Th with few exceptions.

Samples were taken from deep sediments (56–155 m) from the Bulgarian territorial waters plus two samples at maximal depth 2040 m and also were measured for radionuclide content.

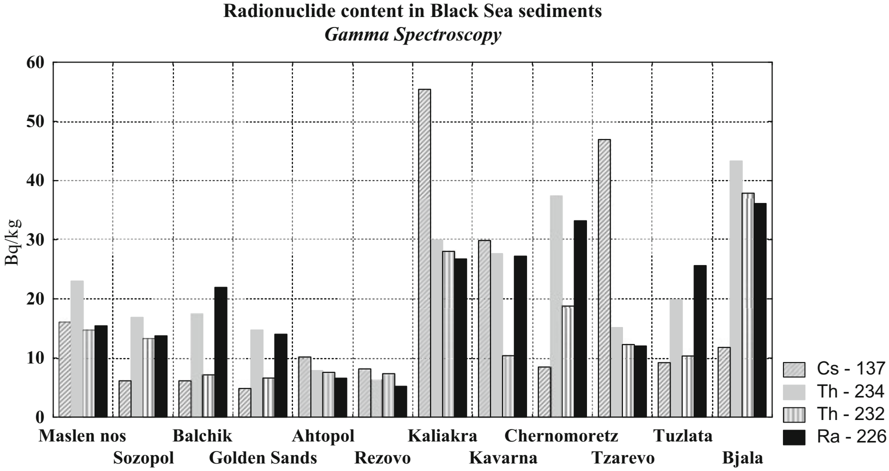


Fig. 18.5 Mean nuclide content in silt and slime sediments along the Bulgarian coast

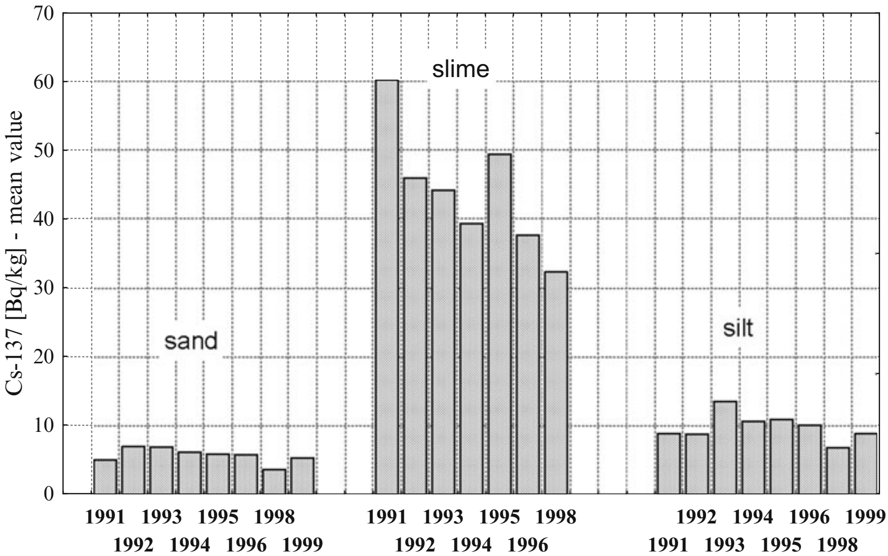


Fig. 18.6 Mean ^{137}Cs content in sediments during the period 1991–1999

The obtained results (Fig. 18.8) show that Cs content is rather low (compared to the shelf), while natural nuclide concentrations increase with the depth. ^{226}Ra nuclide concentration is higher in the middle depths (55–90 Bq/kg) than other natural nuclides while at the bottom 2000 m U content is the highest (90–135 Bq/kg). The character of deep sediment samples is slime except at 2000 m where the matrix is very hard in structure and black in color.

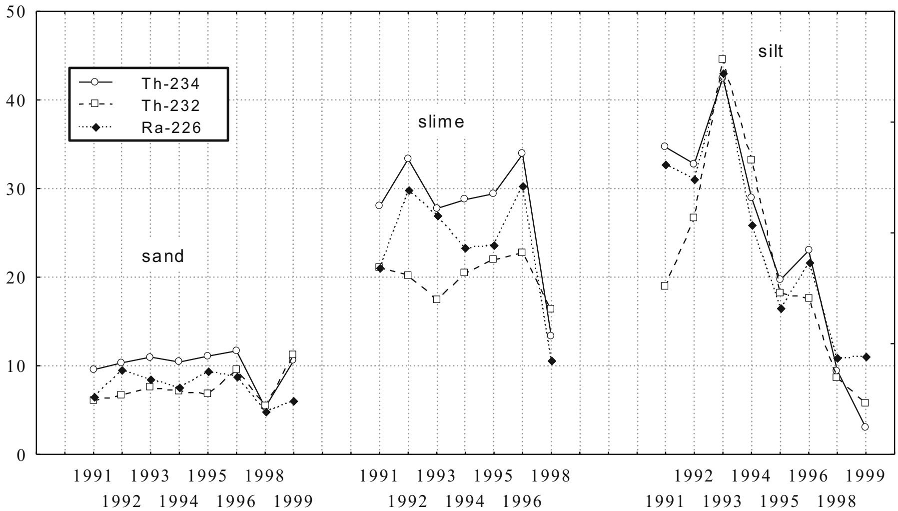


Fig. 18.7 Natural nuclide content (Bq/kg) in Black sea sediments in 1991–1999

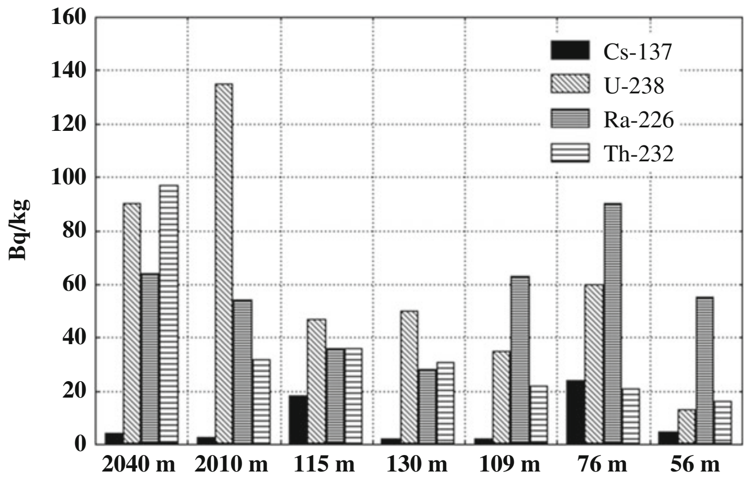


Fig. 18.8 Mean nuclide content in deep-sea sediment samples

The multivariable (cluster) analysis of all measured sediment samples (145) for eight consecutive years depending on all measured nuclides shows that the type of sediment is a basic factor for nuclide accumulation in sediments (Fig. 18.9). The nuclide values for all sand sediments are combined in one cluster (from Albena to Shabla max Eucledian distance is 2.5). The second cluster includes locations close in geographical position and sediment type (slime) – Tuzla, Kavarna and Tzarevo, while Bjala, Chernomoretz and Kaliakra are completely separate from the rest.

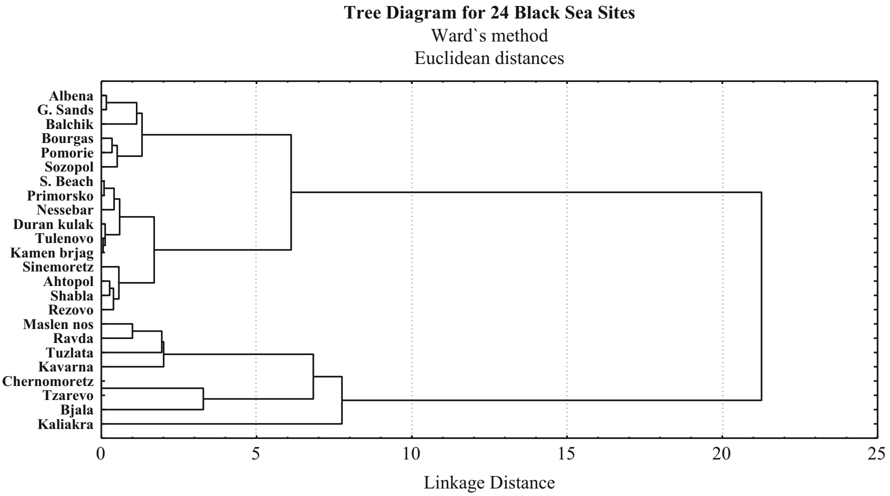


Fig. 18.9 Tree diagram of radionuclide content in Black Sea sediments

The performed correlation analysis for three consecutive season, for each type of sediment at all locations shows, that there is no clear season dependence of isotope concentrations – the calculated correlation coefficients between different seasons are close to 1. The statistical analysis of all nuclide data for all sampling sites (Fig. 18.7) groups together sites with similar sediment matrix (sand, silt or slime) which supports the assumption of nuclide sorption dependence on the type of sediment matrix.

18.2.4.2 Nuclide Content in Algae

The data on the radionuclide content in different algae species are presented in Table 18.1 and on Figs. 18.8 and 18.9. The ^{137}Cs content in different algae species vary on average between 3 and 20 Bq/kg. The content of natural nuclides is close to the lowest limits of detection (LLD).

The most interesting species is *Bryopsis plumosa* whose ^{226}Ra and ^{210}Pb nuclide contents are with some orders of magnitude higher than the same nuclides in other species. The ^{226}Ra contents in Black sea macrophytes vary in the range 2–25 Bq/kg for brown and 3–18 Bq/kg for green species. The accumulation intervals for ^{226}Ra are close to each other for the two brown species and for *Ulva, Cladophora* and *Enteromorpha*, respectively.

The mean values of Ra vary for different species in the range 6.8–11.7 Bq/kg and can be arranged as follows:

Ceramium rubrum $>$ ***Clad. vagabunda*** $=$ ***Cyst. barbata*** $>$ ***Cyst. crinita*** $>$ ***Calith. corumbosum*** $=$ ***Ulva rigida*** $=$ ***Ent. intestinalis*** $>$ ***Chaetom. Gracilis.***

It is evident that the mean values are close to each other and if they are combined, the total mean for all brown and green algae is the following: 10 + 1 Bq/kg ($N = 40$, range 2–25 Bq/kg) for brown species and 8.6 + 0.7 Bq/kg ($N = 40$, range 3–28 Bq/kg) for the green ones. Mean Ra content in red algae is 15 Bq/kg, range 2–39 Bq/kg, which shows similar pattern of natural nuclide accumulation by the algae species along the Black sea coast. ^{210}Pb content in all algae species is in the range 3–40 Bq/kg, which is close to the values of neighbouring Mediterranean Sea and shows the level of this nuclide from recently deposited particles.

The radionuclide content in marine ecosystems and especially in algae is in the limits of published data for the Black Sea and the Mediterranean.

The ^{137}Cs, ^{226}Ra and ^{210}Pb content of the radionuclides has been measured in sediments and macroalgae located in several geographic zones along the Bulgarian Black sea coast, during the period from 1991 to 1999. The accumulation capacity and radionuclide content for different algae species also was determined for three algae phyla in the marine environment. No great difference was found in nuclide accumulation in algae, but the red species seem to accumulate nuclides to a higher degree than the brown and green species.

The data show that macrophytes can be used as reliable indicators for marine environmental assessment. With this paper we intend to fill the lack of data concerning radionuclides in sediments and macroalgae along the whole Bulgarian Black Sea coast. The data can be used as reference levels for further monitoring and control of the marine ecosystem status (Table 18.5).

Figure 18.10 Nuclide content (Bq/kg) in green and brown algae Figs. 18.11, 18.12, 18.13 and 18.14. The analysis of all alga samples for natural radionuclides content from ^{238}U series – ^{226}Ra and ^{210}Pb. Showed ^{226}Ra concentration values in the range 2–28 Bq/kg for red (mean 15 ± 2):, for brown 2–17 Bq/kg (mean 9.8 ± 0.8) and for green 3–18 Bq/kg (mean 9 ± 1). Accumulation intervals for ^{226} Ra are close for the two brown and for green *Ulva rigida*, *Clad. vagabunda* and *Ent. intestinalis*. The ^{226}Ra mean values in different species can be arranged as follows:

Cer. rubrum* > *Clad. vagabunda* = *Cyst. barbata* > *Cyst. crinita* = *Ulva rigida* = *Ent. intestinalis* > *Chaetom. gracilis* > *Callith. corymbosum* = *Cor. officinalis.

The obtained ^{210}Pb average values content in studied algae vary between 4 and 35 Bq/kg (mean 15 ± 1) for red, 2 and 21 Bq/kg (mean 11 ± 1) for brown and from 3 to 16 Bq/kg (mean 8 ± 1) for green algae. If ^{210}Pb mean values are arranged depending on algae species, the following order is obtained:

Cer. rubrum* > *Calith. corymbosum* > *Cor. officinalis* = *Cyst. crinita* > *Chaetom. gracilis* > *Ent. intestinalis* > *Cyst. barbata* > *Clad. vagabunda* > *Ulva rigida

Table 18.5 Nuclide content (Bg/kg) in Black sea algae

Nuclide	No of samples	Mean value ± SD	Minimum value	Maximum value
Chlorophyta				
^{40}K	40	1009 ± 90	300	2500
^{137}Cs	40	4.2 ± 0.5	1.2	13.0
^{226}Ra	40	10 ± 1	3	28
^{210}Pb	40	8.8 ± 0.9	3	22
Phaeophyta				
^{40}K	40	1492 ± 53	1025	2250
^{137}Cs	40	6.1 ± 0.4	2.6	12.0
^{226}Ra	40	10 ± 1	2	25
^{210}Pb	40	12 ± 1	2	30
Rhodophyta				
^{40}K	36	1146 ± 110	90	2100
^{137}Cs	36	7.4 ± 0.8	1.2	18.0
^{226}Ra	36	15 ± 2	3	39
^{210}Pb	36	15.8 ± 1.5	4	40

18.2.4.3 Heavy Metals in Black Sea Sediments

The distribution of the recent bottom sediments in the Black sea shows a variable pattern. The sediment composition and origin depend on the provenance areas, hydrodynamic and lithodynamic activity in the contact zone of the sea, and on the morphology of the bottom topography. Sediment formation is also influenced by the solid riverine runoff and coastal abrasion, slope-derived supply, and biogenic and chemogenic matter (Ignatov (2008)).

Heavy metal concentrations in surface sediments can provide historical information on heavy metal inputs at that location. Such surface sediment samples are also used as environmental indicators to reflect the current quality of marine systems for many pollutants (Förstner and Salamons 1980). Nijenhuis et al. (1999) reported that the enrichment of trace elements in marine sediments may, in general, originate from the following sources; super and subjacent sediments, through diagenesis; suboxic shelf and slope sediments, hydrothermal input; aeolian input; fluvial runoff; sea water. Heavy metal levels in sediment from the Black Sea were investigated by many researchers (Ergul et al. 2008; Topcuoglu et al. 2002; Topcuoglu et al. 2004; Strezov and Nonova 2003) that measured heavy metal concentrations in sediment samples and found dependence upon seasonal changes within the water column as well as anthropogenic and geological inputs such as weathering and run-off from land-based sources. Furthermore, metal concentrations in both surface sediments and sinking particles also suggest that heavy metal concentration is generally enhanced in the eastern region along the Black sea coast of Turkey.

Bulk heavy metal (Fe, Mn, Co, Cr, Ni, Cu, Zn and Pb) distributions and their chemical partitioning together with total organic carbon and carbonate data were studied in 0–2 cm oxic to anoxic surface sediments, obtained at 18 stations throughout the Black sea by Kiratli and Ergin (1996). Chemical partitioning of the heavy metals revealed that Cu, Cr and Fe seem to be significantly bound to the detrital phases whereas carbonate phases tend to hold considerable amounts of Mn and Pb.

Coban et al. (2009) found heavy metals in sediment at significant levels of 0.47 μg/g for Cd, 67.95 μg/g for Cr, 30.21 μg/g for Cu, 274.4 μg/g for Mn, 37.03 for μg/g Ni, 39.14 μg/g for Pb and 84.6 μg/g for Zn, that were comparable with those found in the estuarine areas of other countries in the region.

Topcuoglu et al. (2003b) determined the radionuclides ^{137}Cs, ^{238}U, ^{232}Th and ^{40}K and Cd, Pb, Cu, Zn and Mn in sediment samples collected from two stations at the eastern Turkish coast of the Black sea. The result from this study showed that radionuclide concentrations in the sediment fraction were significantly higher because of the influence of collection sites. In general, the heavy metal concentrations in that study were not higher than those previously observed. However, Pb and Cu levels increased in sediment in the Turkish area of the Black Sea in the investigated years.

In conclusion, heavy metal pollution in the Black sea has attracted considerable research attention since last 20 years. Sources of heavy metals in the Black sea ecosystem can be mainly attributed to terrestrially derived waste water discharges, agricultural and industrial run-off, river run-off atmospheric deposition of combustion residues, and shipping activities. It is clear from many studies conducted that the heavy metal pollution in the Black sea should be taken into account. In the last 20 years, in some areas of Black sea, metal concentrations in sea water exceeded the accepted levels. Especially, lead and cadmium levels were found higher in fish species than the legal limit for human consumption. High levels of heavy metals have been reported by the authors, suggesting that heavy metal pollution in algae and sediments from certain regions of Black Sea is rather high.

The Black Sea is a unique ecosystem because it is an inner sea with low salinity, half-isolated from the Mediterranean with hydrology and phytobentos different from the other seas in the same biogeographic region.

The antropogenic contamination of marine ecosystems is a very important stress factor and defines the necessity for systematic monitoring and control of contaminants (heavy metals – HM, radionuclides, etc.) that affect marine biota. The main sources of Black Sea pollution are atmospheric fallout, the big rivers run-off as well as local pollutant emissions (Tuncer et al. 1998).

Macrophytic algae, being one of the primary stages in the trophic chain, play a major role in marine ecosystems (Kilgore et al. 1993). Algae interact with the environment through processes that include chemical bioconcentration, excretion, organic matter production and decomposition (Carpenter and Lodge 1986). They have been used as a signal for the living status of marine ecosystems and considered as valuable indicators for HM assessment in the major components of the water ecosystems because of their accumulation capacity (Forsberg et al. 1988). Some algae possess ecological mutability so they can survive in contaminated habitat (Kalugina-Gutnik 1975). Closely related species may exhibit different accumulation capabilities for trace elements, so there is a need to identify indicators that are biologically dominant and widespread in the ecosystems. This will allow intraspecific comparison of accumulated metal concentrations over large geographical areas (Rainbow 1995; Rainbow and Phillips 1993).

HM are among the most studied contaminants in marine ecosystems. Their effect is through direct poisoning as well as by accumulation and transfer along the trophic chain, by which they influence the functioning of biosphere (Babich et al. 1985).

Metal levels in algae reflect local geology or local anthropogenic activities and the contamination is generally similar to background levels of the sites. Today's HM concentrations in marine environment are generally more than ten times higher than it was in prehistoric times. The levels are consistently higher in surface waters than in deeper ones along the sea coast during the period spring 1996 to summer 2002. Fe has a great binding capability for alga lipids and is accumulated to the highest degree in the Black Sea green macrophytes.

The measured Fe concentrations in Bulgarian algae are with one or two orders of magnitude higher than the other HM (with mean value 650 μg/g). Maximum Fe values are obtained for *C. vagabunda, C. coleothrix* and *C. gracilis*, while in the other three species Fe content is three times lower. A higher value of Fe is observed in *E. intestinalis* from Sinemoretz and Rezovo (autumn 1996 and summer 2000, respectively). The lowest Fe concentration was measured in *U. rigida* species from Ravda (spring 1998) and at Ahtopol (autumn 1996).

If mean Fe values are compared in all green algae depending on the location, a tendency is obtained of increasing Fe content from north to south. If Fe values are plotted for each green species vs. location, it is clear that the observed north-south tendency is mainly due to *Enteromorpha* species whose values increase southwards. Fe concentration for the other green species is more constant with geographical location (e.g., mean Fe values vs. location for *U. rigida* are in the range 300 ± 170 μg/g for the whole Black Sea coast).

The results for Mn vary in narrower interval than Fe (mean value 84 μg/g). Low Mn content is measured for *U. rigida, E. intestinalis* and *B. plumosa*, while the highest is obtained for *C. coleothrix*. Mn concentrations in different regions change in the following order:

Ahtopol < Kaliakra < Shabla < Tuzlata ≈ Ravda < Sinemoretz < Rezovo.

The mean Mn values for Tuzlata, Ravda and Sinemoretz are close and it is evident that there is no geographic dependence for Mn content. Our data show that green algae from Kaliakra (north) and Ahtopol (south) sites accumulate Fe and Mn to the lowest extent while the highest content is measured at Rezovo (south). The high Fe and Mn biosorption, compared to the other HM, is connected with their function and major role in the metabolytic processes in marine organisms.

The trace element Cu (like Fe) belongs to the group of biologically important metal ions. Trace metals should be monitored because they play an important role in metabolism and their high or low concentrations can be equally harmful to the living organisms. Cu, Pb and Cd content in green algae are presented on Fig. 18.15.

The Cu data interval in Bulgarian algae is wider compared to Pb and Cd but if mean values (μg/g) for all algae are compared, we get for Cu 5.6 $\pm$ 0.5, Pb 3.3 $\pm$ 0.3 and Cd 1.1 $\pm$ 0.2. The accumulation patterns sequence is the same for all green algae except *C. coleothrix* where Pb prevails.

Cu mean values are relatively constant along the whole Bulgarian coast (unlike Fe and Mn), and the low Cu content in the environment means that there is no contamination in the marine ecosystems with Cu. The same is true for Pb and Cd whose mean value variations are also small. These results can be explained with the lack of industrial pollution along the coast, except close to the big cities (ports) of Burgas and Varna. The studied locations in this paper are outside the dwelling places and this is done in order to obtain the characteristic background values for the measured HM concentrations along the whole coast.

The highest Cu content is measured in *E. intestinalis* from Rossenetz –148 μg/g, which is due to the known anthropogenic contamination of the copper mine in the vicinity. The synergism between Cu and Fe is clearly demonstrated in Rossenetz as Fe value is also high (4890 μg/g) while the Pb and Cd values are normal.

The behavior of Pb in water ecosystems is complex and its concentration in a great number of natural waters is not higher than 1 μg/g. Pb is found in seawaters mainly in the form of different organic compounds. Pb content in the studied Black Sea alga species varies in a more narrow interval than Cu. *C. gracilis*, *C. vagabunda, E. intestinalis* and *B. plumosa* species accumulate Pb in a rather similar way. Pb content variations along the coast are small (like Cu) which also means lack of contamination with Pb.

The determination of Cd content is an important task for the monitoring of HM in marine ecosystems. Cd is poisonous for living organisms even in low concentrations, so it is a hazardous anthropogenic contaminant that should be controlled. It can be concluded from the data in Fig. 18.3 that Cd is present in green algae in comparatively low concentrations – from 0.2 to 3.2 μg/g dry weight. The lowest Cd content is in the southern region Sinemoretz, but as a whole the concentration range is narrow in all sites with no geographic dependence. Judging from the alga type, the highest degree of Cd accumulation is found in *C. coleothrix*, while the lowest in *Bryopsis* and *U. rigida.*

Data were measured for Zn and Cr content in some of the studied green algae and the obtained mean values for Zn in *Ulva, E. intestinalis* and *B. plumosa* is 15 μg/g (*C. vagabunda* – 23 μg/g) while for Cr in *Ulva, C. vagabunda* and *C. gracilis* – 1.3 μg/g is obtained (*E. intestinalis* – 3.1 μg/g). The Zn and Cr results for Black Sea macroalgae confirm the lack of HM pollution (like Cu, Pb and Cd) along the Bulgarian coast.

The correlation between accumulation levels of HM concentrations is an important factor for evaluation HM behavior in biota and the determining of these correlations. The coefficient data for *Enteromorpha* and *Ulva* macroalgae show negative correlations between Cd and all measured metals in the two algae species. Pb also correlates negatively with all metal ions in *Enteromorpha* and only with Cu in *Ulva*. Significant positive correlation coefficient (synergistic interaction between HM) was obtained only for the pair Fe–Mn in *Enteromorpha* while negative correlation (antagonistic) was obtained for Cu–Cd in *Ulva*. These correlation coefficients differ from unit and therefore the correlation dependence is not clearly expressed, meaning that the variables are connected but with weak functional dependence.

If we assess the obtained algae data depending on the chemical nature of the HM, the obtained tree diagram clearly separates Fe and Cu while Pb and Cd are strongly linked which is clear as these two elements belong to one and the same group of the Periodic table (Fig. 18.10).

Data were obtained for Fe, Mn, Cu, Pb and Cd content in the most widespread Black Sea green macroalgae for the period 1996–2003 (Figs. 18.11, 18.12, 18.13, 18.14 and 18.15) HM environmental behavior in the marine environment of eight locations (Shabla, Tuzlata, Kaliakra, Ravda, Rossenetz, Ahtopol, Sinemoretz, Rezovo), distributed along the whole Bulgarian coast, has been studied. All obtained results prove the dependence of toxic metal accumulation on green algae species as well as on the location (Fig. 18.16).

It can be concluded that Fe, Mn, Cu, Pb and Cd concentration in Black Sea green macroalgae decrease during the studied period. *U. rigida* species accumulate the lowest concentrations of the studied metals. The highest Fe, Mn, Pb and Cd content has been measured in macrophytes from Tuzlata and Rezovo. High Cu concentration is observed in the southern coastal area – Ahtopol and Sinemoretz (the highest at Rossenetz).

All Black Sea green algae data are subjected to cluster analysis for all toxic metal accumulation. The obtained tree diagram for all HM (Fig. 18.17) shows that the algae are combined in two main groups plus *C. coleothrix*. The first main group consist of *Ulva* and *Bryopsis* linked by *Chaetomorpha*. The second group is *Enteromorpha* and *C. vagabunda*.

If the cluster analysis is performed for the toxic elements Cu, Pb and Cd, again two main groups are obtained – first group containing *C. coleothrix* and *Chaetomorpha*. The second group is divided in two – *Enteromorpha*, *Bryopsis*, *C. vagabunda* linked with *Ulva*. The main influence on these clusters is due to the presence of Cu because if we exclude Cu from the cluster process the obtained tree diagrams are less affected.

If the obtained algae data are assessed depending on the chemical nature of the HM, the obtained tree diagram clearly separates Fe and Cu while Pb and Cd are strongly linked which is understandable as these two elements belong to one and the same group of the Periodic table.

In conclusion it can be pointed out that Chlorophyta and Rhodophyta algae phyla can be used as bioindicators for monitoring of the ecological state of the Black Sea environment. A comparative analysis of contaminants in different Bulgarian coastline regions leads to the conclusions that the data obtained for red and green macroalgae illustrate the level of contamination by HM and nuclides at seven locations of the Black Sea Coast.

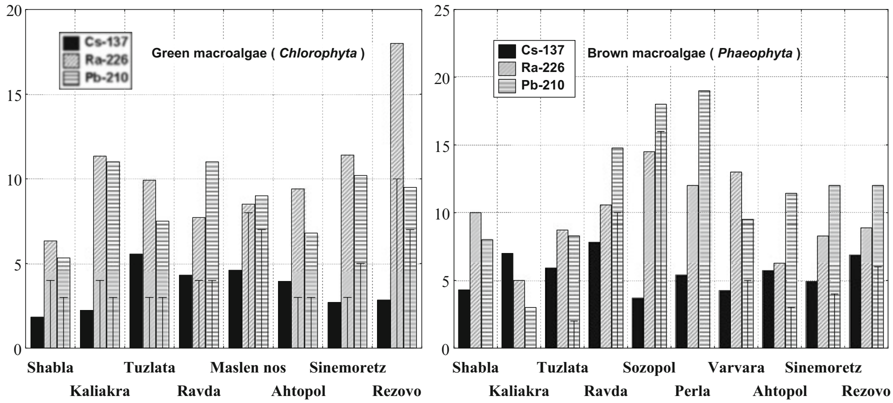


Fig. 18.10 Nuclide contents (Bq/kg) in green and brown algae

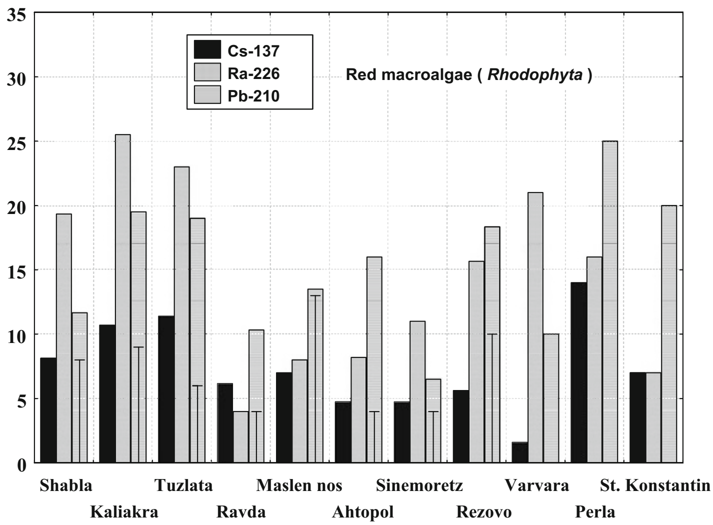


Fig. 18.11 Nuclide contents (Bq/kg) in red algae

The studies of Black Sea macroalgae for marine environmental showed that there is no strict seasonal or local dependence of hazardous element content. All results seem to depend on the biological specificity of the algae and all data show a lack of serious pollution in areas without direct human impact along the Bulgarian Black Sea coast.

All obtained results show that use of macroalgae in marine environmental monitoring reduces the need for complex studies on chemical speciation of aquatic contaminants.

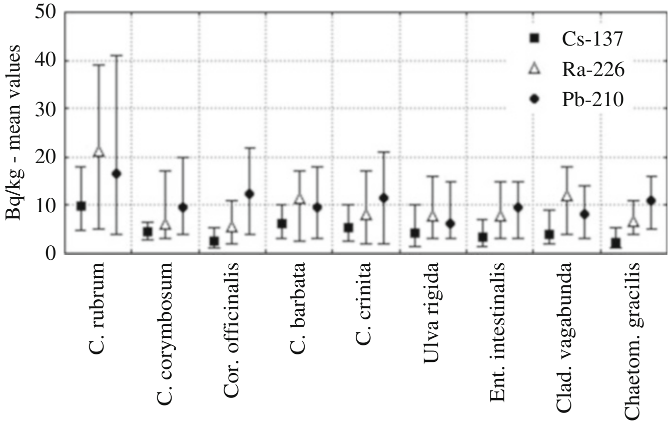
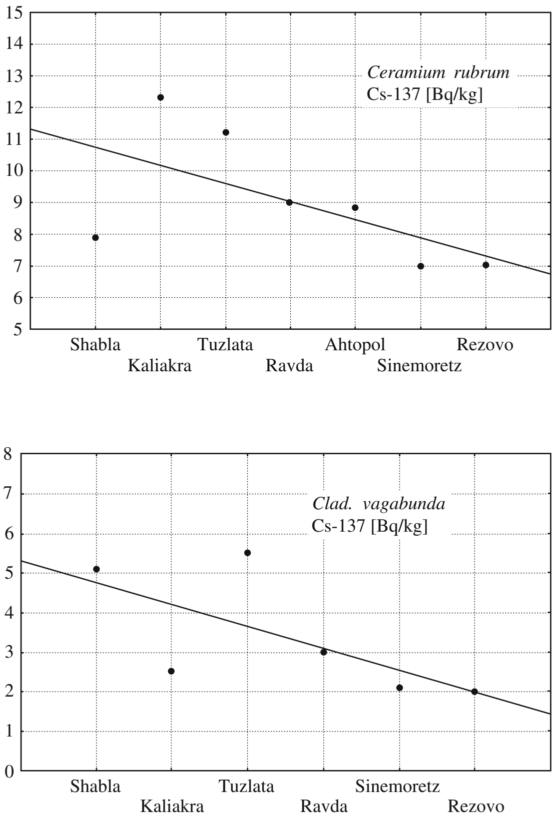


Fig. 18.12 Comparison of nuclide contents (Bq/kg) in different Black Sea algae

Fig. 18.13 ^{137}Cs content in macroalgae – local variations



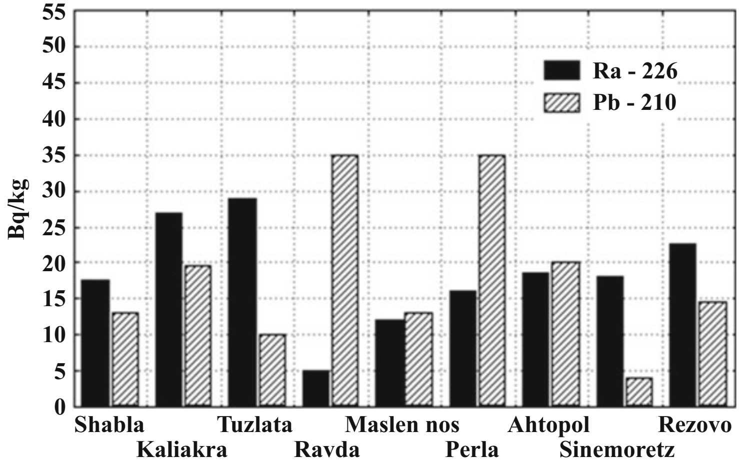


Fig. 18.14 Mean ^{226}Ra and ^{210}Pb content (Bq/kg) in *Ceramium rubrum*

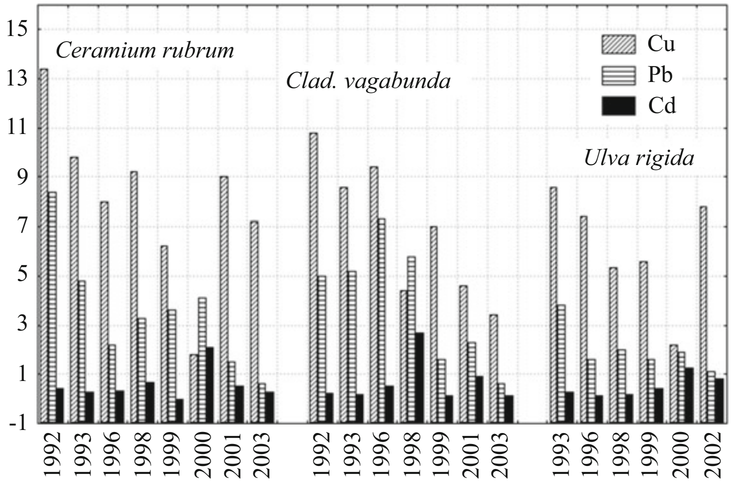


Fig. 18.15 Seasonal variations of HM content (mg/g) in three alga species

18.2.4.4 Heavy Metals in Black Sea Organisms

Topcuoglu et al. (2003a) investigated the metal content in macroalgae samples collected from the Black sea Turkish coast in the period 1998 to 2000. According to the findings of this study, the heavy metal pollution decreased in Turkish coast of the Black sea in the investigated years (Table 18.2). In another study it was determined that the Turkish Black sea coast was subjected to heavy metal pollution and the metal concentrations in macroalgae, sea snails and mussels were very high.

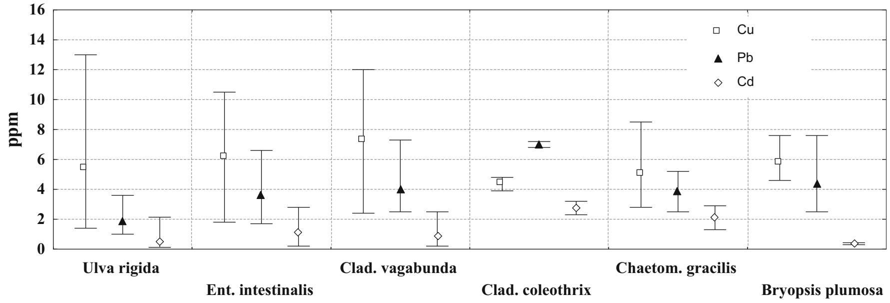
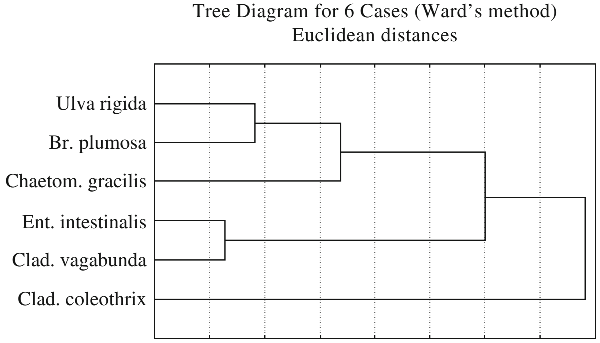


Fig. 18.16 Mean Cu, Pb and Cd content (μg/g) in different algae species

Fig. 18.17 Tree diagram for heavy metal content in green algae species



Topcuoglu et al. (2002), Romero et al. (2005) studied the accumulation of trace metals by measuring them in the mussel collected in the Black sea. The authors found that Cd, Cu, Zn, Hg, Fe, Mn concentration changed between 0.96–1.74 μg/g, 6.64–8.05 μg/g, 108–190 μg/g, 26–33 ng/g, 95–106 μg/g and 14.5–24.5 μg/g mussels, respectively.

Tuzen (2009) measured the trace element concentration in different marine algae (*Antithamnion cruciatum* and *Phyllophora nervosa*) collected from middle and east Black Sea. They found that the highest trace element concentration was determined for iron and the lowest for cadmium (Table 18.2). The authors suggested that the marine algae samples should be analyzed more often in Turkey with respect to toxic elements. Edible marine algae samples could be used as a food supplement to help meet the recommended daily intakes of some mineral and trace elements.

Zinc, copper, cadmium, lead and cobalt concentrations in Mediterranean mussel *Mytilus galloprovincialis* and sea snail *Rapana venosa* from the Sinop coasts of the Black sea have been measured (Turk-Culha et al. 2007). Significant differences were found in metal concentrations between the species. Similar significant differences observed with regard to different metals. The concentrations of Pb, Cd and Co were determined under detection limit for the species. The other metal levels in the Mediterranean mussel and the sea snail were significantly higher than those in fishes.

From 1996 to 2002, Fe, Mn, Cu, Pb and Cd distribution in six green macroalgae species from the Bulgarian Black Sea coast were determined by Strezov and Nonova (2005a). For all algae, average heavy metal concentrations were 650 μg/g for Fe, 184 μg/g for Mn, 5.6 μg/g for Cu, 3.3 μg/g for Pb and 1.1 μg/g for Cd. These data show that heavy metal contents in different species demonstrate various degree of metal accumulation. The obtained higher values in the northern part of the studied zone can be attributed to the discharge influence of the big rivers entering the Black sea, such as Danube, Dnyeper, Dnyester, and local pollutant emissions, as well. The obtained data also show that there is no strong contamination in green macroalgae with heavy and toxic metals along the whole Bulgarian Black sea coast.

Metal contamination in the Black sea alga species (green and red) was studied from 1992 to 2003, using radionuclide approach (Strezov and Nonova 2005b). It was found that radionuclide and metal concentrations depend on the macrophyte nature and all data show the lack of strong pollution along the Bulgarian Black sea coast.

18.2.4.5 Data Comparison Between Neighboring Seas

The comparison of the data (Tables 18.6, 18.7 and 18.8) for radioecological status of the Black sea marine ecosystems and the Mediterranean marine ecosystems concerning the radionuclide and trace metal content indicated no strong anthropogenic pollution along the Bulgarian shore as the Mediterranean data are higher. When comparing the accumulation of HM in one and the same algae the corresponding data for Black sea algae are lower than those from the Marmara Sea or the Mediterranean.

Aquatic organisms, especially macroalgae, are widely used as bioindicators for the study of marine contamination by radionuclides and heavy metals. Some species tolerate high levels of pollutants and can successfully be used to obtain reliable information of marine ecological status. In order to evaluate the ecological status of coastal habitat and provide valuable data for estimation of contamination with radionuclides in Bulgarian Black sea, a monitoring program was started and performed along the coast. Eleven macroalgae species were monitored by collecting samples from 20 reference locations during the 1996–2005 period.

In this way the accumulation of hazardous contaminants was traced over a long period of time and tendencies for the behaviour of those elements were evaluated. The same comparison was made for radionuclides (Table 18.8) in the studied algae species and Black Sea Cs content was found to be similar to the other basins while natural nuclides were slightly higher in the Black sea.

Table 18.6 Heavy metal levels (μg/g dry wt) in some living organism from the Black Sea

Species	Metals						References
	Cd	Co	Zn	Mn	Pb	Cu	
Mussels	<0.02–6.44	<0.05–5.36	78.12–512.5	5.66–22.8	<0.05–2.60	7.21	Topcuoglu et al. (2002)
Sea snail (sofpart)	2.01–41.13	<0.05–0.7	73.3–255.9	3.90–10.01	<0.5	36.19	
[a]*Ulva lactuca*	<0.02/	<0.05/	21.2/	45.1/	<0.1/	13.8	
1998/1999	<0.02	<0.05	9.6	21.8	<0.1	3.87	
[a] *Cystoseira bar.*	<0.02/	<0.05/	35.1/	32.1/	<0.1/	5.7	
1998/1999	<0.02	<0.05	13.9	6.7	<0.1	2.2	
[a]*Pterocladiella*	1.53/	<0.05/	119.8/	91.1/	<0.1/	10.3	
capillacea 1998/99	1.36	<0.05	86.2	52.1	<0.1	5.3	Topcuoglu et al. (2003a, b)
[b]*Ulva lactuca*	<0.2/	<0.05/	13.5/	41.1/	<0.1/	11.3	
1998/1999	<0.2	<0.05	394.4	12.5	<0.1	7.7	
[b]*Cystoseira bar.*	<002/	<0.05/	43.9/	27.3–	<0.1/	593	
1998/1999	<0.02	<0.05	191.5	22.7	<0.1	590	
[b]*Pterocladiela capillacea* 1999	<0.02	<0.05	176.8	10.8	<0.1	<0.03	
Cystoseira crin.	0.22–1.87	–	–	9–60	0.4–6.3	0.3–6.0	Strezov and Nonova (2003)
Cystoseira bar.	0.10–1.25		–	9–54	0.7–2.4	0.6–9.0	
Mussels	<0.02	–	312–396.5	46.9–73.05	<0.05–108	11.7–23.2	Bakan and Böke-Özkoç (2008)

[a]West Black Sea
[b]East Black Sea: μg/kg

Table 18.7 Trace metal content (mg/kg) in marine algae from Black & Mediterranean Seas

Algae	Cd	Cr	Cu	Mn	Zn	Pb	References
Ulva lactuca	1.35	< 1	7.5	–	34.2	6.5	Guven et al. (1998)
Cystoseira barbata	1.3	< 1	4.2	–	33	5.3	Guven et al. (1998)
Ulva lactuca	0.5	0.5	24	50	24.1	23.5	Topcuoglu et al. (2001a)
Cystoseira barbata	0.75	0.95	6.85	25	97	14	Topcuoglu et al. (2001b)
Ceramium rubrum	0.8	1.5	16	59	62	11	Topcuoglu et al.(2001a, b)
Ulva sp.	0.24	4.78	4.7	194	26.1	–	Malea and Haritonidis (2000)
Ulva sp.	0.6	1.56	5.5	–	5.2	3.68	Muse et al. (1999)
Enteromorpha sp.	0.07	0.54	11.4	21	14	1.06	Favero and Frigo (2002)
Ulva sp.	0.18	1.63	5.8	–	45	1.94	Conti and Cecchetti (2003)
Padina pavonica	1.56	3,6	13.3	–	84	11.4	Campanella et al. (2001)
Ulva sp.	0.8	1.8	5.6	40	24	1.7	Strezov and Nonova (2005a)
Ceramium sp.	0.9	6	7.6	120	22	2.2	Strezov and Nonova (2005a)
Cladophora sp.	1	7	6	170	19	3.5	Strezov and Nonova (2005a)
Enteromorpha sp.	0.8	5.3	7	47	14	2.4	Strezov and Nonova (2005a)
Cystoseira sp.	0.3	2.3	4	42	1.6	18	Strezov and Nonova (2005b)
Chaetomorpha sp.	1.3	7	5	180	12	2.7	Strezov and Nonova 2005b)
Corallina sp.	0.7	4.8	15	55	13	1.4	Strezov and Nonova (2005b)
Callithamnion sp.	0.5	3.7	5.4	87	18	2.3	Strezov and Nonova (2005b)

Table 18.8 Radionuclides mean content in Black sea algae (Bq/kg)

Algae	^{137}Cs	^{40}K	^{210}Pb	^{226}Ra	References
Ceramium rubrum	0.8	–	–	–	Bologa et al. (1996)
Cystoseira sp.	15	900	–	–	Guven et al. (1993)
Cladophora sp.	n.d.	2170	–	–	Guven et al. (1993)
Enteromorpha sp.	5	1076	–	–	Guven et al. (1993)
Chaetomorpha sp.	11	2525	–	–	Guven et al. (1993)
Ulva sp.	6	930	–	–	Guven et al. (1993)
Corallina sp.	5	250	–	–	Guven et al. (1993)
Ceramium rubrum	12	880	–	–	Guven et al. (1993)
Ulva lactuca	<3	–	–	–	Topcuoglu et al. (2001a)
Cystoseira barbata	5.9	–	–	–	Topcuoglu et al. (2001b)
Ulva sp.	< 1.2	900	3.49	<1.7	Al-Masri et al. (2003)
Cystoseira sp.	<1.1	1800	8	1.2	Al-Masri et al. (2003)
Ulva lactuca	7.2	–	–	–	Othman et al. (1994)
Ulva sp.	3.4	596	6	9.3	Strezov and Nonova (2005a)
Ceramium sp.	9.4	1343	13	17	Strezov and Nonova (2005b)
Cladophora sp.	12	1300	8	12	Strezov and Nonova (2005a)
Enteromorpha sp.	4.5	690	7	10	Strezov and Nonova (2005a)
Cystoseira sp.	5.4	1400	12	11	Strezov and Nonova (2005b)
Chaetomorpha sp.	2.3	1860	10	7	Strezov and Nonova (2005a)
Corallina sp.	2.1	140	12	10	Strezov and Nonova (2005b)
Callithamnion sp.	4.4	1580	10	7	Strezov and Nonova (2005b)

18.3 Conclusions

Radionuclide and HM accumulation capacity has been studied in Black sea sediments three algae phylum along the Bulgarian Black Sea coast during the period 1996–2004. The natural isotope concentrations are higher than technogenic ones and red alga *Ceramium rubrum* shows the highest level of nuclide concentrations. The status of the marine environment in all studied areas was evaluated by cluster analysis of macroalgae data from all geographic zones. Analysis results show logical geographic dependence of contaminant content and locations of higher content are distinctly separated from those of clean areas.

The full scale monitoring done on the whole Bulgarian Black Sea coast resulted in collecting information for the different equilibrium processes, taking place in the coastal regions which govern the radioactive pollution of rivers, adjacent salt lakes, sea sediments and water and other harmful effects of human activities but also their behaviour in the marine ecosystems (algae, sea mussels, fish and other marine organisms the rates of exchange and the pathways towards man). It can be pointed out that Chlorophyta and Rhodophyta algae phyla can be used as bioindicators for monitoring of eco-toxicological state of the Black Sea environment. A comparative analysis of contaminants in different Bulgarian coastline regions leads to following conclusions:

- A data base for isotope accumulation, sorption and migration of nuclides and HM is created to help the future assessment and biosphere in whole Bulgarian coastal zone.
- The data obtained for red and green macroalgae illustrate the level of contamination at the locations of the Black Sea Coast
- There is no strict seasonal or local dependence of hazardous element content. All results seem to depend on biological specificity of the algae
- All data show the lack of serious pollution along the Bulgarian Black Sea coast.
- All obtained results for sediments and macroalgae in marine environmental monitoring reduces the need of complex studies on chemical speciation of aquatic contaminants and makes algae valuable indicators for the seawater quality assessment.
- Modelling the transfer processes of radionuclides in environment and the different pathways of isotope migration in the marine environment to predict the potential hazard for the population.

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Part V
Chemistry

Chapter 19
Phosphorus Fluxes in the Pelagic Zone of the Black Sea

Aleksandr V. Parkhomenko

Abstract On the basis of these long-term observations of hydrophysical, hydrochemical and biological structure of water the seasonal variability of the upward, regeneration, sedimentation and fluxes of phosphorus from external sources in the photosynthetic zone in the deepwater area of the Black Sea was established. The estimates of the contribution of upward and regeneration fluxes of phosphorus in its total flux into the photosynthetic zone and sedimentation removal in some months urea are obtained. The relationship between the monthly averages of the rising contribution of phosphorus flux and its concentration chlorophyll "a" and biomass of phytoplankton in photosynthesis zone was established. Potentially possible values of the "new", regeneration and total phytoplankton production in the deepwater area of the Black Sea are calculated. The correspondence between the annual estimates of primary production, calculated on the flux of phosphorus and averaged data of direct measurements of phytoplankton production in the deepwater area of the Black Sea is shown. It was found that the average annual value of the upward flux of phosphorus in the photosynthesis zone is equivalent to the average value of its sediment flux, indicating that the balance of the phosphorus cycle and absence of human influence on the level of primary production in the deepwater area of the Black Sea. The results are discussed in terms of the general laws of formation of the "new" and the regeneration of the primary production.

Keywords The Black Sea • Phosphorus • Upward • Regeneration and sedimentation fluxes • Phytoplankton • Primary production

19.1 Introduction

The Black Sea – unique in its physicochemical and biological properties of the pool, in an ecosystem that in recent decades there were significant changes in the chemical and biological structure of the water in the deep sea and coastal areas. The

A.V. Parkhomenko (✉)
Institute of Marine Biological Research A.O. Kovalevsky Russian Academy of Sciences, Sevastopol 299011, Russia
e-mail: parkhomenko.al@yandex.ua

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generalization of these mechanisms dedicated to a number of studies (Vedernikov and Demidov 2002; Vinogradov et al. 1992; North-western part of the Black Sea 2006; Demidov 2008; Mikaelyan et al. 2013). In these studies mainly structural and functional parameters (concentration of nutrients, chlorophyll “a”, phytoplankton and zooplankton biomass, primary production), were used which allowed to establish their interannual and spatial variability. However, despite the large amount of the research and a huge amount of information available on the international database, its fragmentary and unsystematic character does not allow to understand the mechanism of the changes. The main problem is to separate the influence of natural (climatic) and anthropogenic factors on the production characteristics of the ecosystem. From this point of view it is very difficult to interpret the changes in the chemical and biological structure in the deep waters of the Black Sea region. Now, the possibility of approaches based on the study of spatial and temporal variability of the “static” parameters (concentration of biogenic elements, chlorophyll “a”, biomass) to solve these problems is practically exhausted. At the present stage of research problems, associated with the study of the intensity of “exchange” processes between the individual components of the ecosystem, in time and specific environmental conditions, realized through fluxes of energy and matter are very important. Integrated reflection of these fluxes are the fluxes rates of the major nutrients (nitrogen and phosphorus) in freshwater and marine water bodies (Sorokin 1985; Benitez-Nelson 2000; Parkhomenko et al. 2003; Gregoire and Beckers 2004; Parkhomenko 2005, 2007; McCarthy et al. 2007; Krivenko and Parkhomenko 2015; Parkhomenko and Kukushkin 2015).

The main fluxes that provide cycle of phosphorus in marine ecosystems are on the one hand, its income in photic layer with deep waters due to hydro-physical processes (upward phosphorus flux), flux with the river runoff and precipitation, as well as its entry into the process of mineralization of suspended organic substance by heterotrophic organisms (regeneration of phosphorus flux). On the other hand, the flux of phosphorus uptake by phytoplankton and bacteria and its sediment removal from photosynthetic zone.

According to modern concepts, structure and production characteristics of phytoplankton community depends not only on the flux rates of input of nutrients, but also on the source of income. Accordingly, the primary production is divided into two components: the “new” and regeneration (Dugdale and Goering 1967; Eppley and Peterson 1979). The “new” products, synthesized due to external (to the community) fluxes of nutrients, determines the growth of biomass of phytoplankton and can be transferred to higher trophic levels. To fluxes, providing a “new” primary production in the open part of the Black Sea the upward flux of phosphorus, and its supply with river runoff and precipitation is included. This is the difference the “new” primary production from regeneration, which is provided by biogenic elements formed in the process of mineralization of suspended organic matter by heterotrophic organisms.

Using the biogeochemical approach for studying the mechanisms of biosynthesis of primary production formation and functioning of the plankton community is particularly relevant. Since the estimation monthly and annual functional indexes of basic phosphorus cycle fluxes reveals patterns of their seasonal variability, to evaluate the average values of these and the balance of phosphorus in the photic layer, as well as to estimate the influence of anthropogenic factor on the level of primary production in the studied ecosystems. The objective of our research was to study the seasonal variation patterns of the major phosphorus cycle fluxes due to changes in the structural and functional parameters of phytoplankton and hydrochemical conditions in the photosynthesis zone throughout the annual cycle followed by evaluation of the impact of natural and anthropogenic factors on the level of primary production in the deepwater Black Sea area.

19.1.1 Upward and Regeneration of Phosphorus Fluxes in the Pelagial of the Black Sea

A distinctive feature of the Black Sea is weak exchange between surface and deep waters, due to the presence of permanent halocline, which separates its thickness into two relatively isolated areas. The main part of the production-destruction processes takes place within the upper 100–200-meter oxygen-containing layer, beyond which according to various estimates from 3 to 8% of annual primary production of phytoplankton are carried down (Karl and Knauer 1991; Gregoire and Beckers 2004; McCarthy et al. 2007). Within the hydrogen sulfide zone, which occupies more than 80% of the sea of volume, the essential part of mineral nitrogen compounds (ammonium form) and phosphates, however, as shown by the model and balance calculations (Eremeev et al. 2001; Yakushev et al. 2002) for production processes in a light layer of water, these stocks are not available.

Formation of the primary production mainly occurs within the upper 50-m layer, which corresponds to the euphotic zone (Vedernikov and Demidov 1997). Part of the primary products is transformed in zone of photosynthesis in the process of regeneration and grazing zooplankton and the rest organic matter is carried beyond its limits, and 80–90% is mineralized within the cold intermediate layer (CIL) directly underlying the photosynthesis zone (Gregoire and Beckers 2004; McCarthy et al. 2007). Within the boundaries of CIL the main pycnocline, according to its density gradients formed by the vertical structure of the distribution of mineral phosphorus produced in the oxidation of organic material (Konovalov et al. 1997; Yakushev et al. 2002). The layer formed from inorganic mineralization process goes back to the phosphorus euphotic zone confined by upper maximum depth of phosphate deposition. The hydrogen sulfide zone is located below.

In the pelagic zone of the Black Sea on the role of upward phosphorus fluxes in photosynthesis area can be judged only by scattered data obtained in different parts of the sea and the seasons of the year on the basis of hydrological and hydrochemical observations (Gusarova 1992; Boguslavskii et al. 1993; Parkhomenko et al. 2003; Debol'skaya et al. 2007). The same situation was observed in relation to the regeneration of phosphorus flux. Information available in the literature reflect only the results of research obtained in the autumn on the basis of the calculation of excretion of phosphate by mass crustacean zooplankton species without considering the simplest and gelatinous macroplankton (Gutel'makher 1986) and early spring, taking into account trophoecological main groups zooplankton community (Parkhomenko et al. 2003). It is obvious that the above information about the role and the regeneration of the upward fluxes of phosphates, do not give a complete picture of the season variability of these fluxes in the deepwater area of the Black Sea. Therefore to solve these problems in relation to the upward phosphorus flux results of our research (Parkhomenko et al. 2003; Krivenko and Parkhomenko 2015) were used on the basis of the averaging of many years of observations of hydrological, hydro-chemical structure of the deep-water area of the Black Sea. These data were got from international data bank (Black Sea database, Supplied with Ocean Base 3.07 DBMS/NATO SfP-971,818 ODBMS Black Sea Project, July 15, 2003, CD for Windows NT, 98, 2000, Me, XP). Regeneration of phosphorus flux is estimated on the results of research (Parkhomenko et al. 2003; Parkhomenko 2005, 2007; Krivenko and Parkhomenko 2015) obtained on the basis of published the data on the size and species structure of the zooplankton communities in the deepwater area of the Black Sea in 1978 and 1995 to 166 stations in 16 scientific expeditions (Kovalev et al. 1996a, b; Shushkina et al. 1980, 1992; Shushkina and Vinogradov 1991a, b; Zagorodnyaya et al. 2001). The methods, calculation algorithms and estimation of monthly and annual average values of upward and regeneration phosphate fluxes throughout the annual cycle in the deepwater area of the Black Sea detailed in the works (Parkhomenko et al. 2003; Parkhomenko 2005, 2007; Krivenko and Parkhomenko 2015).

19.1.2 Seasonal Variability of the Upward and the Regeneration of Phosphorus Fluxes

According to result of many years of computing the averaged annual variation of the upward flux of phosphates and regeneration was built in the deepwater area of the Black Sea (Fig. 19.1). Analysis of the data showed that the nature of the upstream annual variability of phosphate in the photosynthesis zone (Fig. 19.1) corresponds to the established ideas on the formation of the hydrochemical regime of surface waters in the Black Sea in different seasons (Vinogradov et al. 1992). Income of phosphates by hydrophysical processes gradually increased during the autumn-winter period, reaching maximum values in February and March – 0.26 and 0.2 mg-atP m^{-2} day^{-1}. During the formation of seasonal stratification of surface waters (April–June) the upward flow of phosphate is reduced by about half and in July and August reaches minimum values 0.04 and 0.02 mg-atP m^{-2} day^{-1}. The values of the upward, calculated on monthly profiles of phosphate concentrations are in good agreement with previous estimates of the flow of phosphates in the

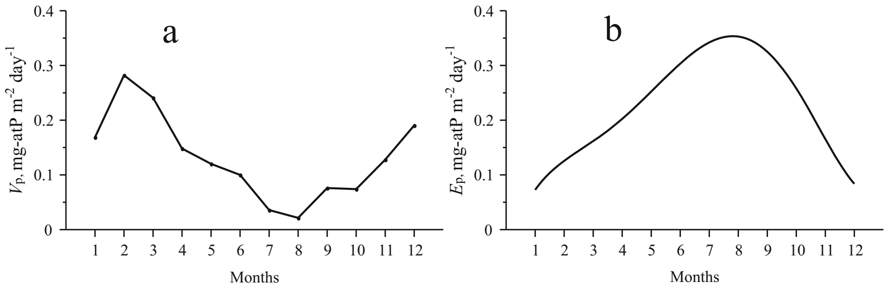

Fig. 19.1 Averaged multiannual seasonal dynamics of the upward flux (**a**) of phosphate and the dynamics of the regeneration flux (**b**) of phosphate in the deep water area of the Black Sea

central areas of the sea in the winter-spring period (Gusarova 1992; Parkhomenko et al. 2003).

Regenerative flux phosphates in photic layer, throughout the year change of phase with the seasonal dynamics of the upward (Fig. 19.1). Minimum monthly phosphorus recovery values (Fig. 19.1) are characteristic of December–January 0.1 mg-atP m^{-2} day^{-1}, which is associated with a lower water temperature and relatively small compared to other seasons, the biomass of zooplankton (Shushkina et al. 1992; Parkhomenko 2005, 2007). From March to May, with an increase in temperature and an increase in the intensity of the exchange of animals and the zooplankton biomass (Shushkina and Vinogradov 1991b) phosphate recovery rate is increased by 2–2.5 times. In summer, they reach maximum values – 0.3 ± 0.03 mg-atPm^{-2} day^{-1}, which corresponds to a fourfold increase in the regeneration upward compared to winter. As can be seen from Fig. 19.1 in the warm season of inorganic phosphorus regeneration processes in the pelagic zone of the Black Sea provides most of it in the algae needs. In winter and spring provision of inorganic phosphorus in phytoplankton is mainly related to an increase in its upward flux. A similar annual variation was obtained for the upward flow of nitrate and ammonium regeneration flux in the open part of the Black Sea (Krivenko and Parkhomenko 2015). To evaluate phosphorus balance on the basis of the results of the above-mentioned we calculated integral values rising and phosphate regeneration flux in the zone of photosynthesis in the pelagic zone of the Black Sea. According to our calculations, the average annual intake of phosphates in the photosynthesis zone with an upward flux and regeneration flux was 48 and 80 mg-atP·m^{-2}·year^{-1}, respectively.

Thus, it was found that the maximum values upward of phosphates entering the zone of photosynthesis due to hydro-physical processes observed in February and March, the minimum values in July and August. In autumn on average two times lower compared to the winter (December–January) and spring (April–May) months. Annual variations of monthly mean values of integral indices of regeneration flux of phosphates in the deepwater area of the Black Sea is a one-vertex character of the curve. The maximum values of these values are observed in the summer period from June to September and the minimum in the winter months. Intermediate values of these parameters match the spring and autumn period.

19.1.3 Contribution of the Upward Flux of Phosphorus to the Total of Its Income into the Zone of Photosynthesis

According to the concept of the "new" and the regeneration products (Dugdale and Goering 1967; Eppley and Peterson 1979) at steady state between the elements of the biotic nitrogen balance in the photic layer of open ocean areas supported by a dynamic equilibrium. Upward flux of nitrates entering the surface water by physical processes is equivalent to sedimentation flux of particulate organic nitrogen and is equal to the rate of uptake of nitrate by phytoplankton.

Assuming that within the selected scale averaging observed stationary condition, calculated upward flux of phosphorus corresponds to the "new" production, its flux regeneration – regenerative production, and the value of f-ratio (the proportion of "new" products) – F_P index the upward contribution of phosphorus flux calculated using the formula:

$$F_P = V \cdot 100\%/(E + V) \tag{19.1}$$

Where the V – ascending E – regenerative flux of phosphates, mg-atP m^{-2} day^{-1}.

Seasonal variability of the upstream contribution to the total income of phosphorus in the photosynthesis zone was considered on the basis of monthly averages of the F_P (Fig. 19.2), the value of which vary from 10 to 70% during the year. The maximum values are observed during the period from December to March and in July and August, they are reduced to a minimum. In spring and autumn, the magnitude of this figure is an average of 30%. In an average year the upward flux of inorganic phosphorus provides – 37% of its total income in the photic layer.

It is known that increasing the share of "new"/export production typical of the area of the ocean or the seasons of the year with an intensive vertical mixing of waters is accompanied by the accumulation of algal biomass and the increase in primary production (Eppley and Peterson 1979; Falkowski et al. 2003). According to our estimates, in the deepwater area of the Black Sea change of upward flux of phosphate is mainly determined by the change in the coefficient of vertical turbulent diffusion (K_Z). A fivefold increase in the value of K_Z in winter compared to July–August, in average corresponds to a similar increase in the rate of income of phosphate (Fig. 19.2a). But significant change in the phosphate concentration gradient throughout the year is not established (Krivenko and Parkhomenko 2015). Only in winter, when K_Z was adopted as a constant, change in the concentration gradients of phosphorus defined by two-fold change of upward flux in the period from December to March. The intensity of mixing of surface water also

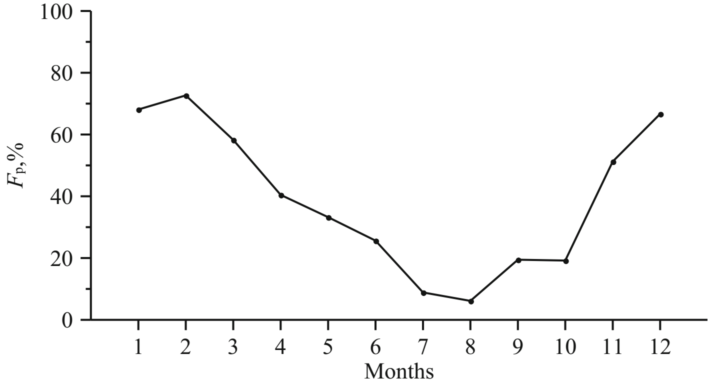

Fig. 19.2 Seasonal variability of Fp-ratio calculated by flux of phosphate in euphotic zone in deep water area of the Black Sea

affects the speed of regeneration of nutrients, that is described by inverse relationship between the average monthly values of regeneration flux and K_Z (Fig. 19.3). In summer, the high stability of the water layer and minimum values of K_Z, the average observed in more than three-fold increase of regeneration flux compared with cold period of the year.

The increasing of the part of "new"/export production with increasing trophic status of water is expressed in the functional dependencies between the values of f-ratio and nitrate content in the medium, the concentration of chlorophyll "a", phytoplankton biomass, primary production, obtained in different regions of the ocean and generalized in several previously published studies (Falkowski et al. 2003; Dunne et al. 2005). Similar dependences were obtained by us for the Black Sea when comparing the monthly averages of F_P and related integrated assessments and hydro-chemical the productive indicators in the photic layer (Fig. 19.4).

The relationship between the F_P and integral values of phosphate content in the layer of 0–40 m is described by the logarithmic function with the coefficient of determination of 0.86 (Fig. 19.4a). Earlier, a similar relationship between the content of nitrate in the environment and the value of f-ratio was obtained for ocean waters (Platt and Harrison 1985; Harrison et al. 1987; Murray et al. 1989), as well as the Black Sea (Krivenko 2005). The general laws correspond the accumulation of phytoplankton biomass in areas with higher values of f/e-ratio. Its reflection its the relationship between monthly average data of the Fp and concentration chlorophyll "a" calculated according to (Vedernikov and Demidov 1997) (Fig. 19.4b), and also according to the phytoplankton biomass (Krivenko and Parkhomenko 2010) (Fig. 19.4c) for photosynthesis zone deep sea area. These dependences are well described by a logarithmic function with coefficients of determination of 0.62 for the "a" chlorophyll (Fig. 19.4b) and 0.70 for biomass of phytoplankton (Fig. 19.4c). Thus, the nature of obtained dependences corresponds to the general laws of formation of the "new" and regenerative products in general, in the oceans, and the Black Sea in particular.

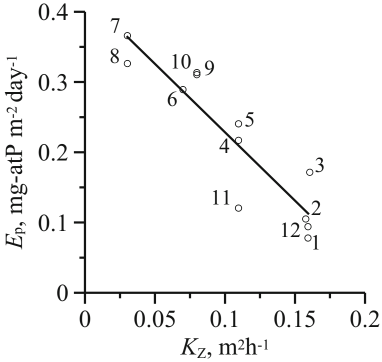

Fig. 19.3 Relationship of the monthly averaged regeneration flux of phosphate and K_Z used for the calculation of the upward flux. The numbers at the points refer to the month of the averaged data

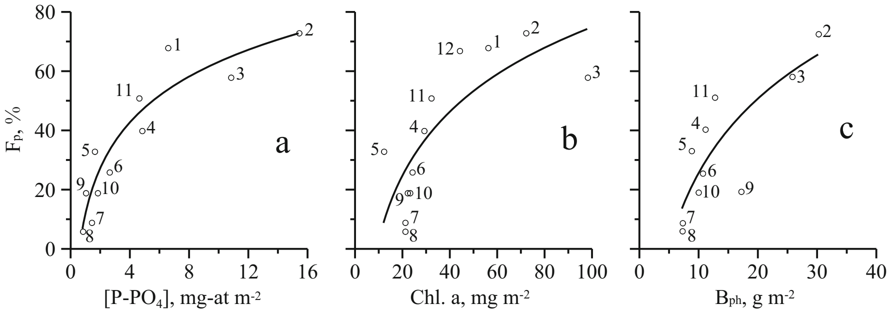

Fig. 19.4 Relationship between the monthly average of F_P (**a**–**c**) and integral concentration of phosphate (**a**), chlorophyll a (**b**) and phytoplankton biomass (**c**) in euphotic zone the deep water area of the Black Sea. The *numbers* at the points refer to the month of the averaged data

19.1.4 Potential Primary Production in Deepwater Area of the Black Sea

By multi-directional annual variation upward flux and regeneration flux of inorganic phosphorus in its total income in photic layer varies in season considerably smaller than its total flux. Total income of inorganic phosphorus in the photosynthesis zone in the warm season (April–October) compared with the winter months is by 1.2 times more. But taking into consideration high degree of variability used in the calculation of a monthly average characteristics, the validity of the differences were not statistically justified. Therefore, we can assume that the total income of inorganic phosphorus in the photosynthesis zone average for the year is maintained at approximately the same level. Significant seasonal differences are possible only in years with extremely cold winters, when the intense convective-wind mixing of water provides additional enrichment of surface waters by nutrients. This assumption is confirmed by the analysis of long-term dynamics of primary production on the basis of satellite data (Finenko et al. 2010), which showed that the seasonal dynamics this index in the deepwater area has no permanent peak in winter. The marked increase in primary production can be traced only in extremely cold winters, when its value can be four times higher than in summer.

Largest monthly flows of inorganic phosphorus income (bottom-up and regeneration fluxes) seasonal variation in primary production has been calculated, which could potentially be synthesized based on them. Recalculation of flows carbon units carried out according to the ratio Redfield 106:16:1 based on seasonal changes in the contribution of bacteria into total consumption of phosphate (phytoplankton, bacteria) by microplankton in photic layer (Parkhomenko 2009). The values obtained were compared with the averaged on the same scale data long-term experimental studies carried out using the isotope ^{14}C (Fig. 19.5). It is evident that the seasonal variability of the calculated values is in the variability of boundaries experimentally obtained monthly primary production values, and for most of the year, our estimates are within the range of variability. In January–March, they are closer to the minimum values of primary production, which seems quite logical, since we have taken in the calculation of the value K_Z for the winter months more in line with a moderate climate condition.

Obviously, higher productivity is typical for the harsh winters. Therefore, there was the highest value of primary production in February and March (from experimental data) can be attributed mainly growth of the "new" product, which is synthesized from the income of nutrients from deep layers. The difference between the minimum and maximum average monthly primary production estimates in February–March is about 100%, or 300–400 mgCm^{-2} day^{-1} (Fig. 19.5). If we assume that the value of the F_P, which is equal to 50–70%, corresponding to the terms of the warm winter, the "new" production in extremely cold winters may by increased by 2–3 times, and its contribution to overall primary synthesis may reach 70–85%. According to our calculations, the value of the annual primary production, which can be synthesized based on the upward and regeneration fluxes phosphate was 120 gCm^{-2} year^{-1}, which is comparable with the estimates of this parameter from measurements in situ – 110 gCm^{-2} year^{-1} (Demidov 2008), 130 gCm^{-2} year^{-1}, (Stelmakh et al. 1998) and 137 gCm^{-2} year^{-1} (Vedernikov and Demidov 1997). Value calculated and experimentally derived primary production of monthly and annual average estimates means that the calculated rate of inorganic phosphorus income the zone of photosynthesis due to the upward and regeneration fluxes throughout the year is enough primary production level observed in the deepwater area of the Black Sea.

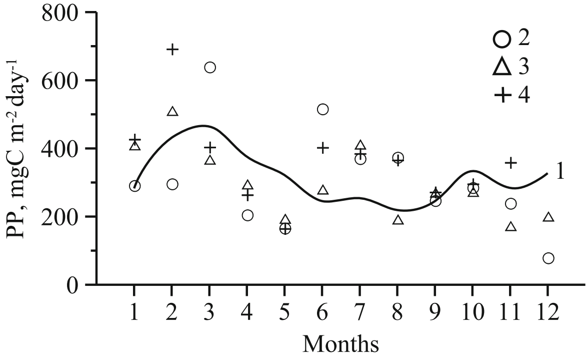

Fig. 19.5 Comparison of the seasonal dynamics of the primary production in the deep water area of the Black Sea, calculated by the phosphorus flux (*1*) to the averaged data of the *in situ* measurements: *2* – Stelmakh et al. 1998; *3* – Demidov 2008; *4* – Vedernikov and Demidov 1997

19.2 Evaluation of Sediment Flux of Particulate Organic Phosphorus from the Photic Layer of the Pelagial of the Black Sea

Sedimentation flow of particulate organic phosphorus is an important component of biogeochemical phosphorus cycle, ensuring its balance in the marine and freshwater environment. In recent decades on the shelf and in the open part of the Black Sea, large-scale studies using different methods (traditional sampling method (filtration on glass fiber filters BOB), sediment traps and uranium-thorium method) were carried out, that allowed us to obtain a large amount of spatial data by temporal and vertical distribution of the content of particulate organic carbon (C_{POM}), nitrogen (N_{POM}), phosphorus and their fluxes (Izdar et al. 1987; Hay et al. 1990; Karl and Knauer 1991; Gulin et al. 1995; Burlakova et al. 1998, 2003; Samyshev 2009; Kukushkin 2012). However, due to the methodological difficulties of using sediment traps at shallow depths (40–60 m) and time-consuming determination of particulate organic carbon (C_{POM}), nitrogen (N_{POM}) and phosphorus (P_{POM}) in field conditions (Yakushev and Korzhikova 1990; Gulin et al. 1995; Burlakova et al. 1998;) fluxes studies C_{VOV} flows of N_{VOV}, have been limited. Analysis of the available data in the literature showed that mainly they reflect the assessment of C_{POM} flows and N_{POM} (Karl and Knauer 1991; Gulin et al. 1995; Burlakova et al. 2003; Samyshev 2009). Estimates of annual variability of sedimentation flow of deep water area of the Black Sea in zone of photosynthesis are absent, with the exception of model calculations the average annual value of this flux in the western part of the sea (Yegorov 2001). To solve this problem we used the results of studies on spatial and vertical distribution of the content of particulate organic carbon were used (C_{POM}), nitrogen (N_{POM}) and phosphorus (P_{VOV}) in the layer (0–150 m), obtained in 10 scientific expeditions on the 51 stations in the period 1985–1994 in the deepwater area of the Black Sea (Kukushkin and Parkhomenko 2015). The methods, of algorithm calculation and study of monthly and annual average values of sedimentation flux of particulate organic phosphorus are described in the work (Parkhomenko and Kukushkin 2015).

To estimate the annual variability of the sedimentation flux of photosynthesis zone deep water area of the Black Sea used two variants of calculation. The first is based on the use of long-term data measured total primary production. The basis of the model analysis of the monthly mean values of the "new" primary production were laid as its value corresponds to the amount of organic matter exported from the zone of photosynthesis in the deep layers of the sea (Eppley and Peterson 1979). Average values of the "new" primary production is determined by the difference between the measured average monthly amount of the total primary production (TPP) in the period (1973–1995) (Vedernikov and Demidov 1997) and the values of regenerative products, calculated in accordance with the integral value of the regeneration of phosphorus flux over the same time period (Parkhomenko 2005), taking into account the uptake of phosphate by bacteria (Parkhomenko 2009). Sedimentation flux of P_{POM} was integral monthly average of the "new" primary production and the weight ratio C: P = 106: 1 (Table 19.1). According to the data in Table 19.1 P_{POM} flux values during the year varied over a wide range (0.019–0.336 mg-atP·m^{-2}·day^{-1}). The highest values of this indicator varied in the range (0.065–0.336 mg-atP·m^{-2}·day^{-1}) and consistent with the cold season (November–March). In the warm season (April–October), they decreased and ranged from 0.021 to 0.147 mg-atP·m^{-2}·day^{-1}, and the average value of the flux was equal to 44.89 mg-atP·m^{-2}·year^{-1}.

The second variant of the sedimentation flux P_{POM} annual variability assessment is based on the measured and calculated average concentrations of photosynthesis zone (Parkhomenko and Kukushkin 2015). Sedimentation P_{POM} flux was calculated as the product of the average concentration in the P_{POM} in photosynthesis zone and deposition rate (Table 19.2). The deposition rate P_{POM} calculated by dividing the monthly average flux sedimentation, resulting in model calculations (Table 19.2) and its weighted average concentrations in the photic layer of pelagial the Black Sea. As shown in Table 19.2 the value of this indicator during the year varied over a wide range (0.021–0.341 mg-atP·m^{-2}·day^{-1}). The highest values of this flux (0.065–0.341 mg-atP·m^{-2}·day^{-1}) correspond to the cold season (November–March), they decreased and varied from 0.021 to 0.147 mg-atP·m^{-2}·day^{-1} in the warm season (April–October), and the average value of the flux was 46 mg-atP·m^{-2}·year^{-1}.

Annual variability of sedimentation P_{POM} flux generally was in line with the seasonal changes to the annual weighted average concentration of P_{POM} of chlorophyll "a" and phytoplankton biomass in the photosynthetic zone, indicating a key role not only seasonal variability of phytoplankton and of hydro-physical and sedimentary processes on the intensity of the sedimentation flux of P_{POM}. Similar results were obtained in C_{POM} and N_{POM} in the photosynthesis zone sedimentation flux studies central western cyclonic gyre in the Black Sea (Gulin et al. 1995). The seasonal changes of the sedimentation flux P_{POM}, calculated on the average monthly values of the "new" primary production are well matched with the annual variability of the sedimentation flux P_{POM}, calculated on a weighted average of its concentration in the photic layer. Average annual values were almost identical and were, respectively, 44.9 and 46 mg-atP·m^{-2}·year^{-1}, which indicates a high

Table 19.1 Total primary production (TPP), regeneration phosphorus flux (RPhF), regeneration primary production (RPP), "new" primary production (NPP), P_{POM} sedimentation flux (SF)

Months	TPP, mg-at $C \cdot m^{-2} \cdot day^{-1}$	(RPhF), mg-at $P \cdot m^{-2} \cdot day^{-1}$	RPP, mg-at $C \cdot m^{-2} \cdot day^{-1}$	NPP, mg-at $C \cdot m^{2} \cdot day^{-1}$	SF, mg-at $P \cdot m^{-2} \cdot day^{-1}$
1	35.4	0.071	7.5	27.5	0.259
2	45.8	0.096	10.2	35.6	0.336
3	43.1	0.154	16.3	26.8	0.252
4	×	×	×	×	×
5	24.0	0.206	21.8	2.2	0.021
6	27.7	0.203	21.5	6.2	0.058
7	44.2	0.258	27.3	16.5	0.155
8	26.2	0.229	24.2	2	0.019
9	29.2	0.219	23.2	6	0.057
10	26.4	0.219	23.2	3.2	0.030
11	22.2	0.103	10.9	11.3	0.106
12	15.8	0.084	8.9	6.9	0.065
Z					44.89

Note: Monthly average TPP for April were not accounted, since it significantly exceeded available in literature data (Vedernikov and Demidov 1997; Stelmakh et al. 1998); *Z* annual average value, mg-at $P \cdot m^{-2} \cdot year^{-1}$

precision of model calculations. Thus, we use different approaches to calculate flux sedimentation P_{POM} of photosynthesis zone, which are based on both instrumental measurements and theoretical backgrounds. This let us properly assess its seasonal variability and average annual value in the deepwater area of the Black Sea. Comparison of average annual values of the upward flux of phosphorus and sediment flux P_{POM} derived from of the deer area of the Black Sea showed that they were respectively 48 and 46 mg-at$P \cdot m^{-2} \cdot year^{-1}$ and their ratio corresponds to almost one. This ratio indicates the average balance of processes average annual income of phosphorus and its sediment removal from the photosynthetic zone deepwater area of the Black Sea.

19.3 Assessment of Phosphorus Income from Outside Sources in the Black Sea

The Black Sea, since 1970 is under constant pressure by chemical pollution from land-based sources and atmospheric precipitation. This is due primarily to its geographic location and the huge catchment area of 1,760,000 km^2 (Mikhailov and Mikhailova 2008), where a population of about 162 million people live and high industrial, agricultural and resort potential is located (Mee 1992). Furthermore, it is necessary to take into consideration a number of distinctive features of the Sea, such as limited water exchange through the Bosporus Strait, the presence of small thickness (150–200) m of the upper layer of oxygen relative depth of

Table 19.2 Within-year variability of measured ($P_{POM\ MEAS}$) and calculated ($P_{POM\ CALC}$) average weighted concentration of particulate organic phosphorus and its sedimentation flux (SF P_{POM}) from photosynthesis zone (PhZ) of the deep-water section of the Black Sea

Months	PhZ, m	$P_{POM\ MEAS}$, mg-atP·m^{-3}	N/n	$P_{POM\ CALC}$, mg-atP·m^{-3}	N/n	w_s, m·day^{-1}	SF P_{POM}, mg-atP·m^{-2}·day^{-1}
1	40	0.028 ± 0.002	1/3	0.036 ± 0.010	2/52	7.2	0.259
2	30	×	×	0.055 ± 0.010	2/6	6.2	0.341
3	45	0.062 ± 0.010	1/10	0.060 ± 0.011	3/59	4.1	0.246
4	50	0.052 ± 0.014	2/12	0.051 ± 0.010	2/87	×	×
5	60	0.034 ± 0.002	1/3	0.035 ± 0.004	1/12	0.6	0.021
6	60	0.037 ± 0.007	1/6	0.045 ± 0.014	2/28	1.3	0.058
7	65	0.034	1/2	0.046 ± 0.019	1/15	3.2	0.147
8	50	×	×	0.048 ± 0.012	3/46	1.3	0.062
9	50	0.042 ± 0.005	1/2	0.045 ± 0.012	1/55	1.2	0.054
10	55	×	×	0.040 ± 0.006	3/20	0.7	0.028
11	45	0.030	1/1	0.041 ± 0.012	4/39	2.6	0.107
12	40	0.033 ± 0.003	1/2	0.024 ± 0.004	1/25	2.7	0.065
Z	×	×	×	×	×	×	46.0

Note: w_s rate of P_{POM} sedimentation, *Z* annual average value, mg-at P·m^{-2}·year^{-1}, *N* number of surveys, *n* number of sites, × measurements and calculations were not carried out

hydrogen sulfide zone, as well as the presence of the shelf, which is located in the northwestern part of the sea with an area of 60,000 km^2 (Mee 1992; Ivanov and Belokopytov 2011).

According to the literature the most complete summary of the results of research of income of nutrients (nitrogen and phosphorus) in the Black Sea during the period (1950–2000) is presented in the work (Garkavaya and Bogatova 2006). According to estimates the average annual flow of phosphates with the river runoff of the Danube, the Dnieper, the Dniester and the Southern Bug in the period (1950–1960) in the north-western part of the sea (NWPM) was 15,000 tP·year^{-1}. However, over the 5-year period (1980–1985) the average annual income of phosphorus with the runoff of the rivers flowing into the Black Sea basin from the territories (Russia, Ukraine, Bulgaria, Romania, Turkey, Georgia) increased sharply and amounted to – 52,000 tP·year^{-1} (Gubanov 1992). At the same time, the value of this indicator for the ten-year period (1980–1990) was slightly lower and amounted to 44,600 tP·year^{-1} (Garkavaya and Bogatova 2006). In more recent studies, since 1993 to 1996, carried out in the framework of an international project with the participation of researchers from Russia, Ukraine, Bulgaria, Romania, Turkey, Georgia close value of this index is equal to 42,604 tP·year^{-1} was obtained (The Black Sea 1997). At the same time, it is estimated (Garkavaya and Bogatova 2006) the average value of income of phosphorus to the river flow over a ten year period (1990–2000) sharply decreased and amounted to 22,000 tP·year^{-1} (Garkavaya and Bogatova 2006), which is practically comparable with the value of this parameter obtained in period (1950–1960). From the above

Table 19.3 The average income of phosphorus from external sources in the Black Sea during the period (1980–1996)

Sources of phosphorus income		$tP \cdot year^{-1}$	%
V_1	River runoff	46,401	62.1
V_2	Precipitation	19,620	26.3
V_3	Domestic and industrial effluents	8675	11.6
The total average annual income of phosphorus flux		74,696	100

mentioned data it is clear that the highest level of phosphorus anthropogenic load on the Black Sea was in the period (1980–1996). In further calculations we use the value of the average annual income of phosphates with a total river runoff into the Black Sea during this period of time equal to – 46,401 $tP \cdot year^{-1}$ (Table 19.3) calculated as the arithmetic average value of the 5-year period (1980–1985), a 10-year period (1980–1990) and a three-year period (1993–1996).

The second most important income of phosphorus flux into the Black Sea is associated with precipitation. Precipitation (rain, snow) play an important role in the income of nutrients (nitrogen and phosphorus) in the Black Sea basin. In recent decades, air pollution associated with vehicle exhaust fumes and smoke from the large industrial enterprises, as well as carrying out work in seaports during loading and unloading ships of transport fleet (State of the Environment 2002; Garkavaya and Bogatova 2006) Unlike land-based sources, the special feature of income of nutrients from atmospheric deposition is that they are able to embrace and influence the functioning of the planktonic community of large areas of the open part of the Black Sea. For a rough estimation of the average annual income of phosphorus with precipitation on the Black Sea we used the results of multi years of research. Thus, it is estimated (Rozhdestvenskiy 1998) the average value of income of phosphorus to the precipitation for the period (1980–1990) was 22,000 $tP \cdot year^{-1}$. The close value of this index is equal to 17,240 tP $year^{-1}$ was obtained in studies of the Ukrainian Scientific-Research Institute of Ecological Problems in the period (1993–1997) (State of the Environment 2002). In further calculations we use an arithmetic average value of the average annual flow of phosphorus equal to 19,620 $tP \cdot year^{-1}$ (Table 19.3), calculated according to the results of research (Rozhdestvenskiy 1998; State of the Environment 2002).

A significant contribution to phosphorus income make local land-based sources of purified and non purified domestic and industrial effluents from small and large settlements. To estimate the average annual income of phosphorus from domestic and industrial effluents we used the results of research conducted in the period from 1993 to 1996 in the framework of the international project. The average annual income of phosphorus from domestic and industrial effluents in the Black Sea basin in the period corresponded – 6627 and 2048 $tP \cdot year^{-1}$, respectively, and their total flux – 8675 $tP \cdot year^{-1}$ (The Black Sea 1997). According to our estimates, the total average annual income of phosphorus flux from external sources in the Black Sea water during most of anthropogenic load of nutrients from 1980 to 1996 amounted to 74,696 $tP \cdot year^{-1}$ (Table 19.3). It is known that the income of nutrients (nitrogen and phosphorus) from land-based sources has a significant impact on the hydrochemical conditions of environment, and as a result on the structure and functioning of the planktonic community, as well as the benthic flora and fauna in the coastal areas of the Black Sea (Fashchuk et al. 1991; Cociasu et al. 1996; The Black Sea 1997; Orlova et al. 1999; Berlinsky et al. 2003; North-western part of the Black sea: biology and ecology 2006). Thus, the assessment of primary production, obtained in the transformed waters on offshore NWPM, in the coastal areas of Bulgaria, Romania, Turkey, indicate a high level of primary production, the relevant area of the eutrophic type (Cociasu et al. 1996; Demidov 2008; Finenko et al. 2010). However, the question of the influence of anthropogenic nutrients on the biosynthesis of primary production in the deepwater area of the Black Sea remains open. In this regard, using the quantitative evaluation of the upward the regeneration of phosphorus fluxes and the flux of its income from outside sources we took an attempt to answer this question. To solve it, we, on the basis of literature data made calculations of the average annual income of phosphorus in the Black Sea during the period of the greatest anthropogenic load, which according to our estimates amounted to – 74,696 tP·year^{-1} (Table 19.3). However, it is known that on the shelf share of the NWPM is about 75% of the chemical pollution of the total content in the river flow entering the Black Sea (Zats 1993). Total phosphorus income from land-based sources (river runoff, industrial and domestic effluents) in the sea water area was equal to 55,076 tP·year^{-1} (Table. 19.3). In this case, the value of the average annual income of phosphorus in the NWPM is – 41,307 tP·year^{-1}, and in the coastal areas of the rest sea water can only come 13,769 tP·year^{-1}. It is earlier established that due to the chemical and physical processes of the mineral and organic forms of nitrogen, phosphorus, silicon is reduced by (30–50%) in the process of transformation of water runoff from the river estuary waters and seawater barrier at the border with salinity (2–5%) with subsequent transition to the bottom sediments (Garkavaya and Bogatova 2006). In addition, in the shelf zone of the north-western part of the sea to the border salinity 17‰, part of phosphorus is actively absorbed by phytoplankton and bacteria, followed by removal of sedimentation in the bottom sediments, the other part of it is removed with the stream along the south-western coast of the Bosporus Strait and only a small part of it can reach the deep-sea area. According to estimates (Sovga et al. 2000) from the north-western shelf in to the deep water areas of the sea can come about 15,000 tP·year^{-1}. Then, a potential average annual income of phosphorus in the deepwater part of the sea will be provided by the river runoff in the amount of 13,769 tP·year^{-1}, with precipitation – 19,620 tP·year^{-1}, entering from the north-western shelf – 15,000 tP·year^{-1} at the total value of this index – 48,389 tP·year^{-1}. Assuming that the incoming phosphorus from these sources is distributed evenly across the Black Sea, the annual average of his arrival in the calculation of the sea an area of 423,000 km^2 will be – 0.11 gP·m^{-2}·year^{-1}. As can be seen from Table 19.4, a key role in phosphorus income into the photic layer of the deepwater area of the Black Sea belongs to the regeneration and the upward fluxes, equal 97.3% of the total its income part of phosphorus from external sources (river runoff, precipitation, stream from the north-western part of the sea) was, only 2.7%, which potentially provides

Table 19.4 The average annual of phosphorus fluxes in the photic layer deepwater area of the Black Sea during the period (1980–1996)

Phosphorus fluxes		$gP{\cdot}m^{-2}{\cdot}year^{-1}$	%
V_1	Regeneration flux	2.49	61.0
V_2	Upward flux	1.49	36.3
V_3	River runoff, precipitation, domestic and industrial effluents and flux of NWPM	0.11	2.7
The total average annual income of phosphorus in photic layer		4.08	100

annual average growth of phytoplankton production – 4.5 $gPm^{-2}{\cdot}year^{-1}$ or 3.3% of the average annual primary production in the deepwater area of the Black Sea, equal to 135 $gCm^{-2}{\cdot}year^{-1}$ (Vedernikov and Demidov 1997). Obviously, the ratio of receipt of fluxes of phosphorus (regeneration and upward), equal to 97.3% and the flux of its revenues from external sources (river runoff, industrial and domestic effluents, precipitation and flux from NWPM) equal to 2.7% clearly indicates a lack of process eutrophication in the photic layer deep-water areal of the Black sea.

19.4 Conclusion

Based on monthly data averaging obtained during multiyear observations on the vertical distribution of phosphates, the coefficients of the vertical exchange of water and zooplankton development indicators seasonal variation of the upward and regeneration of inorganic phosphorus fluxes of the photic layer in deepwater area of the Black Sea is evaluated. When calculating the upward flux of phosphorus it was supposed that its value during the year is determined by the intensity of turbulent exchange and the concentration gradient of phosphate at the upper boundary of the main pycnocline. The reliability of the initial assumption is confirmed by the consistency of the results obtained on its basis. Using two independent methods of calculation it was determined by the seasonal dynamics of the total income of inorganic phosphorus in photic layer, which is consistent with the average monthly amount of primary production measured in situ. The relative contribution of upward and regeneration of phosphorus fluxes to ensure the photosynthesis zone throughout the year changes directionally and functionally coupled with the seasonal dynamics of mixing intensity of water, hydro-chemical conditions and quantitative indexes of phytoplankton development. From December to March income of phosphates is controlled mainly by hydrophysical processes and in the summer months by biological processes. In the transitional seasons of phosphorus regeneration provides a large part of income, but the upward flux of phosphorus contribution in these months larger than in summer. Seasonal changes in the upstream contribution (F_P) corresponds to the annual dynamics of the share of "new" and exports in the total primary synthesis of the material in the pelagial of the Black Sea. Dependencies between the average monthly amount of the F_P and a production indicators (integrated phosphate, chlorophyll "a", the biomass of phytoplankton photosynthesis) are similar to the laws obtained for oceanic waters with different trophic status. The nature of the dependences obtained corresponds to the general laws of formation of the "new" and regenerative products in general, in the oceans, and the Black Sea in particular.

According to long-term studies of primary production and particulate organic phosphorus in the photosynthesis zone received the annual variation of the sedimentation of its flow from the photosynthesis zone and calculated annual average P_{POM} in the deepwater area of the Black Sea. Comparison of average values of the upward flux of phosphorus and sediment flux it produced at deep water area of the Black Sea showed that they were respectively 48 and 46 mg-atP·m^{-2}·year^{-1}, and their ratio corresponds to almost one. This ratio indicates the average balance of processes, income of phosphorus and sediment removal from the photosynthetic zone deepwater area of the Black Sea.

According to our estimates in the photic layer of the deepwater area sea a key role in the biosynthesis of primary production play upward and regeneration of phosphorus fluxes, they accounted for – 97.3% of the total of its income. The flux of phosphorus from external sources (river runoff, industrial and domestic effluents, precipitation and flux from the north-western part of the sea) was 2.7%. Potentially phosphorus flux from external sources can provide phytoplankton production increase of not more than 3.3%, relative to the average annual primary production. These results indicate the absence of anthropogenic eutrophication in the deepwater area of the Black Sea, even in the period of greatest anthropogenic load from 1980 to 1996.

The above mentioned results findings highlight just some of the issues of the vast problem of phosphorus cycling in marine ecosystems. However, even the decision of these questions brings us closer to an understanding of security mechanisms in nutrients of plankton community and its functioning in the marine ecosystem.

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Chapter 20
Oil Hydrocarbons in Bottom Sediments of Sevastopol Bay (SW Crimean Peninsula, Black Sea): Spatial and Temporal Trends

Tatyana S. Osadchaya

Abstract Long-term observations for oil pollution of bottom sediments of Sevastopol Bay allowed to create the unique anthropogenic history of the region. Large volume of accumulated data allows to characterize dynamics of changes in the pollution status of the Bay at various temporal and spatial scales and to reveal the most vulnerable areas as a consequence of ever-growing economic development. The present study offers the results of comparative analysis of physical-chemical characteristics and distribution patterns of oil hydrocarbons in bottom sediments upper layer (0–5 sm) of the Sevastopol Bay on the data of environmental surveys of 2000 and 2009.

20.1 Introduction

The range of technogenic impacts to coastal water areas is extremely wide and diverse, but taking into account that modern life without the hydrocarbon compounds is almost impossible, this kind of pollution in order of importance in the formation of a common ecological quality of marine environment, has long considered in a par with natural geochemical, physical and biological processes (Zaitsev 2006; Mee and Topping 1999; Bologa 2001a; Mironov et al. 2003; Strategic…2006). In the case of such a large maritime centre like the city of Sevastopol, whose coastal waters since the founding of the city provide primarily the port services (as for the civil-industrial, and the military-naval purposes), the presence and a wide spread of oil and oil products in marine environment is quite explainable. An active maritime traffic, numerous port facilities and moorings, ship repair and shipbuilding enterprises are only listed stationary sources of the hydrocarbon pollution. Also, there are numerous terrestrial activities that are not always directly attribute (and are not always taken into account) to oil pollution such as an expansion of residential and recreational construction, developing network of the

T.S. Osadchaya (✉)
The A.O. Kovalevsky Institute of Marine Biological Researches (IMBR), Sevastopol, Russia
e-mail: ots51@mail.ru

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roads with a large number of parking and petrol stations (vehicle emissions) etc. Complicated combination of all factors defines and overall level of oil pollution and the features of distribution/accumulation in various components of a given water area (Ovsyaniy et al. 2001; Osadchaya 2010).

Oil and oil products, entering into marine environment by a variety ways are sorbed on the particles of suspended matter, undergo the chemical and biochemical transformation and, ultimately, pass from the water column to bottom sediments. Accumulating all entering substances, the sediments promote their removal from the water environment, participating thereby in self-cleaning process. At the same time, an unstable weather conditions, relatively shallow depths of the water area cause an intense mixing of water and bottom masses, creating, thereby, a threat of secondary pollution of the marine environment. In this context, when assessing long-term changes in water areas, determination of the content of pollutants in bottom sediments has the advantage that the indicator is integrating in time and in space (Osadchaya et al. 2004; Wilson et al. 2008; Mironov et al. 2009).

20.2 Study Area

Sevastopol region occupies the southwestern part of the Crimean Peninsula; its coastline covers 158 km. Total square of regional marine area is about 379.5 km^2 and includes a series the bays (about 30) among which a leading position belongs to Sevastopol Bay (Fig. 20.1). The area of the Bay is represented by semi-closed elongated configuration oriented in the eastern direction; total length is ~7 km, maximal width is about 1 km; the depths varies from 20 m (at an entrance) to 4–5 m in the top with average depth about 12.5 m. The Chernaya river with a catchment area about 427 km^2 and average annual drain about 56.8 mln. m^3 flows into eastern

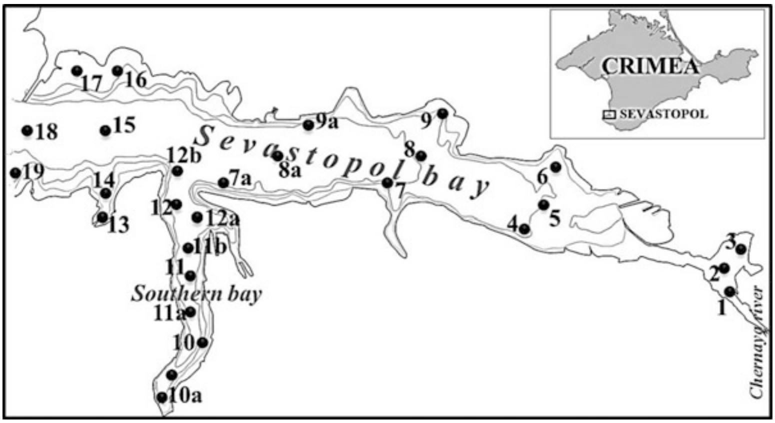

Fig. 20.1 The map – scheme of sampling the bottom sediments in Sevastopol Bay (the letter "a" designates additional sampling stations in 2009)

part of the Bay. The ratio between the catchment area and the area of Sevastopol Bay is estimated 56 that indicates how significant the terrigenous component is to sedimentation. In Sevastopol Bay sedimentation goes at relatively high rate – about 2.4 mm/year. as a study based on ^{137}Cs measurements has shown (Egorov et al. 2002). This estimate closely approximately the sedimentation rates characteristic of the northwestern Black Sea and the Azov Sea – 2.3 and 2.5 mm/year, correspondingly (Gulin et al. 1984).

20.3 Material and Methods

To compare the changes in oil pollution levels of bottom sediments of Sevastopol Bay (SW Crimean Peninsula, Black Sea), the results of complex environmental surveys of 2000, 2009 were used (Fig. 20.1). Study methods included: – sampling of bottom sediments with a modified Petersen dredge having the catchment area 0.025 m^2 (three replicates per station); – granulometric analysis by siege method which provided fractionation of the sediment through dry dispersion; – measurements of Eh, pH immediately after sampling with the use of needle – shaped platinum electrodes coupled with an argentum chlor electrode and a combined glass electrode (Shishkina 1980) and – natural moisture content using traditional weighing technique (Shostak and Lyusternik 1988). Determination the concentrations of oil hydrocarbons (total) was made by using method of infrared spectrometry (IR spectrometer FSM 1201), based on the measurement of absorption intensity of the methylene (−CH2) and the methyl (−CH3) groups in near infrared area of a range (2700–3100 cm^{-1}) that covers over 90% of petroleum hydrocarbons (Kiryukhina and Gubasaryan 2000).

20.4 Results and Discussion

All analyzed indices are given in Table 20.1. Grahulometric composition of bottom sediments on a bigger area of Sevastopol Bay was characterized by prevalence of aleuro- pelitic silts (of gray to black colour with smell of hydrogen sulfide). Black silts were steadily concentrated in the central area of the Bay and Southern bay (Fig. 20.1; st. 7–9a; 10–12b;); mixed substratums (the sands with mollusk shells, light silts etc.) were registered only on separate stations near the Bay mouth (Fig. 20.1; st. 17–19).

Natural moisture varied between the sampling sites but with a characteristic decrease of appropriate values from the black to grey silts and then to “others”. The range of pH showed a relative stability of acid-base balance for the most sediments (from near neutral up to weakly alkaline conditions). In 2000, the most sediments were characterized by negative Eh; the positive values were registered only at some stations of the more seaward area of the Bay (Fig. 20.1; st.: 14, 16, 17–19).

Table 20.1 Physical-chemical indices and the concentrations of oil hydrocarbons (OH, mg 100 g^{-1} sed. dry weight) in different types of bottom sediments of the Sevastopol Bay (2000, 2009)

Type/indices	%[a]	Moisture, %	pH	Eh, mV	OH, mg 100 g^{-1}
2000					
Black silt	47.4	42.00. . .78.51	7.05. . .8.04	(+21). . .(−189)	82.0. . .1708.8
Dark-gray silt	26.3	54.83...66.35	7.16. . .7.60	(+1). . .(−167)	34.0. . .250.8
Gray silt	10.5	49.90. . .67.53	7.30. . .7.55	(+21). . .(− 89)	40.0. . .114.0
Other[b]	15.5	26.56. . .72.69	7.90. . .8.17	(+251). . .(−114)	1.0. . .14.0
2009					
Black silt	31.6	50.40. . .69.26	7.08. . .7.85	(−178). . .(−114)	143.8. . .1369.5
Dark-gray silt	31.6	50.56. . .67.49	7.38. . .7.82	(−174). . .(−55)	90.4. . .856.6
Gray silt	26.3	35.85. . .54.07	7.47. . .7.56	(−69). . .(−247)	19.0. . .196.0
Other[b]	10.5	18.05. . .33.50	7.52. . .7.75	(−20). . .(−29)	24.3. . .189.3

Note:
[a]% (quota) from total number of sampling stations
[b]mixed substratum (the sands, mollusk shells, silt etc.)

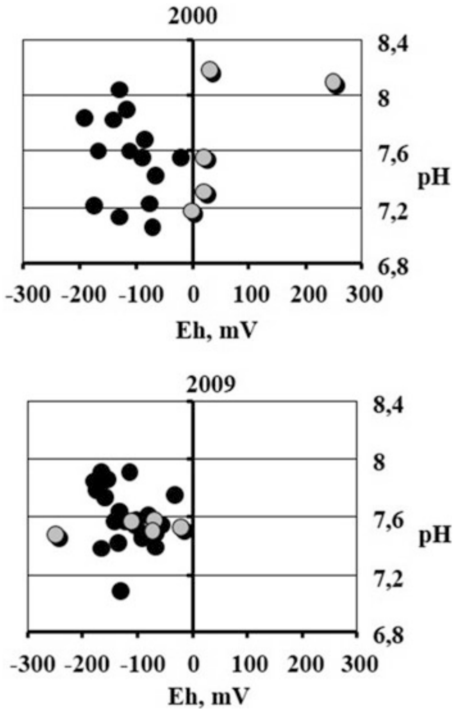

Fig. 20.2 Diagram Eh and pH in bottom sediments of Sevastopol Bay (2000, 2009)

Figure 20.2 shows that sharp changes of physical-chemical profile of bottom surface in this area have led to the fact that in 2009, the sediments with such conditions (positive Eh) have not been detected on any of the sampling stations.

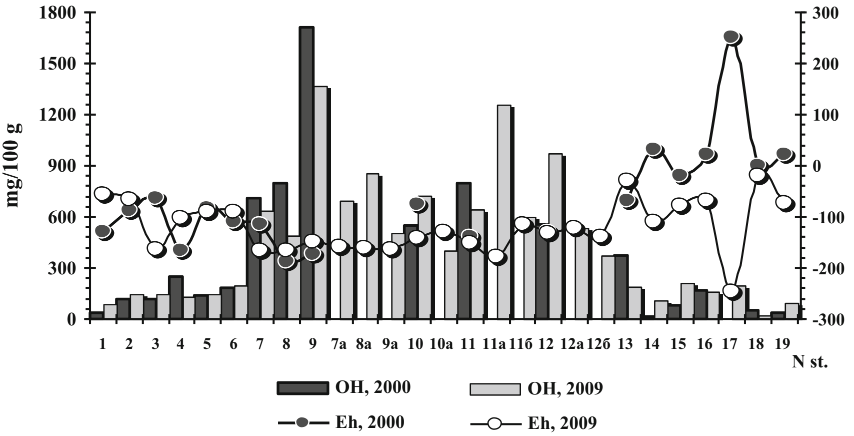

Fig. 20.3 Absolute concentrations of oil hydrocarbons and redox potential in bottom sediment of Sevastopol Bay

The absolute concentrations of hydrocarbons varied depending on the type of sediment and the sampling location. The stable high hydrocarbon content has registered in the central area and Southern bay where the bottom surface has been covered by mainly the black and dark-grey silts with negative Eh (Fig. 20.3). The sediments of eastern and western areas of the Bay (Fig. 20.3; st.: 1–6, 13–19) were characterized by lower content of hydrocarbons but a larger variability of Eh. Obvious similarity of spatial pollution gradients confirms the presence of oil hydrocarbons on almost the entire area of bottom surface of Sevastopol Bay for a long time.

Total effect of physical-chemical characteristics of bottom sediments on the concentrating or rejection of polluting substances is essential because they determine the spatial distribution of pollutants in surface sediment layer, and hence the localization of areas of high anthropogenic pressure. In particular, the morphometric structure and hydrodynamic features special for Sevastopol Bay are the factors which strongly influence granulometric fraction distribution in the uppermost layer of the bottom sediment (Osadchaya and Alyomov 2005; Romanov et al. 2007). Flood events typical for the river Chernaya determine qualitative and dimensional heterogeneity of the terrigenous substances entering the Bay; the river stream deceleration towards the Bay mouth and presence of dynamic anticyclonic formation with downwelling sea water in the centre have effect on distribution and accumulation of fine-grained aleurite and pelite fractions prevailing in the Bay sediments (Ovsyaniy et al. 2000). Such morphological composition, even without anthropogenic loading, can promote to forming the unfavourable conditions in bottom environment (Kirukhina 1992).

In case of Sevastopol Bay, an excess enrichment of bottom environment by organic matter leads to exhaustion of a stock the oxidizers even in the top-most layers of sediments (Osadchaya et al. 2003; Orekhova and Konovalov 2009). It is reported (Ivanov et al. 2006), that the Sevastopol Bay receives annually about 300–350 t of allochthonous organic substances brought with the untreated or insufficiently treated sewages from more than 30 uncontrolled outlets located along the shores. High content of organic substances stimulates the intensity of oxidation-reduction processes going through the depths of sediment; it is also the basic factor which controls accumulation process of oil hydrocarbons (Kirukhina 1988).

Taking into account a large area of Sevastopol Bay and a great number of various polluted discharges, a localization the zones with increased content of hydrocarbons are not always determined by proximity to direct source of the pollution. At the same time, in borders of the main water area there are the regions where a 'historical' coincidence of all factors (both the natural, and the anthropogenic) determines permanent anthropogenic pressure. For example, Southern bay (Fig. 20.1) is the biggest 'small' bay of the main water area (of total length about 2.4 km). Beginning from the city foundation, it is a traditional place of parking lot of different ships; the entire coastline of the bay is occupied by numerous moorings, docks, shipyards, etc. A vast area in the top part of the bay is a crossing point of the main city transport lines including the railway and bus stations, and so, it is the focus of various industrial-municipal discharges along the shores. As a result, the Southern bay concerns to the zone of very hard pollution for a long time and not only with regard to oil hydrocarbons (Osadchaya et al. 2004; Ignatyeva et al. 2005; Stokozov 2010).

The central part of Sevastopol Bay (Fig. 20.1; st.7–9a) is the area of intensive navigation and with numerous industrial and military objects located on the adjacent land. All these factors, in total with the features of hydrodynamical regime of the Bay (it is described above), exert a great influence both to morphology of the bottom, and the processes of pollutant accumulation. Adverse environmental conditions in this region can also be supported by the inflow of polluted water masses from the Southern bay, especially under impact of prolonged south winds (Mironov 1987).

Compared with the above-described areas, the pollution status in the top part and at the Bay exit can be characterized as relatively more favorable. Formation the bottom deposits, caused by the direct river inflow, promotes to decreasing the sediment ability to retain the pollutants incoming to the top area (Konovalov 2009). The more intensive water exchange with open sea at the bay entrance creates nearly the same situation resulting to formation the low and moderately polluted zones.

For comparison, the spatial-temporal distribution patterns of oil hydrocarbons in bottom sediments of Sevastopol Bay we have used a special index based on the ratio of absolute concentrations the pollutant on each station to 'average characteristic concentration' for various type of sediment calculated as follow:

$$M = C_i/A,$$

where C_i is an absolute concentration of given pollutant (oil hydrocarbons in our case) on i-th sampling station; A – average characteristic concentration of the

Fig. 20.4 The distribution patterns of oil hydrocarbons in bottom sediments of Sevastopol Bay in 2000 (**a**), 2009 (**b**)

pollutant for different sediment type (Klenkin et al. 2007). Ranging of studied area by the values of M (ie the multiplicity average characteristic concentration) allows to analyze distribution of the pollutants irrespective of its absolute content and type of sediments. In particular: $M \leq 1$ indicates the lack of 'fresh or new' receipts of pollution into given area; $M > 1$ testifies about considerable (and permanently acting)) anthropogenic load during the analyzed period of time. The lack of need in determination of threshold or background concentrations is the main advantage of such approach in comparison with other widely used quantitative criteria for evaluation of environmental pollution (Hakanson 1980; Wilson and Jeffrey 1987; Dauvalter 1997; Adami et al. 2000). In case of a wide spreading of the pollution, an establishment of such values is not always possible or correct. Also, majority of applied criteria do not take into account the composition of bottom sediments which can be homogenous and heterogeneous both in different regions, and in borders of the same area.

The results of performed analysis (Fig. 20.4) showed, rather a redistribution, than considerable decreasing of oil pollution of the Bay bottom surface by 2009, in particular: the reduction in area of the sites with extremely high concentrations of oil hydrocarbons (black color on Fig. 20.4) but an increase of pollution levels in areas where in 2000, the anthropogenic load was quite low. In 2009, the radical changes in the physical-chemical profile of bottom sediments have been registered it is in these areas.

20.5 Conclusions

Because of the high operational capacity of Sevastopol Bay, the intensive navigation and dense urbanization along the shoreline, the sources of the oil pollution are numerous and of various origins. Natural features of the hydrodynamics, morphometry, sedimentation in total with anthropogenic influence promote to formation a special, rather stable in time and space, distribution pattern of oil hydrocarbons in the Bay sediments. Having accumulated in excess, oil pollution of bottom surface has already triggered imbalance between the processes of transformation and accumulation towards the prevalence of the latter and it, in turn, testifies that assimilative capacity of the Bay in relation to the oil hydrocarbons is at critical level. In view of the fact that regional economic development is an ever-growing process, the results of its impact on the Bay water area are easily predictable and without real measures in the field of coastal and maritime spatial planning, draw optimistic conclusions concerning improvement in pollution status of Sevastopol Bay is while not possible.

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Part VI
Biology and Microbiology

Chapter 21
Macrophytobenthos from the Romanian Black Sea Coast – An Overview of the Studies and Actual State

Daciana Sava

Abstract The unique nature of the Black Sea, (stated as "unicum hydrobiologicum" by N.M. Knipovich) refers not only to its physico-chemical conditions, but also to its biodiversity. Several decades ago, under the influence of different events that occurred, the Black Sea ecosystem, and the Romanian coastal area, were affected. Under the influence of pollution and eutrophication, the state of all living communities from both qualitative and quantitative point of view, has changed. A number of observations that took place in the last years, confirmed the qualitative decline (fewer species), and the near disappearance of perennial species (brown and red algae) and as a consequence, the disappearance of associated or epiphytic species, and the uniformity of algal belts occur.

The research provides data obtained from the study of the macrophytobenthos from the Romanian littoral, both in northern and southern sector, where the macroalgae were collected from various types of hard substratum, several times a year, in both cold and warm seasons. In each sample, species were identified, and representative individuals were kept for the herbarium collection. The ecological factors influence the development of macrophytes along the Romanian shore, so they must be mentioned in all these studies.

The research shows that because of the newly created ecological conditions, the actual algal communities consist of a smaller number of species than previously reported, and most of them are opportunistic species with a short life cycle and rapid growth, like species from green algae *Enteromorpha*, *Ulva* and *Cladophora* genera, and *Ceramiun* from red algae, that persisted and proliferated under these environmental conditions displaying considerable biomass.

Keywords Romanian coast • Black Sea • Macrophytobenthos • Environmental changes

D. Sava (✉)
Faculty of Natural and Agricultural Sciences, University Ovidius of Constanţa, Campus B, University Alley 1, Constanta, Romania
e-mail: daciana.sava@gmail.com

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21.1 Introduction

The macrobenthic flora (algae and phanerogames), that represents the submerse vegetation from the Romanian Black Sea waters, represents a very important ecosystem component, being source of oxygen, external metabolites, food, shelter and breeding area for animals (invertebrates and fish), and not least, have a role protecting the fauna against the disturbing water/wave action and excessive light.

Considering this, the continuous quantitative and qualitative lowering of algal diversity and biomass is catastrophic for benthic life and for the entire ecosystem of this north-western part of the Black Sea.

Taking into consideration that the macroalgal substrate is particularly important and needs protection because of it's important role in the marine ecosystem, a new approach is necessary in order to establish the modifications of macroalgae in the newly created ecological conditions and appropriate ways of conservation.

21.2 Historical Considerations

Macroalgal flora was studied at the Romanian Black sea coast beginning with over a century ago, for the first time by Russian and Romanian scientists, and later on by Bulgarian, Turkish and Georgian ones.

We can mention Kanitz "Plantas Romaniae" (1881) where J. Schaarschmidt listed 233 species of algae, out of which 50 marine species, and only six macrophytes.

Also marking the beginning of marine benthal algology at our coast, is a monograph of the algological flora from Romania (both fresh and marine waters), published in 1907 by E. Teodorescu, in which 32 species of macrophyta were mentioned in samples taken from rocky bottoms along the Romanian coast.

One of the most important steps, in the development of marine biology in general and algology in particular in Romania, is the foundation of two important research institutes, one is the Marine Zoological Station at Agigea in 1926 by Ion Borcea, and the other one is the Bio-oceanographic Institute in Constanţa in 1932 by Grigore Antipa.

The algological research owes a lot to the outstanding algologist Maria Celan, who started her activity in 1930, when Professor Ion Borcea, remarking her attraction for the research work, entrusted her with the study of macrophytic algae, a field of science not yet researched in Romania to which she will dedicate her entire life. Celan contributed with taxonomical, cytological and ecological research upon macrophytic vegetation from the Black Sea coast.

The results of Celan's first observations in the field of macrophytic algae at our littoral materialized in articles published under the title "Notes sur la flore algologique du littoral rumain de la Mer Noire," between 1935 and 1938, in several volumes of the Bulletin and Memoirs of the Scientific Sections of the Romanian Academy (Celan, 1935–1936a. 1935–1936b, 1937a, b, 1938). In these first publications, Maria Celan presents a number of algae considered new for the Romanian littoral (*Gelidiella antipae* and *Phyllophora brodiaei*).

Further on, after working on her research for five years in France, at the Sorbonne University in Paris, she materialized the results of her work in 1940, presenting her doctoral thesis entitled: "Recherches citologiques sur les algues rouges" (Celan 1940). In this thesis, besides other valuable conclusions, an element of absolute novelty, is the use of Feulgen coloration in the nucleus of red algae. The successful application of this technique contributed to the understanding of the structures of different types of cells in these algae, as well as their development and evolution.

The continuation of the studies on the macrophytic algal flora means new contributions to the knowledge of this flora at our littoral with taxonomical and ecological studies (Celan 1948, 1958a, b, 1960; Celan and Şerbănescu 1959).

In 1962, the scientist publishes in the paper "New marine algae for the Romanian littoral of the Black Sea" a number of 18 new species from groups of blue algae (Cyanophyta) and green algae (Chlorophyta), (Celan 1962), and further on, in 1964, in "Note sur les algues brunes (Phaeophyta) du littoral roumain de la mer Noire," Celan describes brown algae mentioning the species *Ectocarpus caliacre* and *E. lebedii* f.*agigensis* as new for science and *Cystoseira bosphorica* and *Streblonema stilophorae* as new for the Black Sea (Celan 1964a, b).

Celan was interested in green algae and mostly in genera that raise difficulties from systematic point of view particularly the *Enteromorpha* genus. (Celan 1975, 1979a, b).

The red algae are another group studied by Celan, from which red algae of the genera *Ceramium* and *Polysiphonia* that both represent important components of benthic vegetation. (Celan 1981a, b; Celan and Bavaru 1966).

Celan was also interested in the study of algal associations, which she began in 1946, when she publishes the first paper in which she presents an overview of the autumn marine vegetation in Agigea (Celan 1948, 1977).

Later on she continued the studies of algal communities together with her collaborators, (Celan and Bavaru 1973, 1978; Celan et al. 1979).

Another important contributor to the knowledge of algal flora is H. V. Skolka, who was the first to describe the repartition of the red algae *Phyllophora* at the Romanian sea shore (Skolka 1956), and continued the observations regarding the macroalgal phytocoenoses and their repartition along the shore (Skolka and Bodeanu 1971; Skolka et al. 1980).

A. Bavaru begins his research studies with algologist Maria Celan, but afterwards, mainly after 1970, he continued his research in algal systematics and phytocoenology, with contributions on the macrobenthic vegetation in general (Bavaru 1970, 1977, 1981) and especially *Cystoseira* populations (Bavaru 1971, 1972).

Research on macroalgae was also an important preoccupation of A.S. Bologa, who was preoccupied about the state of macroalgal vegetation (Celan and Bologa 1981, 1983; Bologa 1987–1988), and also about the decline of the macroalgal vegetation and marine biodiversity in general (Bologa 2001; Bologa and Sava 2006; Sava and Bologa 2008, 2010).

A.S Bologa extended also his research to the physiology and chemistry of macroalgae e.g., he studied the photosynthetic productivity of benthic algae (Bologa 1979, 1980), as well as their capacity to accumulate radioactive isotopes, representing useful bioindicators for this type of pollution (Bologa et al. 1983).

In his papers F. Vasiliu, studied the species of the *Enteromorpha* genus (Celan and Vasiliu 1975), and also the taxonomy and ecology of all the groups of macroalgae from the Romanian littoral.

Several decades ago these studies showed a much higher number of species, subspecies and varieties as presently found in the coastal waters. The continuous quantitative and qualitative lowering of algal diversity and biomass becomes evident when analyzing the related literature.

According to A.D. Zinova, in 1967, the Black Sea macroalgoflora totalized a number of 277 species with 74 Chlorophyta, 3 Xanthophyta, 71 Phaeophyta and 129 Rhodophyta (Zinova 1967). But further research carried out after 1970 showed a gradual impoverishment, especially from the qualitative point of view, of the macrophytobenthos.

The observations on the both qualitatively and quantitatively decline of the macroalgal flora, initiated by Celan, were confirmed. In 1969, only 77 species were identified (Skolka 1969), later, in 1977, 86 species (Bavaru 1977) and 69 and 55 respectively, after 1980 (Vasiliu 1984, 1996).

It is considered that these changes are due to a number of causes such as: the increase of eutrophication, massive frosts, the silting of the rocky bottom with suspended matter, decrease of light penetration in the water column due to the same suspensions, (Bologa 1987/88).

In more recent years, unfortunately few research has been carried out regarding the present state of the macroalgal flora (Bologa 2001; Sava 2006; Sava et al. 2007a, b).

Taking this into consideration, a new approach of such studies is absolutely necessary in order to establish the major modifications that occurred in the state of macrophytobenthos, under the influence of harmful factors that disturbed the quality of the marine environment and biodiversity.

A number of scientific papers were published, showing the actual state and proposing measures and ways of conservation of the coastal marine environment. (Sava et al. 2003, 2011; Sava and Bologa 2010; Bologa and Sava 2012; Marin et al. 2015), or showing the interest in the biochemical content of macroalgae (Balaban et al. 2013; Trifan et al. 2015a) or their pharmaceutical importance; (Trifan et al. 2015b; Trifan et al. 2016).

Table 21.1 Stations, transects and depth of macroalagal sampling along Romanian Black sea coast

Sampling station	Transect	Bottom type	Sampling depth (m)
Midia		Rocky – natural/artificial tetrapods	0.5–1
Constanţa	Cazino	Rocky – natural	0.5–1
	Trei Papuci	Rocky – natural	0.5–1
	Pescărie	Rocky/tetrapods natural and artificial	0.5–3
Eforie Nord		Rocky/tetrapods – natural and artificial	0.5–1
Mangalia		Rocky/tetrapods – natural and artificial	0.5–3
2 Mai		Rocky – natural	0.5–3

21.3 Material and Methods

The selection of the study sites considered as principal criteria the presence of a rocky, natural or artificial bottom, because one of the most important conditions for the development of macrophytes is the presence of a hard substratum. The sampling stations were established between Midia (north) and 2 Mai (south), as shown in Table 21.1.

The present research has been carried out between 2014 and 2016, completing the observations that took place in previous years.

Samples for the qualitative determinations have been collected, in three replicates, from various depths between 0.5 and 3 m, in plastic bags, together with a label, mentioning station, date, and depth of collection. All samples were brought fresh in the laboratory, carefully washed for sediments and associated fauna, and separated in the following phylla: Chlorophyta (green algae), Phaeophyta (brown algae), Rhodophyta (red algae). Species identification was made with the help of algological handbooks and scientific literature, using macroscopic characteristics, where possible, but also microscopic examination whenever was necessary.

21.4 Results and Discussion

In the samples collected during the period of study, 16 Chlorophyta, 5 Phaeophyta and 11 Rhodophyta were found, as shown in the following table (Table 21.2).

Table 21.2 Species list

CHLOROPHYTA	
Order Ulvales	
Family Ulotrichaceae	*Ulothrix implexa* (Fig. 21.1)
	Ulothrix flacca (syn. *U. pseudoflacca*)
Family Ulvaceae	*Ulva lactuca* (Fig. 21.2)
	Ulva intestinalis (syn. *Enteromorpha intestinalis*) (Fig. 21.3)
	Ulva compressa (syn. *Enteromorpha compressa*)
	Ulva flexuosa (syn. *Enteromorpha flexuosa*)
	Ulva linza (syn. *Enteromorpha linza*)
	Ulva prolifera (syn. *Enteromorpha prolifera*)
Order Cladophorales	
Family Cladophoraceae	*Cladophora albida*
	Cladophora dalmatica
	Cladophora laetevirens
	Cladophora sericea
	Cladophora vagabunda
	Chaetomorpha aerea
Family Acrosiphonaceae	*Urospora penicilliformis*
Order Bryopsidales	
Fam. Bryopsidaceae	*Bryopsis plumosa*
PHAEOPHYTA	
Order Ectocarpales	
Family Ectocarpaceae	*Ectocarpus confervoides*
	Ectocarpus siliculosus
Order Scytospinales	
Family Scytosiphonaceae	*Scytosiphon lomentaria*
Order Punctariales	
Family Punctariaceae	*Punctaria latifolia*
Order Fucales	
Family Cystoseiraceae	*Cystoseira barbata* (Fig. 21.4)
RHODOPHYTA	
Order Bangiales	
Family Bangiaceae	*Porphyra leucosticta* (syn. *Pyropia leucosticta)*
	Bangia fuscopurpurea
Order Cryptonemiales	
Family Corallinaceae	*Corallina officinalis*
Order Rhodimeniales	
Family Champiaceae	*Lomentaria clavellosa*
Order Ceramiales	
Family Ceramiaceae	*Ceramium rubrum*
	Ceramium elegans
	Ceramium diaphanum
	Callithamnion corymbosum

(continued)

Table 21.2 (continued)

Family Rhodomelaceae	*Polysiphonia elongata*
Order Gigartinales	
Family Phyllophoraceae	*Phyllophora pseudoceranoides*
Order Hildenbrandiales	
Family Hildenbrandiaceae	*Hildenbrandia rubra*

Fig. 21.1 *Ulothrix implexa* (on rocky bottom -Midia)

Fig. 21.2 *Ulva lactuca* (herbarium specimen)

Compared with previously reported results, the most important change over the decades, suffered by the algal flora along the Romanian shore, is the qualitative decline (Table 21.3).

Fig. 21.3 *Ulva intestinalis (*syn. *Enteromorpha intestinalis*) (Pescărie- Constanţa)

Fig. 21.4 *Cystoseira barbata* (Mangalia)

Table 21.3 Number of algal species between 1977 and 2006, compared to present study

Phyllum	Bavaru 1977 (Bavaru 1977)	Vasiliu, 1980–1995 (Vasiliu 1996)	Sava, Bologa (2006)	Present study (2014–2016)
Chlorophyta	31	22	16	16
Phaeophyta	14	9	4	5
Rhodophyta	41	24	10	11
Total	86	55	30	32

This comparison entitle some discussion:

– the various values in number of species of macrophytes, may be due to the incertitudes created by some forms and varieties and by the consideration of microscopic forms; in the present study, microscopic macrophytes were not considered;
– because eutrophication generally favours the development of green algae, specially species of *Enteromorpha* and *Cladophora* genera, it is obvious that Chlorophyta prevails against red and brown algae, after year 2000;
– there is a dramatic decrease regarding the number of Rhodophyta, this being explained by the fact that this group is the most sensitive to pollution, even though some genera of red algae (*Ceramium*) can also develop in eutrophic waters, sometimes covering the hard substratum up to 90%.
– as for brown algae, the number of species also decreased and nowadays, only four cold season species and one perennial (*Cystoseira*) were found;
– it can be pointed out also some positive signs, that is the reappearance of species that were considered lost for many years, such as *Lomentaria clavellosa* and *Phyllophora pseudoceranoides* but unfortunately, no exact data about its location and biomass could be achieved, as the thalli, of both species were collected from the beach, teared away from the rocky bottom.

Natural factors, such as cold winters, formation of ice layers and low water temperatures can only partially explain the disappearance of many algal species, but moreover high water turbidity, eutrophication and even pollution of marine waters, lead to the reduction of specific biodiversity.

The small number of brown and red macrophytes, highlight once again the domination of the eurithermal and opportunistic green algal species along the Romanian littoral. *Cladophora* and *Ulva* species were constantly present, both on the northern and southern part of the shore.

This is understandable knowing that the green macroalgal species are characterized by a fast development cycle and abundant proliferation, especially in the warm season because of the specific environmental conditions, (high water temperature, large amount of nutrients). Furthermore, these species can use as substratum not only the hard and rocky one, represented by natural platforms or artificial constructions, but they can also grow on shells of mussels that sometimes can cover the whole surface of rocky bottoms, and also last but not the least, they can live as epiphytes on larger and harder vegetal substrate (such as the *Cystoseira* thalli).

In the cold season of the year (spring and autumn), *Urospora* and *Ulothrix* species were found both in the north and the south of the coast. This is the characteristic vegetation, that, together with red and brown stenothermic algae *Porphyra leuctosticta* (syn.*Pyropia leucosticta*), *Ectocarpus siliculosus, Scytosiphon lomentaria* is present until the water temperature increases, and becames favourable to the abundant development of green eurithermic and opportunistic species.

A comparison can be made between the northern and southern zone of our coast, that shows that in present environmental conditions, a more diverse macroalgal flora develops in the southern sector of the Romanian shore, compared with the northern part. This is due to the presence of a bigger surface of hard substratum and less polluted waters in the south of our coast (mainly 2 Mai-Vama-Veche area).

21.5 Conclusions

Knowing the fact that macroalgae are important elements in the marine ecosystem and play an important part in the development of marine life, continuous studies are absolutely necessary in order to monitor the development and evolution of macrophytobenthos diversity.

These observations confirmed: a qualitative decline after year 2000 regarding all taxonomic groups, having as consequence the uniformity of algal belts, the almost disappearance of perennial species (this fact having as consequence the disappearance of associated or epiphytic species and a non-stable equilibrium of macrophytic communities), much lower productions (compared with those of *Cystoseira* in previous years). A very important part of the study should be the continuous observation of the evolution of the physical-chemical parameters of shallow waters, that can give valuable information about the environment quality but also about the expected amelioration of the state of the marine ecosystem. In several reports on the quality of Romanian coastal waters, it can be noted an improvement, specially in what concerns the decrease of nutrients, and the reduced number of algal blooms, but even now the concentrations are higher than the ones measured before 1960–1970 (years that mark the start of the eutrophication process at our littoral).

The most important change over the decades, suffered by the algal flora in general, and red macrophytes in special, along the Romanian shore, is the qualitative decline, compensated by a quantitative richness of a small number of species from the *Ulva* and *Cladophora* genera.

Some considerations on the future measures may include: a continuous observation of the evolution of the physical-chemical parameters of shallow waters; a continuous biodiversity biomonitoring in order to enable observations of all the changes that might occur; submission of projects with all interested partners, that have to motion rapid, integrated and realistic rehabilitation programs.

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Chapter 22
Cenchrus longispinus (Hack) Fernald, One of the most Aggressive Alien Plants on the Romanian Black Sea Coast

Marius Făgăraş

Abstract *Cenchrus longispinus* (Hack) Fernald is one of the alien plants with a quick spreading on the Romanian Black Sea coast. Big populations of longspine sandbur have been recorded in Mamaia, the biggest resort on the Romanian Black Sea coast, situated near Constanța city, one of the most important harbors of the Black Sea. In some areas of Mamaia, longspine sandbur is already occupying large surfaces of the beaches and is causing discomfort to the tourists who walk barefoot on the sand. Smaller local populations and isolated specimens were recorded on the beach between Mamaia and Năvodari, in Constanta harbor, in Constanta city (in Tăbăcărie park) and on the beach of Vama Veche, a small resort close to the border with Bulgaria. In the coastal area of the Danube Delta Biosphere Reserve, longspine sandbur has not been noticed yet.

The spreading of this alien plant in the coastal area depends on humans and animals. Its spiny burs are dispersed in many ways such as clinging to the fur of animals, shoes, clothing, or car tyres. *Cenchrus longispinus* was accidentally introduced in Mamaia resort most likely by the tourists, or through the goods trade in the resort. Constanta harbor could also be a gate for the entering of this species on the Romanian seacoast. The quick increase of the sandy surfaces infested by *Cenchrus longispinus* over the past 5 years in Mamaia resort and north of Mamaia, indicates the high ability of the species to occupy new territories and the risk of its spreading along the coastal area of Romania in the neighboring countries.

Mowing the colonies with longspine sandbur and the meadows infested with this noxious weed, before the maturing of the burs is a non-polluting method for the control of this alien species.

Keywords *Cenchrus longispinus* • Invasive alien plant • Romanian Black Sea coast • Mamaia resort

M. Făgăraş (✉)
Faculty of Natural and Agricultural Sciences, Ovidius University of Constanta, 1 University Street, 900470 Constanta, Romania
e-mail: marius.fagaras@univ-ovidius.ro

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22.1 Introduction

IUCN defines invasive species as "alien species which become established in natural or semi-natural ecosystems or habitats, are an agent of change and threaten native biological diversity" (McNeely et al. 2001). The invasive alien plants are those which produce descendants, sometimes in large amounts, at considerable distance from the parental plants and cover large stretches (Richardson et al. 2000). A general pattern is that the spread of invasive plant species leads to the replacement of native species, because most invasive plants grow vigorously and form extensive patches that tolerate only very few native species (Weber 2005).

The introduction of invasive species has increased with the modern trade and travel, so that biological invasions have become a consequence of globalization that facilitates the spread of invasive non-native species. The spread of invasive alien species poses a serious threat to the conservation of natural and semi-natural habitats (Weber 2005). They change the character, form or nature of ecosystems and have a tremendous impact on the native floral communities. In the competition between invasive plants and native plants, the invaders have a superior competitive ability (Weber 2005).

Early detection and rapid assessment of invasive plants can limit the damage and this allows an efficient control of the most dangerous species. Therefore, monitoring programs are required in high risk areas or along transfer routes (Lodge et al. 2006).

The coastline has a higher proportion of alien plants compared with the inland areas (Anastasiu et al. 2011). More than 80% of all alien species reported for Dobrogea (140 taxa, according with Anastasiu and Negrean 2009) have been noticed along the coastline, especially around the Constanta and Midia harbors.

Commercial navigation is one of the biggest sources of invasive plants. The intense economic activities in the area of some maritime harbors (Constanta, Midia and Mangalia) have increased the risk of accidental introduction into Romania of some non-native invasive plants, especially south of Cape Midia, on the southern Romanian Black Sea coast. Alien species subsequently spread along the seacoast, through the transportation of goods and due to the mobility of humans and their pets. Tourists, on their clothes and shoes, as well as pets on their fur, have introduced seeds, fruits or fragments of alien species in the coastal area.

In the natural habitats of the littoral zone, invasive plants can cause the local extinction of some native species (Făgăraș and Niculescu 2015), for instance through competition for limited resources (food, light, space). The impact of some invasive species may sometimes be so profound that they can alter the structure and functioning of the coastal ecosystems (Weber 2005).

Field surveys carried out in the coastal area of Romania in the past years, have led to the identification of some alien plants which have a typical behavior for invasive species. Such a species is *Cenchrus longispinus* (longspine sandbur), an aggressive alien plant which has already become abundant on different beaches of Mamaia resort and is an element of discomfort for the tourists who walk barefoot on the beach.

22.2 Material and Methods

Invasive alien species are defined according with Richardson et al. (2000) and Weber (2005). The nomenclature of the species is in accordance with Flora Europaea (Tutin et al. 1980) and the Vascular Plants of Romania (Sârbu et al. 2013). The taxonomic affiliation of the species follows the recommendations of the Angiosperms Phylogeny Group III system (APG III 2009). Chorological data are given on the basis of the field observations and of the national and international literature (Ciocârlan et al. 2004; Sârbu et al. 2013; Verloove and Sanchez Gullon 2012; DeLissle 1963; Arianoutsou et al. 2010; Mosyakin 1995, EPPO Global Database). The nomenclature of the plant communities and of the syntaxonomic units is in accordance with Sanda et al. (2008). The phytosociological releves were accomplished in accordance with the methodology of Braun-Blanquet' school.

22.3 Results and Discussion

Cenchrus longispinus seems to be the most widespread species of the genus *Cenchrus* in the Mediterranean area (Verloove and Sanchez Gullon 2012). Native in United States, Southern Canada, Mexico, Central America and the West Indies (DeLissle 1963), the longspine sandbur is naturalized in Australia, South Africa, Iran, the Mediterranean area – in Italy, Croatia, France, Greece, Israel, Morocco (Verloove and Sanchez Gullon 2012), Western Europe – in Belgium, Central and Eastern Europe – in Hungary, Ukraine and Romania (www.eppo.int). The Adriatic Sea coast in Italy is probably the oldest centre of naturalization of *Cenchrus longispinus* in Europe. In Italy, this species has been known since 1933 from Lido del Cavallino, in Venezia province (Corbetta 1964) and is presently widely naturalized in this area (Verloove and Sanchez Gullon 2012).

In Ukraine, one of the neighboring countries of Romania, *Cenchrus longispinus* is an aggressive weed in sandy habitats in the south of the country and in ruderal habitats within the city of Dnipro. *Cenchrus longispinus* is invading the Black Sea Biosphere Reserve in Ukraine where it colonizes sandy steppes and alluvial habitats. In Hungary, the plant is recorded in open grasslands, particularly in the great Hungarian Plain (www.eppo.int).

Longspine sandbur is an annual or short lived perennial plant which belongs to *Poaceae* family, *Panicoideae* subfamily and *Paniceae* tribus (APG III 2009). It has several upright stems or creeping along the ground, often forming mats. (Fig. 22.1). Each stem and upper branch terminates in a spike with 4–20 spiny burs (Fig. 22.2). Burs consist of flower clusters enclosed in spiny bracts. The outer surfaces of the burs are covered with flattened spines, more or less pubescent, up to 6 mm long. The spines become very sharp when the burs dry. The fruits (achenes) persist in the burs. After maturing, the spiny fruits become yellow and finally light tan. Flowering takes place from July through September (www.illinoiswildflowers.info).

Fig. 22.1 General aspect of *Cenchrus longispinus*

Fig. 22.2 Spike with a lot of spiny burs

The seeds of *Cenchrus longispinus* can remain viable in the soil for up to 5 years and can germinate after a rainy period. Each plant can contain up to 1000 egg-shaped seeds (www.eppo.int).

Cenchrus longispinus usually grows on sandy soils and in recently disturbed habitats. It can also be found along roads, railways and in abandoned fields. Burs are dispersed in many ways, such as clinging to animals, shoes, clothing or car tyres. The winds are another way in which the burs disseminate in the coastal area.

Cenchrus longispinus has often been mistaken for some closely related congeners such as *Cenchrus tribuloides* or *Cenchrus spinifex*. *Cenchrus longispinus* most closely resembles *Cenchrus spinifex* and therefore these species were often confused. Sometimes these species are intermixed in the same areas (Verloove and Sanchez Gullon 2012).

Cenchrus spinifex (syn. *Cenchrus incertus*) – coast sandbur, was recorded in Romania for the first time in 1991 in Vama Veche village (Ciocârlan et al. 1991). Subsequently, it was identified in other locations from Dobrogea region – Constanța harbor, Mamaia, Jurilovca, Măcin, Jijila (Ciocârlan et al. 2004; Oprea 2005; Făgăraş and Bercu 2012) and in South-Eastern Moldavia – in Galați railway station (Sârbu et al. 2011).

The spines of *Cenchrus spinifex* are always fewer (20–30), the inner spines being distinctly flattened (up to 3 mm wide at base) and the bristle-like outer spines are nearly always missing (Verloove and Sanchez Gullon 2012). The bur of *Cenchrus longispinus* has relatively long and numerous spines (30–50), the inner ones being terete to slightly flattened at their base (at most 1 mm wide) and the outer ones, often bristle-like and relatively slender (Verloove and Sanchez Gullon 2012). Both species are aggressive and can invade sands, green spaces and disturbed habitats.

The latest detailed morphological descriptions and improved identification key of the species belonging to the genus *Cenchrus* (especially of the burs), published in 2012 by Verloove and Sanchez Gullón, have allowed the accurate identification of the species *Cenchrus longispinus* on the Romanian seacoast where it was confused in previous surveys with *Cenchrus spinifex* (Sârbu et al. 2011; Făgăraş and Bercu 2012). Therefore, first mentions of the alien species *Cenchrus longispinus* in Romania are relatively recent (Oprea et al. 2012; Sârbu et al. 2013).

In the flora of the Republic of Bulgaria, only *Cenchrus spinifex* is mentioned as invasive plant, recorded in the harbor and in the railway station of Ruse town (Petrova et al. 2013). However, some images from Bulgaria rather seem to belong to the species *Cenchrus longispinus* than to the species *Cenchrus spinifex*. Although the longspine sandbur was not recorded yet in the coastal area of Bulgaria, the risk of this species spreading from Romania along the Black Sea coast is very high.

During field surveys carried out in the Romanian coastal area, big populations of *Cenchrus longispinus* have been observed in Mamaia, the biggest resort on the Romanian Black Sea coast, situated near Constanța city, one of the most important harbors of the Black Sea. Smaller local populations and isolated specimens were recorded on the beach between Mamaia and Năvodari, in Constanta harbor, in Constanta city (in Tăbăcărie park) and on the beach of Vama Veche, close to the border with Bulgaria (Fig. 22.3).

North of Cape Midia, on the northern coast of Romania, longspine sandbur has not been recorded until now. Midia harbor, the biggest oil harbour of Romania, is interposed between the beach of Navodari and the southern beaches of the Danube Delta Biosphere Reserve (Corbu beach, Chituc sandbank), and it is a barrier for the spreading of this species toward the north (Fig. 22.3). In the coastal area of the Razelm-Sinoe lagoon complex (known as Southern Delta), the anthropogenic impact is generally low and this could be another explanation for the lack of the longspine sandbur on the beaches of the southern delta. Unfortunately, tourism and grazing in the Danube Delta are two of the risk factors for the possible future spreading of the longspine sandbur on the northern coast of Romania, protected within the Danube Delta Biosphere Reserve.

In the Danube Delta Biosphere Reserve, only *Cenchrus spinifex* is mentioned in the bibliographical sources, in Jurilovca (Ciocârlan et al. 2004) and in the area of Cape Dolojman (Doroftei et al. 2011), but not on the seacoast. Reporting by

Fig. 22.3 Spreading area of the species *Cenchrus longispinus* on the Romanian Black Sea coast

confusion with *Cenchrus longispinus* of the species *Cenchrus spinifex* in the Danube Delta is a possibility which should be considered.

Cenchrus longispinus grows in large colonies in Mamaia, in the beach area of some hotels (Sulina, Ovidiu, Tomis, Iaki, Riviera, Modern, Central, Savoy, Selena). Smaller populations of longspine sandbur were noticed north of Mamaia, in the proximity of the hotel Blue beach and of some camping sites such as: "Camping Turist", "Camping GPM" and "Camping S Mamaia". On the beach of Vama Veche (Fig. 22.3), only a small cluster of *Cenchrus longispinus* was noticed close to hotel Amphora, along the access pathway from the hotel to the beach.

In Mamaia resort and north of Mamaia, *Cenchrus longispinus* is abundant on the sand dunes (Fig. 22.4), in the ruderal areas of the beaches, around and on the terraces of the beach bars (Fig. 22.5), along the access zones to the beach (Fig. 22.6), near some camping sites or in the green spaces from the proximity of beaches (Fig.22.7). Longspine sandbur usually causes inconvenience to tourists due to its spiny burs which can injure people's hands and feet, and the mouth of pets in infested areas of the beaches.

Fig. 22.4 *C. longispinus* on the sand dunes in Mamaia resort

Fig. 22.5 *C. longispinus* on the terraces of the beach bars

Fig. 22.6 *C. longispinus* along the access zones to the beach in Mamaia

Fig. 22.7 *C. longispinus* in the green spaces in Mamaia

Longspine sandbur forms colonies or monodominant phytocoenoses in association with psammophilous, steppe or ruderal plant species, such us: *Cynodon dactylon, Bromus tectorum, Salsola kali subsp. ruthenica, Xanthium italicum, Tribulus terrestris, Corispermum nitidum, Plantago arenaria, Polygonum oxyspermum subsp. raii, Secale sylvestre, Silene conica, Atriplex tatarica, Atriplex nitens, Polygonum maritimum, Amaranthus retroflexus, Lolium perenne, Chenopodium album, Solanum nigrum* etc. (Table 22.1).

Table 22.1 Floristic composition of phytocoenoses with *Cenchrus longispinus*

Relevé number	R1	R2	R3	R4	R5	R6	R7	R8	K
Area (m2)	100	100	100	100	100	100	100	100	
Cover (%)	30	70	70	60	60	60	50	50	
Number of taxa	6	8	9	9	7	10	10	10	
Dominant taxa									
Cenchrus longispinus	2	4	4	4	3	3	2	2	V
Cakilion maritimae									
Salsola kali ssp. ruthenica	–	–	+	+	1	+	2	2	IV
Festucion valesiacae									
Cynodon dactylon	1	+	–	+	–	1	+	1	IV
Medicago falcata	–	–	–	–	–	+	–	–	I
Bassio laniflorae-Bromion tectorum									
Bromus tectorum	–	1	+	+	1	+	–	1	IV
Corispermum nitidum	–	–	–	+	–	–	1	+	II
Plantago arenaria	–	–	–	+	–	–	1	–	II
Secale sylvestre	–	–	–	–	–	1	–	+	II
Silene conica	+	+	–	–	–	–	–	–	II
Festucion vaginatae + Scabiosion ucrainicae									
Tribulus terrestris	+	–	+	–	+	–	–	–	II
Centaurea arenaria ssp. *borysthenica*	–	–	–	–	–	–	–	+	I
Alyssum hirsutum	–	–	–	+	–	–	–	–	I
Cynanchum acutum	–	–	–	–	+	–	–	–	I
Tragus racemosus	–	–	–	–	–	+	–	–	I
Conyza canadensis	–	–	–	–	–	+	–	–	I
Elymion gigantei									
Polygonum oxyspermum ssp. raii	–	+	–	–	+	+	–	–	II
Polygonum maritimum	–	–	–	–	–	–	+	–	I
Artemisia tschernieviana	–	–	–	–	–	–	+	–	I
Eryngium maritimum	–	–	–	–	–	–	–	+	I
Leymus racemosus ssp. sabulosus	–	–	–	–	–	–	–	+	I
Gypsophyla perfoliata	–	–	–	–	–	–	+	–	I
Chenopodietea									
Atriplex tatarica	–	–	+	–	–	–	–	–	I
Atriplex nitens	–	+	–	–	–	–	–	–	I
Chenopodium album	+	–	–	–	–	–	–	–	I
Solanum nigrum	–	–	–	+	–	–	–	–	I
Portulaca oleracea	–	+	–	–	–	–	–	–	I
Melilotus alba	–	–	+	–	–	–	–	–	I
Other species									
Xanthium italicum	–	–	+	+	1	1	+	1	IV
Amaranthus retroflexus	–	–	+	–	–	–	+	–	II
Lolium perenne	1	+	–	–	–	–	–	–	II
Elymus repens	–	–	+	–	–	–	–	–	I

Location of the releves: Mamaia – hotel Sulina (R1), hotel Tomis (R2), hotel Iaki (R3), hotel Central (R4), Hotel Blue Beach (R5), camping Turist (R6); North Mamaia-Năvodari: camping GPM (R7), camping S Mamaia (R8)

Regarding the syntaxonomic affinities, *Cenchrus longispinus* is accompanied mainly by plant species typical for the alliances *Cakilion maritimae* Morariu 1957, *Bassio laniflorae-Bromion tectorum* (Soó 1957) Borhidi 1996, *Festucion valesiacae* Klika 1931 and *Festucion vaginatae* Soó 1957 (Table 22.1). The plant associations *Secali sylvestris – Brometum tectorum* Hargitai 1940, *Bromo – Cynodontetum* I. Pop 1970 and *Salsolo ruthenicae – Xanthietum strumarii* Oberd. et Tx. 1950 are the most frequent plant communities in which *Cenchrus longispinus* has been noticed in Mamaia resort and north of Mamaia.

For each of the eight phytocoenoses was calculated the sum of the abundance-dominance index (AD) for all the accompanying species, as well as the value of the abundance-dominance index for *Cenchrus longispinus* (Table 22.2). The sum of the abundance-dominance index was calculated on the basis of the percentage values of the Braun Blanquet's scale for abundance-dominance: + = 0.1%, 1 = 5%, 2 = 17.5%, 3 = 37.5%, 4 = 62.5%, 5 = 87.5% (Borza and Boşcaiu 1965).

In accordance with Table 22.2, the phytocoenoses with *Cenchrus longispinus* from the central zone of Mamaia (R2–R4) are monodominant, because the value of the AD index for longspine sandbur is much higher than the sum of AD for all accompanying species. The abundance and covering of the accompanying plants is practical negligible in these releves.

In the releves from the northern side of Mamaia (R5–R6), the value of the AD index for *Cenchrus longispinus* is double than the AD index of accompanying species and the vegetation maintains the monodominat aspect.

In the camping area situated north of Mamaia resort (R7–R8), the AD of accompanying species is higher (almost double) compared with that of *Cenchrus longispinus*. In these releves, longspine sandbur is at most co-dominant with other species and it is not able to give the dominant note to the vegetation.

In the southern part of Mamaia (R1), *Cenchrus longispinus* is slightly dominant in the ruderal areas of the beaches and close to the green spaces.

Big local populations of longspine sandbur within Mamaia resort make us to consider that this species was introduced for the first time in the central zone of Mamaia, either by the tourists (by means of the spiny burs stuck to clothing, shoes, on the fur of pets) or through the transportation of goods in the resort. Regarding the provenance of the burs, it is difficult to specify the origin of the first colonizing specimens. The origin of the burs could be most probably in the Mediterranean Europe or in the neighboring countries of Romania (Ukraine, Hungary). The harbor of Constanta is another possible way for the entering of this species on the

Table 22.2 Values of the AD for the accompanying species and for *C. longispinus* (R1 = H. Sulina, R2 = H. Tomis, R3 = H. Iaki, R4 = H. Central, R5 = H. Blue beach, R6 = CampingTurist, R7 = Camping GPM, R8 = Camping S Mamaia)

Releves	R1	R2	R3	R4	R5	R6	R7	R8
$\sum$AD all species (%)	27.8	68.1	63.3	63.3	52.8	53.1	45.6	50.5
AD *C. longispinus* (%)	17.5	62.5	62.5	62.5	37.5	37.5	17.5	17.5
$\sum$AD accompanying species (%)	10.3	5.6	0.8	0.8	15.3	15.6	28.1	33

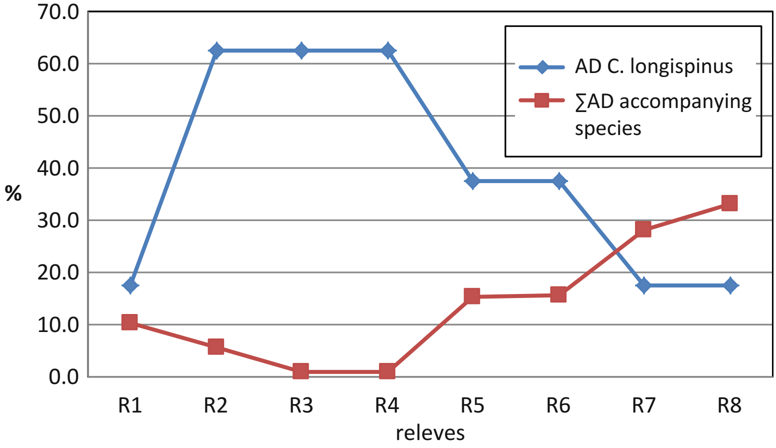

Fig. 22.8 Value of AD for *C. longispinus* and accompanying species on different beaches of Mamaia resort and north of Mamaia

Romanian seacoast, although the longspine sandbur was noticed in the harbor area only in small clusters.

Figure 22.8 highlights the high value of AD of the longspine sandbur in the central zone of Mamaia, which can be considered a center of dissemination of this species along the seacoast. The efforts for the control and eradication of the longspine sandbur have to be concentrated here first.

The chemical control of the species *Cenchrus longispinus* is effective using glyphosate, paraquat, fluazifop and other herbicides (www.eppo.int). Unfortunately, the herbicides affect both the noxious species and the natural vegetation of the beaches and is a factor of chemical pollution. The use of herbicides is not advisable on the beaches used for touristic activities (on beaches, in general) and is forbidden by the Romanian legislation (Government Emergency Ordinance no. 202/2002). Therefore, the best non-polluting methods for the control of this alien species have to be identified. Mowing the colonies with longspine sandbur on the beaches and the meadows infested with this noxious weed before the maturing of the burs is one of the clean and cheap method proposed for the control of the species *Cenchrus longispinus*.

22.4 Conclusions

Cenchrus longispinus is one of the most aggressive non-native plant species, with a quick spreading on the Romanian Black Sea coast.

The biggest populations of longspine sandbur have been recorded on different beaches in the central zone of Mamaia resort where it already causes discomfort to the tourists who walk barefoot on the sand. In other locations on the southern Romanian seacoast, only small clusters or isolated specimens of this species occur.

North of Cape Midia, in the coastal area of the Danube Delta Biosphere Reserve, *Cenchrus longispinus* has not been noticed yet.

The spreading of this noxious plant in the coastal area depends mainly on humans and animals. Its spiny burs are dispersed in many ways such as clinging to the fur of animals, to shoes, clothing, tyres of cars.

Big populations of longspine sandbur in Mamaia resort, make us consider that this species was unintentionally introduced for the first time here, either by the tourists or through the transportation of goods in the resort. Constanta harbor is another possible way for unintentional introduction of this species on the Romanian seacoast.

The spectacular increase of the sandy surfaces infested by this species over the past 5 years, demonstrates the high capacity of reproduction and spreading of the plant in favorable conditions, typical behavior for an invasive plant.

The risk of the future spreading of this species in the coastal area of the Danube Delta and also on the Bulgarian seacoast, must be taken into consideration due to increase of tourism.

The best non-polluting methods for the control of this alien species in the coastal areas of the Black Sea have to be identified.

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Chapter 23
New Equipment and Technologies Used for Rapa Whelk Harvesting at the Romanian Black Sea Coast

George Ţiganov, Cristian-Sorin Danilov, Magda Ioana Nenciu, Eugen Anton, and Aurel Năstase

Abstract An invasive species, the rapa whelk (*Rapana venosa* Valenciennes, 1846) was reported for the first time in the Black Sea in 1946 in the area of the Novorossysky Port, and, at the Romanian coast, back in 1963. Due to its excellent gourmet properties, rapa whelk has become the target of exploitation at an industrial scale for operators carrying out fishing activities at the Romanian coast. Initially, the *R. venosa* population was exploited only with the help of divers, by manual harvesting, but currently, starting with the second half of the year 2013, as a result of the authorisition in the fishing sector of the beam trawl, rapa whelck harvesting is being accomplished by both techniques: manual, by divers, and mechanised, by beam trawl. The legalization of beam trawl fisheries resulted in the implementation of changes in the structure of the fishing fleet (increasing the number of vessels with lengths greater than 12 m) and equipping these vessels with facilities/equipment adequate for a combined fishing: stationary (gillnets, goby pots, longlines etc.) and active (pelagic trawl, beam trawl etc.).

Keywords Black sea • *Rapana venosa* • Beam trawl • Gillnets • Pelagic trawl

23.1 Aims and Background

After a decreasing trend during 2002–2010, when it dropped from more than 2000 t, in 2002, to 1390–1940 t, during 2003–2006, and below 500 t during 2007–2009, reaching a minimum value in 2010/258 t, in the past years the total catches of Romanian Black Sea fisheries have recorded an increasing trend, namely 568 t, in

G. Ţiganov (✉) • A. Năstase
DDNIRD – Danube Delta National Institute for Research and Development, 165 Babadag Street, Tulcea, Romania
e-mail: gtiganov@alpha.rmri.ro; george.tiganov@ddni.ro

C.-S. Danilov • M.I. Nenciu • E. Anton
NIMRD – National Institute for Marine Research and Development "Grigore Antipa", 300 Mamaia Blvd, Constanta, Romania

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2011, 835 t, in 2012, 1711 t in 2013 and 2231 t in 2014 (more than 23.31% higher than the previous year) (NIMRD 2015). This increase of catches during the past years was not due to the fish fauna, but to the emergence of economic operators' interest in the manual and beam trawl harvesting of the rapa whelk (*Rapana venosa* Valenciennes, 1846), which increased the catches year by year, from about 65% of the total catch in 2012 to 89% in 2014 (NIMRD 2015).

The low level of overall fishery catches is mainly caused by the decrease of fishing effort (drop in the number of coastal trawlers, pound nets and, consequently, of the staff involved in fisheries) and by the influence of hydroclimatic conditions of fish populations, as well as by the increase of production costs and lack of a fishery market (Maximov and Staicu 2008; Radu et al. 2013; Danilov et al. 2016). This situation has imposed the need for the orientation of fishing activities and exploitation towards other marine living resources, such as the rapa whelk.

The gastropod *R. venosa* is an invasive species, reported for the first time in the Black Sea as *Rapana thomasiana* (Crosse 1861) around the Novorossysky Port in 1946, although it was considered that it had settled in the Pontic basin around 1930–1940 (Daskalov and Rätz 2011). This large voracious predator quickly colonized the shallow coastal areas of the Black Sea. It is a carnivorous species, feeding mainly on the bivalves *Mytilus galloprovincialis, Mya arenaria, Chione gallina*. At the Romanian coast it was first reported in 1963, at the mouths of the Danube (Gomoiu 1972), from where it has expanded rapidly to the south, becoming a common species. Today, it is common on all types of substrate (rocky, sandy, muddy) between 3 and 45 m depth (Skolka and Gomoiu 2004).

In other Black Sea countries (Turkey, for instance), the increase in rapa whelk abundance has triggered a commercial fishery since the early 1980s using dredge and hookah (divers) systems. The rapa whelk represents an important input for the economy of Turkey (Duzgunes 2001). The species was traditionally captured by dredges, but during recent years the fishery seems to be changing to the hookah systems because of its fishing efficiency and the high market value. The fishing effort is steadily increasing year after year and the average size of the individuals fished are dropping, suggesting a tendency to overexploitation of the fishery (Aydin et al. 2016).

At the Romanian coast, fishing for *R. venosa* was first performed only using divers, because this is a method which provides high selectivity of the catches and protection of habitats. However, this method has proved to be expensive due to high costs of operation (high costs with services rendered by divers and with boats used during harvesting) as compared with the size of catches taken (modest catches due to limited number of hours of immersion per day, in accordance with normative laws, and the major influence of hydroclimatic conditions). Significantly increased catches of rapa whelk and, implicitly, higher profitability of exploitation result from the use of mechanized equipment for harvesting, such as, for example, the beam trawl (not recommended to be used on rough/rocky bottoms, where there is an imminent danger of snagging and loss of the fishing gear). From these considerations, it is ideal that the two methods, with divers and beam trawl, should be practised combined.

The management of exploitation by fishing of this gasteropod has a dual function: to regulate its sustainable economic exploitation and to make use of this service as an instrument for environment control, while keeping the population *R. venosa* at a level which cannot constitute a threat to the ecosystem. Recent stock assessment of *R. venosa* made by NIMRD's experts during 2012–2014 estimated the stock at the Romanian coast of the Black Sea around 14,000 t (with a corresponding TAC value of about 5700 t/year) (NIMRD 2015).

Before the legalization of beam trawl use, *R. venosa* was harvested manually by divers, but the yield proved to be very low, for example in 2012 only 588 t were harvested, approximately 10.3% of the TAC. In 2013, after obtaining the authorisation for the use of beam trawl for harvesting rapa whelk (*Order no. 1696 of 11.07.2013, Order no. 400 of 2013, setting-up the fishing prohibition periods and areas, as well aquatic resources protection zones in 2013*), the catch increased 2.27 times compared to 2012 (from 588 t in 2012 to 1338 tonnes in 2013), the TAC being carried out at a rate of 23.5%.

23.2 Experimental

Manual harvesting activities of rapa whelk with divers are usually performed with boats with sizes up to 10 m, which are powered either by engine or with paddles (Fig. 23.1a, b).

For fishing activities using the beam trawl for *R. venosa* harvesting vessels of the fleet segments 12–18 m and 24–40 m are used, equipped with installations/equipment that make it easy to perform a combined fishing, both with passive and active gears (Fig. 23.2).

The beam trawl is a towed filtering gear in terms of construction and consists of a beam (metal pipe) supported at its ends by two metal skids and the net (collection bag consisting of cap, base and side). The traverse and feet are the backbone frame that attaches the net, which in turn is fixed to the front of the foot on a frame of resistance (rope, cable or chain), which aims to engage and direct to the concentration zone of the bag the target species (*R. venosa*) (Fig. 23.3).

During operation, the bottom of the beam trawl (base feet) is tangent to the bottom of the sea, which allows harvesting of rapana fixed on the sandy or sandy-muddy substrate. In the case of use of such tools, other organisms which live on the bottom of the sea (such as mussels, crustaceans and gobies) may also be collected by accident, for objective reasons (poor operation of the tool due to strong currents, tides, variations in speed of trawling etc.). Depending on the equipment of the vessels, they may operate with one or two beam trawls (Fig. 23.4).

Fig. 23.1 Boats used by divers for manual *R. venosa* harvesting: length of 10.5 m (**a**) and 7 m (**b**) (original)

23.3 Results and Discussion

Beam trawl fishing activities are conducted in the north of the Romanian coastline, between Cape Midia and Portita, at depths between 20 and 29 m (Fig. 23.5).

As vessels fishing for rapa whelk are not equipped with refrigeration rooms for keeping catches under the optimum conditions, the duration of fishing trips is limited to a maximum 1–3 days, depending on hydroclimatic conditions and vessel capacity.

Generally, the duration of one towing does not exceed 60 min, the horizontal opening to the mouth of the beam trawl has a constant value of 5 m and towing speed is around 2.8 knts (1.23 m/s). Under such circumstances, the area covered during one haul with a beam trawl is $A = 0.022\ km^2$. The length of the wire during towing is 2.5–3 times greater in relation with the water depth. Catches range from 60 to 100 kg to max. 1500 kg (Fig. 23.6).

Fig. 23.2 Vessel used for beam-trawl *R. venosa* harvesting: length of 15 m (**a**) and 26 m (**b**) (original)

Fig. 23.3 Beam trawl (http://slideplayer.com/slide/10598946/)

In accordance with the mesh size of the bag (2a = 110 mm), beam trawls generaly proved to be selective, the specimens retained being larger than 6 cm (the minimum size at which *R. venosa* can be retained is 5 cm).

The increase in *R. venosa* catches by means of beam trawl fishing by vessels with length greater than 12 m led by default to a few changes in the structure of the fishing fleet (an increasing number of multi-functional vessels, in the fleet segment 12–18 m). As such, while in 2013 only 4 vessels belonging to the fleet segment 12–18 m fished with beam trawl, in 2014, their number increased by 6 vessels.

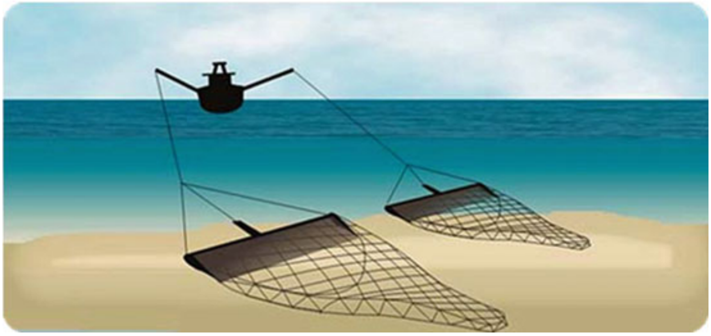

Fig. 23.4 Tangent position of the beam trawl with the seabed during fishing operation (www.ecomare.nl)

Fig. 23.5 Vessels over 12 m fishing with beam trawl

Fig. 23.6 *R*. *venosa* catches during fishing operations with beam trawl

By practising beam trawl fishing, catches of rapa whelk increased 3.3 times in 2014, as compared with the reference year 2012, and 1.5 times as compared with 2013, the TAC being achieved in a share of 34.27%.

In 2014, the greatest share in the total catch of *R. venosa* (1953 t) was held by the fleet segment 12–18 m, with a percentage of 45%, while catches taken by manual harvesting with divers represented about 20% of the total catch.

With reference to selectivity, the size of the *R. venosa* specimens retained by the bag of the beam trawl, during fishing operations, varied between 5.5–11.5 cm, which demonstrates that the mesh size of 5.5 cm ensures a good selectivity.

The rapa whelk catches achieved by vessels engaged in fishing activities along the Romanian coast are contracted by processing factories/plants and by other companies in the country and abroad, which capitalize it in the market in various forms (fresh, frozen, canned). Local restaurants have also started to include *R. venosa* in their menus.

23.4 Conclusions

Changes in the fish fauna composition of the Black Sea have primarily involved alterations in the number of individuals in specific populations and, for many species, fish populations have declined so sharply that they have lost their importance for commercial fishing. These changes reflected in the overall catches recorded, which dropped sharply during 1990s–2000s. However, starting with 2009, Romanian Black Sea fishery catches have recorded an increasing trend. Yet, this is not the consequence of a massive restoration of fish stocks or an increase of fishing effort, but the result of shifting the target species. The invasive gastropod *R. venosa* has raised the interest of economic operators due to its low exploitation costs compared to other valuable species (turbot, for instance).

During 2009–2012, rapa whelk fishing was made only by hand, by divers, being the only harvesting technique allowed by legislation. Starting with 2013, beam trawls were legalized and started to be used. Consequently, catches have increased from 1 year to the other, from approximately 1.7 t (2009) up to 1338 t (2013). Once the beam trawl use has become legal, many commercial companies in the field have shifted their business towards purchasing or manufacturing this type of gear, corresponding to their vessel capacity. As such, the number of vessels equipped with this type of gear has increased yearly, and many of them have two beam trawls towed simultaneously.

From the selectivity point of view, the gear used for rapa whelk fishing (beam trawl) does not retain immature specimens of *R. venosa* and no juvenile fish belonging to certain demersal fish species (gobies, red mullet, whiting). Rarely in catches of rapa whelk may appear some juveniles of turbot, flounder and sole, however, after emptying the bag they are released in to the sea. Yet, there is some concern on the potential effects of beam trawl on the seabed (Zengin 2006), which should be investigated in the future (Danilov et al. 2015).

Also, as a consequence of exploitation, the drop of *R. venosa* populations was acknowledged, which requires future research meant to determine the actual stock size and total allowable catch (TAC), aiming at underpinning the rapa whelk fisheries on a scientific background and to reconcile these economically valuable activities for coastal communities with nature conservation (Zaharia et al. 2012, 2014).

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Chapter 24
Some Aspects of the Biology and the Present State of the Population of *Protodorvillea kefersteini* (Polychaeta: Dorvilleidae) in the Coastal Zone of the Crimea (The Black Sea)

Vera Kopiy

Abstract In the Black Sea, 3 Genus of Dorvilleidae were reported: *Dorvillea* Parfitt, 1866; *Schistomerngos* Jumars, 1974; *Protodorvillea* Rettibone, 1961. In the Black Sea, *Protodorvillea kefersteini* (Uljanin, 1877) occurs near the shores of Bulgaria and along the Crimean coastline (Kiseleva, Polychaete worms (Polychaeta) of the Black Sea and the Sea of Azov, Kola Research Centre Press RAS, Apatity, 409 p, 2004; Marinov, Bull Zool Inst Bulg. Bulgarian Academy of Sciences 21:69–75, 1966).

The aims of the present paper are to learn more about the biology of *P. kefersteini* and to increase our knowledge about the present state of its population structures along the coast of Crimea.

Samples of macrobenthos were collected from different areas of the Crimean coastal zone (the Black Sea), during 2006–2011. More than 800 benthos samples were collected from the pseudolitoral zone by using a hand bottom-sampler with the 0.04 m^2 capture area. Pseuvdolitoral is a narrow strip of beach. It is between the top edge of the splash and riprap beach.

Polychaetes *P. kefersteini* usually inhabits coastal coarse sandy with a mixture of gravel, shell, sandy soil or sand with a mixture of mud.

The annual density fluctuations of the polychaeta *P. kefersteini* was investigated in the coastal zone of the Crimea. The number was significantly different in different regions of the Crimea coast. In different seasons of the year spatial distribution of *P. kefersteini* by depths was different. Over the entire observation time abundance of the polychaetes was greatest in the belt below the water edge. In summer and autumn polychaetes *P. kefersteini* were absent above the water edge, and in winter and spring – along the water edge.

Though population of *P. kefersteini* includes polychaetes of different body sizes. For the first time growth and development of juvenile (0.3–1.45-mm large) *P. kefersteini* were studied and the time at which chaetae first arose on the body.

V. Kopiy (✉)
The Institute of Marine Biological Research RAS, 99011 Sevastopol, Crimea, Russia
e-mail: verakopiy@gmail.com

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Conclusions. Carrying out this work, we for the first time explored distribution of the polychaeta *P. kefersteini* along the Crimean shoreline and by pseudolitoral depths. In the size structure of *P. kefersteini* population inhabiting the pseudolitoral zone 20–35-mm long worms dominate (75%); with increasing depth they occur more and more rarely, decreasing to 21% at 1 m and to 1% at 1.5 m depths. For the first time growth and development of juvenile (0.3–1.45-mm large) *P. kefersteini* were studied and the time at which chaetae first arose on the body determined; in particular, forked chaeta appeared in the individuals with 2–3-segment bodies.

Keywords Polychaeta • Dorvilleidae • *Protodorvillea kefersteini* • The Black Sea

24.1 Introduction

In the Black Sea, 3 Genus of Dorvilleidae were reported: *Dorvillea* Parfitt, 1866; *Schistomerngos* Jumars 1974; *Protodorvillea* Rettibone, 1961. *Protodorvillea kefersteini* is widespread in the Mediterranean Sea, the Atlantic coast of North America, Ireland and Argentina (Garry and Simpson 2006; Jumars 1974; Kiseleva 2004; Malthus et al. 2006; Willems et al. 2009; Zaabi et al. 2009). In the Black Sea, this species occurs near the shores of Bulgaria and along the Crimean coastline (Boltachova et al. 2002; Kiseleva 2004; Kopiy 2011; Şahin 2012; Yakubova 1930).

This species usually inhabits coastal coarse sandy with a mixture of gravel, shell, sandy soil or sand with a mixture of mud, among eelgrass roots to a depth of 20 m (Losovskaya 1977; Marinov 1966; Surugiu 2005; Vinogradov 1949). According to others, *P. kefersteinia* registered at a depth of 44 and 60 m. Protodorvillea tolerant of lack of oxygen and the presence of H_2S (Jumars 1974; Kiseleva 2004; Zaabi et al. 2009).

The aims of the present paper are to learn more about the biology of *P. kefersteinia* and to increase our knowledge about the present state of its population structures along the coast of Crimea.

24.2 Materials and Methods

Samples of macrobenthos were collected from different areas of the Crimean coastal zone (the Black Sea), during 2006–2011 (Fig. 24.1).

More than 800 benthos samples were collected from the pseudolitoral zone by using a hand bottom-sampler with the 0.04 m^2 capture area. Pseuvdolitoral is a narrow strip of beach. It is between the top edge of the splash and riprap beach. Samples were then fixed with 4% formaldehyde and transferred to the laboratory (Department of the Ecology of Benthos, IMBR). The material was washed with tap water on a sieve with 0.5 mm mesh size and then sorted according to taxonomic groups. Specimens of *P. kefersteini* were examined under a stereomicroscope.

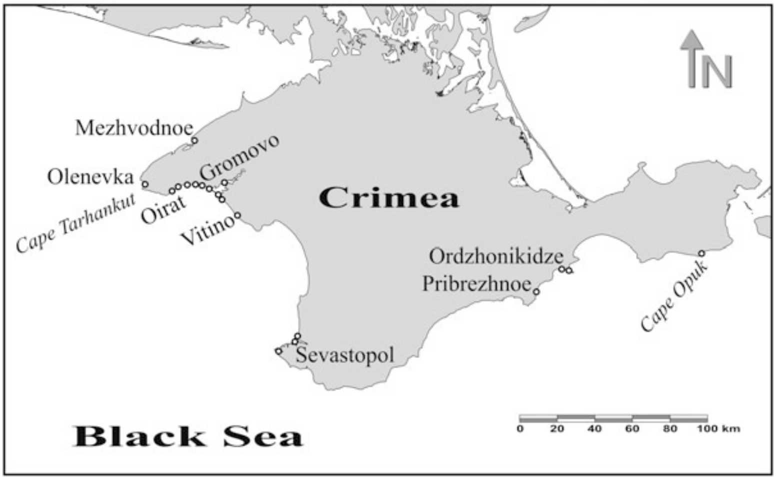

Fig. 24.1 The map of sampling locations

In Sevastopol bays samples were collected monthly for 13 months. On other areas of the Crimean coastal zone samples were taken in the summer once. Samples were taken at two sections, in duplicate.

The length of the worms was measured using an ocular micrometer. Before weighing worms dried on filter paper then weighed to the nearest 0.0005 mg.

24.3 Results

Polychaetes *P. kefersteini* have roundish-conical prostomium with two pairs of eyes. Palps with palpostyle. Antennae short, cylindrical. Pygidium with 2 long and 2 short anal cirri. Dorsal tuft of adult worms combines both simple (hair-like, or capilliform) and forked chaetae; ventral tuft is of compound chaetae. Body length to 15–20 mm, 5–10-mm long individuals prevail. Body yellowish in colour (Begun et al. 2010; Jumars 1974; Kiseleva 2004).

Adult worms from our samples were to 2–3.5 mm in length (16–28 segments), palps to 0.35–0.5 mm long (Fig. 24.2).

Carrying out this study, we observed growth and development of juvenile and young *P. kefersteini* which inhabited 1 m and 1.5 m depths (Fig. 24.3).

Individuals with the body of one segment have well-developed jaws, two pair of eyes, hair-like chaetae, two pairs of pygidial cirri. In 2–3 segment worms compound chaetae appear in addition to the capilliform. Forked chaetae arise on the first two anterior segments of 4-segment worms and on the first three segments of 5-segment polychaetes. As the body is growing on, the fourth anterior segment of 6–8-segment worms and the fifth and sixth segments of 9–10-segment individuals

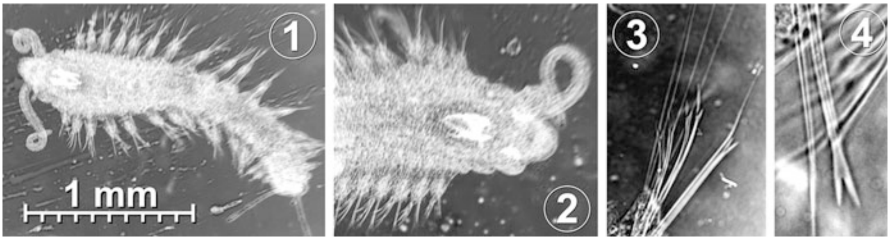

Fig. 24.2 The polychaete *P. kefersteini*: (*1* – the overall view; *2* – prostomium; *3* – compound and capilliform chaetae; *4* – forked chaeta)

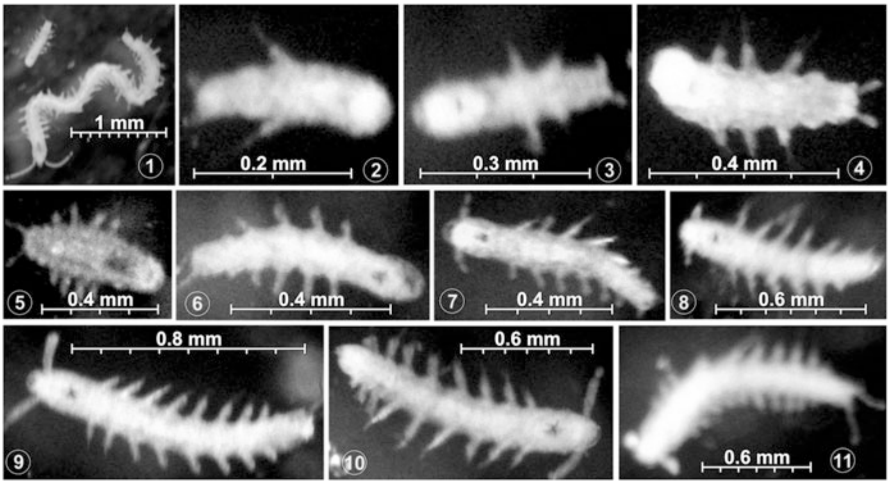

Fig. 24.3 The juvenile and young polychaetes *P. kefersteini* from the 1.5-m depth

become equipped with the forked chaetae. Prostomial appendages become visible in 6-segment worms; with increasing length of the body, the length of appendages accordingly increases.

Different size groups were differently represented; in the total abundance of *P. kefersteini* individuals having the bodies from one to 6–8-segments in length dominated (Fig. 24.4).

At the depth of 1 m the presence of worms with the bodies of one segment and of 6–8 segments were evaluated 19% and 62%, respectively, and at 1.5-m depth – 17% and 54%, respectively. Body length of these polychaetes increased from 0.3 to 1.45 mm, correspondingly (Fig. 24.5).

As the records evidence, only solitary *P. kefersteini* were present in samples taken from the pseudolitoral zone of Karadag and Lisiya bay (SE Crimea). Similarly rare this polychaete was in samples collected along the western coast of the

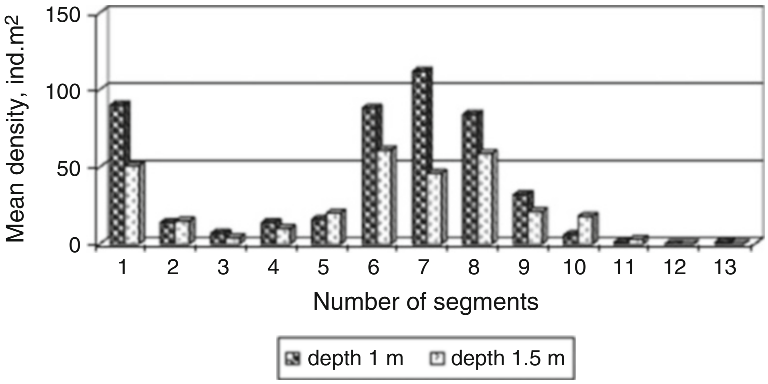

Fig. 24.4 Size ratio of juvenile polychaetes *P. kefersteini* collected at 1-m and at 1.5-m depths

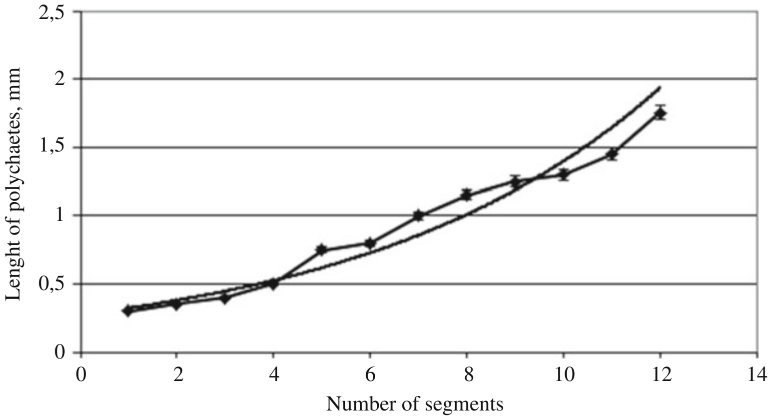

Fig. 24.5 Correlation between the length and the number of segments of *P. kefersteini*

Crimea: sporadic findings were made only on the southern spit of coastal salt Lake Donuzlav. In Kazachaya bay of Sevastopol polychaetes *P. kefersteini* were seen nearly year round whereas in Sevastopol Bay not a single one has been detected for the 13-month period of observations (Kopiy et al. 2010; Kopiy 2011).

Though population of *P. kefersteini* includes polychaetes of different body sizes, 75% of their total abundance in the water-edge zone was due to the worms longer than 20 mm. The share of large polychaetes decreased to 21% at 1-m depth and drastically dropped to 1% at 1.5-m depth (Fig. 24.6).

In different seasons of the year spatial distribution of *P. kefersteini* by depths was different (Fig. 24.7).

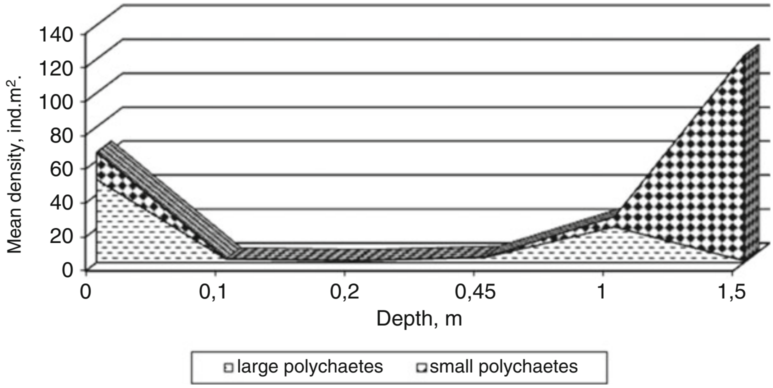

Fig. 24.6 Spatial distribution of *P. kefersteini* by depths

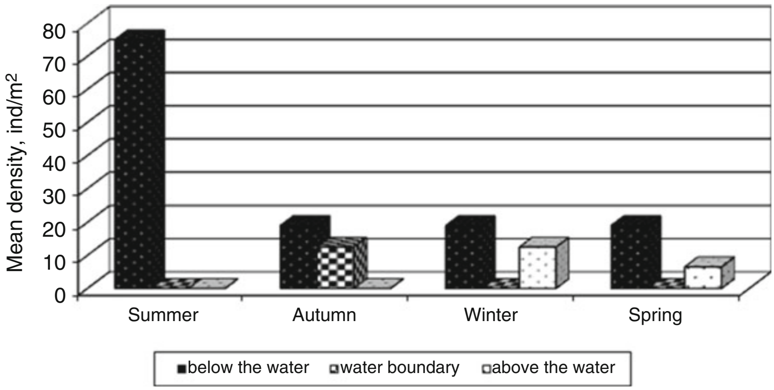

Fig. 24.7 The abundance of *P. kefersteini* in different seasons of the pseudolittoral zone

Over the entire observation time abundance of the polychaetes was greatest in the belt below the water edge. In summer and autumn polychaetes *P. kefersteini* were absent above the water edge, and in winter and spring – along the water edge.

Hypothetically, the spatial distribution depends on characteristics of the habitat. In all seasons of the year these polychaetes preferred keeping in the area below the water edge that provided them relatively stable habitat, without drastic temperature difference and dry periods.

Seasonal dynamics of the numbers and biomass of *P. kefersteini* dwelling in Kazachaya bay was analyzed using results of our investigation. For this, from June 2007 to July 2008, samples were gathered from two different sites of the bay: in one the sea bed was sandy and in the other – mixed sand and dead shell debris. In both sites *P. kefersteini* were seen almost year round. In July 2007, their reproduction in the two areas of the bay has reached peak; yet the estimate was 2.7 times larger for the sandy habitat than for the sand with shell debris (Fig. 24.8).

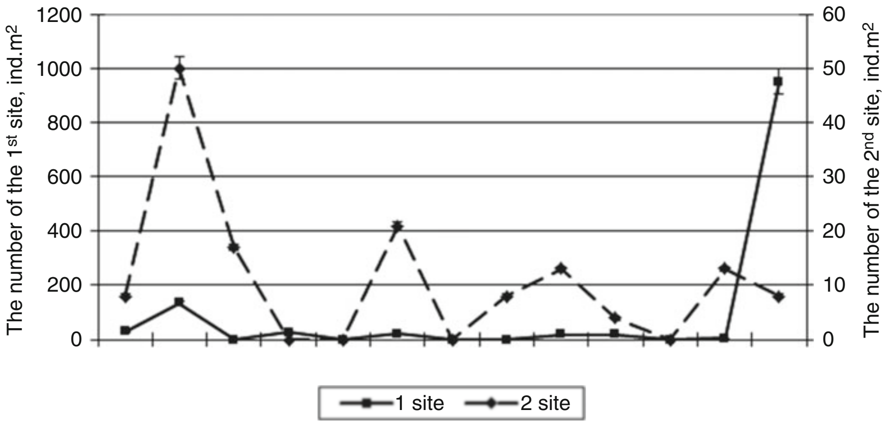

Fig. 24.8 The abundance of *P. kefersteini* in Kazachaya bay in 2006–2007

24.4 Conclusions

Carrying out this work, we for the first time explored distribution of the polychaete *P. kefersteini* along the Crimean shoreline and by pseudolitoral depths. In the size structure of *P. kefersteini* population inhabiting the pseudolitoral zone 20–35-mm long worms dominate (75%); with increasing depth they occur more and more rarely, decreasing to 21% at 1 m and to 1% at 1.5 m depths. For the first time growth and development of juvenile (0.3–1.45-mm large) *P. kefersteini* were studied and the time at which chaetae first arose on the body determined; in particular, forked chaeta appeared in the individuals with 2–3-segment bodies.

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Chapter 25
Governance and Socio Economic Implications of the Black Sea Small Scale Fisheries (Bulgaria)

Violin St. Raykov and Simona Nicheva

Abstract Characteristic of the Black Sea basin is that most of the fish occupy extensive areas, located in the exclusive zone of several riparian countries. Current Bulgarian marine fleet capacity comprises 2030 active fishing vessels. There are 1934 fishing boats less than 12 m representing 95.27% of all vessels. The majority of the fleet (84%) are below 7.9 m in length. The main fishing grounds are coastal (to 30–40 m depth) and offshore (to 100 m depths). In Bulgaria, it is more properly to put the accent on the separate regulations of the fishery, instead of its integral management. These regulations concerns in very small extension the shared fish stocks, which are exploited without control, because of the restriction measures absence. Much more different is the attitude concerning the so called "domestic fish stocks" with some elements of management applied. But even such a scheme in force remains imperfect, because of the insufficient control. Present policy regarding Bulgarian marine fishery is orientated to the production mainly, as far as the fish protein in the country is not corresponding to the demands. Indicated production orientated marine fishery, is stimulated by the lack of adequate management rules of the fishing activities. Taking into consideration the entire existent EU regulations and national legislation in force regarding the small scale fisheries, wider environmental, economic and social aspects in a balanced manner should be regarded.

Keywords Black Sea • Fishery • Regulations • Control • Management • Environment • Social aspects • Balance

V. St. Raykov (✉)
Institute of Oceanology – BAS, 40 Parvi Mai str., P.O.Box 152, 9000 Varna, Bulgaria
e-mail: vraykov@io-bas.bg

S. Nicheva
Executive Agency for Fisheries and Aquaculture, Bourgas, Bulgaria

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25.1 Introduction

Bulgaria has a coastline of 378 km length on the Black Sea and has land frontiers with Turkey, Greece, FYR of Macedonia, Serbia and Romania. Its territorial sea extends out to 12 nm and has an area of 6506 km^2, the area of the continental shelf extending from the coastline of Bulgaria is 10,886 km^2 and the country's Exclusive Economic Zone in the Black Sea is about 25,699 km^2 (Anon 2006a, b). Most of the fishing activities are carried out in territorial waters. The main ports used by fishermen for landing catches are in Baltchik, Burgas, Varna, Sozopol and Nessebar. The Bulgarian fishing fleet consists of 1994 vessels (EC fleet register, 2013) with a total of 6476 GT and 5544 kW. The fleet decreased compared to previous years 2547 in 2008 and 2546 in 2007. The Bulgarian fleet operates exclusively in the Black Sea and 95.28% of the Bulgarian vessels are <12 m length and most of the vessels use set gillnets (anchored) as their preferred gear type. The species composition of landing during the period 2001–2011 includes 36 species of fish, mollusks and crustaceans. The most important target pelagic fish species are European sprat (*Sprattus sprattus*), Mediterranean horse mackerel (*Trachurus mediterraneus*) and Anchovy (*Engraulis encrasicolus*). Demersal fish species with commercial importance are – Turbot (*Psetta maxima*), Gobies (Gobiidae) and Picked dogfish (*Squalus acanthias*). In the last decade from the molluscs increasing commercial value has the Rapa whelk (*Rapana venosa*) (Anon 2007).

The Bulgarian marine fishery takes place in the Black Sea (GFCM Fishing Sub-area 37.4 (Division 37.4.2), and Geographical Sub-area (GSA 29). The fishing opportunities are limited by the specific characteristics of the Black Sea and the exploitation of the fish resources is concentrated in the shelf area (depths under 100–110 m are anoxic). The main fishing grounds are coastal (to 30–40 m depth) and offshore (to 100 m depths). Most of the fishing activities are carried out in territorial waters (12 miles), but a significant part of fishing occurs up to 100 m depth. Open (coastal) sea fishing practices are either demersal (by bottom-set gillnets) or pelagic (by pelagic trawls), whereas in shallow waters close to the coastline small scale fisheries are based on stationary trap nets, gillnets and hook-and-line methods. Recreational fishing is also well developed. The information about fleet, operating in Bulgarian Black Sea area, is recorded in the Fishing Vessel Register (FVR), maintained by National Agency of Fisheries and Aquaculture (NAFA). Fisheries Authorizations are granted each year and every eligible gear is sealed by NAFA inspectors. The FVR contains data on registered fishing vessels including their length, gross tonnage, maximum main engine power, registration number, age of the vessel and owner, which is updated in real-time (COM 2010). Most of the fishing activities are carried-out in territorial waters. The main ports used by fishermen for landing catches are in Burgas, Varna, Baltchik, Sozopol, Nessebar and seven fishing points (Fig. 25.1a). The number of fisherman varies, as most of them are only partially engaged with such activities, since they have other professions. The biggest number of fisherman is in area of Balchik, Kavarna, Varna,

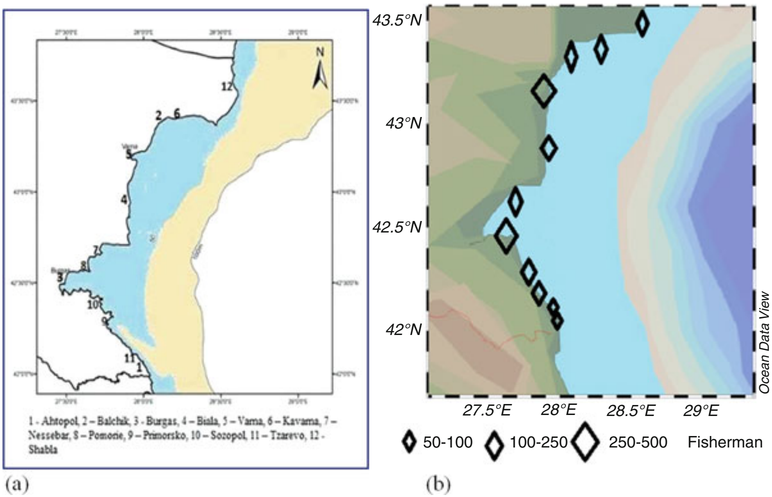


Fig. 25.1 (**a**) The landing ports (**b**) fisherman (in numbers) in Bulgarian Black Sea coast

Biala, Nessebar, Pomorie, Burgas, Sozopol, Primorsko, Kiten, Carevo, Ahtopol (Fig. 25.1b).

According to the present state of the fisheries sector, the improvement and financial suport of the reorganisation of the fishing activities, also ensuring a sustainable fishing, are required, taking into account environment protection, social development and economical welfare aspects. Romania and Bulgaria are interested in the protection of the resources and in the preservation of the customs of the fishermen communities and in their social and economical development for the stabilisation of the coastal zone. Also, both countries are interested in developing the fishery communities and their involvement in the sustainable exploitation of the marine living resources.

25.2 Description of Small-Scale Fisheries

In Black Sea, the restricted area (coastal waters and shelf until 120 m depths) where suitable conditions for life exist. Under these depths, no life forms, with exception one species *Disulfovibrio* bacteria is possible, due to Hydrogen sulphur (H_2S) anaerobic and toxic environment. In this context, the fishery is also restricted till 100–120 m depths, highly dependent on local species, with shared stocks and in less extent on migratory species, which can be fished in separate time of the year.

Everywhere in the Black Sea the fishing grounds are connected with the shelf, where the concentrations of the basic fishing resources are distributed and the routes of their migration pass. The fishing grounds of the Bulgarian sector are with small depths (up to 100–120 m.) - from Cape Kartalburun to the river Rezovo in southern direction. Fishing by active fishing gears is carried out on small fishing vessels (>12 m) in the 3-miles zone offshore (Raykov 2006). During summer (July–August), most abundant fish species in front of the Bulgarian Black Sea coast is the sprat, dwelling in the water column under the termocline (usually under 10.5 C)-under 20 m. The warm period (May–October) is the main fishing season along the entire Bulgarian coast. During this period (start in May) the spring migration of the horse mackerel (*Trachurus mediterraneus*) and Anchovy (*Engraulis encrasicolus*) occurs. The two species migrate near the shore for spawning and feeding. The second migration of the horse mackerel occurs in September–October. During these months, depending on economic reasons (fuel price) many fishing vessels are orientated for (horse mackerel) active fishing with OTM in the southern part down the city of Bourgas.

Trap nets (60 with GPS and registered) were situated along the Bulgarian coast, being in the Southern region-Bourgas to Ahtopol with highest concentration. Very low percent of the total catches belongs to the stationary pound nets. Most actively exploited demersal fish species in Bulgarian territorial waters is the turbot (with gillnets), excluding 45–60 day period of complete ban every year. Fishing free zones are those areas used as military polygons, and protected areas – e.g., regions in front of Cape Kaliakra (500 m from the coast) and marine reserve" Cockatrice" in the southern BG part. Fishery beyond the 3-mile zone till 12 miles (EEZ zone) is permitted. The most intensive fisheries of the Black Sea sprat is conducted in April till October with bottom and mid-water trawls on vessels 15–30 m long and >30 m (very small number). After 12-mile zone special permission is needed for fishing. Harvesting of Black Sea sprat is conducted during the day, when the sprat aggregations become denser and are successfully fished by trawling fishing gears. The length of Black Sea sprat in catches makes up 65–120 mm. Whiting (*Merlangius merlangus euxinus*) represents by-catch of the sprat fishery (by active fishing gears) and is not fished independently. Its agglomerations are close to the bottom, usually under 60–70 m depths. Highly migrating species like bluefish (*Pomatomus saltatrix*) and bonito (*Sarda sarda*) are being caught by passive fishing gears in the BG southern part (Sozopol, Nessebar, mostly) accidentally, during (August–October) (Raykov 2006).

(*Rapana venosa*) fishery, although forbidden with dredge and bottom trawls (most recently in 2012) allowed in special zones by beam trawls), is one of the main fishery activities with high economic value. Rapa whelk is fished on sandy bottoms. Fisheries of picked dogfish and rays (thornback ray and stingray) are conducted with baited hooks and dogfish nets all year when the hydro-meteorological conditions are suitable, most often where sprat (its main food) are concentrated. Sturgeon fishery is banned with all means in the Bulgarian Black Sea waters (Kolarov 2010).

Bulgaria has a coastline of 378 km, a continental shelf of 10,886 km^2 and an Exclusive Economic Zone in the Black Sea of about 25,699 km^2. Most of the fishing activities are carried out in territorial waters (up to 12 nm). On 31 December 2013 the Bulgarian fleet consists of 2043 vessels, operating only in the Black Sea, (Fig. 25.2) with an aggregated total of 6587 GT and 57,383 kW (COM 2010). There are 1949 fishing vessels smaller than 12 m representing approximately 95.4% of all

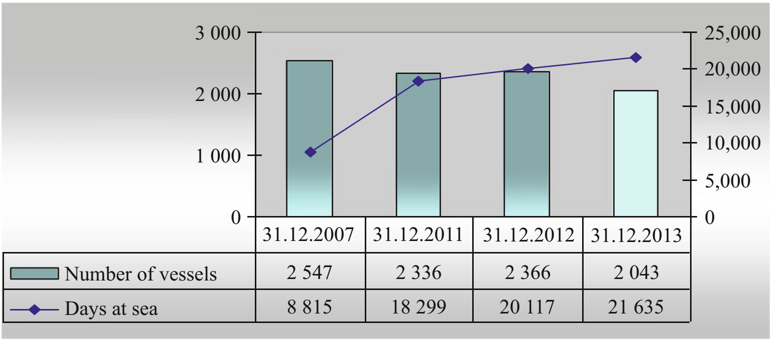


Fig. 25.2 Number of vessels and days at sea for the period 2007–2013 (NAFA 2013)

Bulgarian vessels, most of them use set gillnets (anchored) as their preferred gear type (FOMLR AG 2008) The averrage age of the Bulgarian fishing fleet is 20 years. It is evident from Fig. 25.2. (presented below), that the number of the registered vessels from accession date of Bulgaria to the EU (01/01/2007) decreased by 20% and their days at sea have risen by nearly 240%, i.e. the fisherman became more active during these time period.

Table 25.1 and Fig. 25.3 presents data on the fishing activity of vessels with same length class for 2011, 2012 and 2013.

According estimated technical and economical indicators only LAO 18–24 m shows better sustainable balance between fishing capacity and fishing opportunities.

During 2013 NAFA take effective administrative measures against the non-active fishing vessels. As a result of this measures from the register of the fishing vessels are taken out a big number of fishing vessels – total of 392 non-active fishing vessels.

The most common species caught in the Black Sea are:

pelagic fish species: European sprat (*Sprattus sprattus*), Mediterranean horse mackerel (*Trachurus mediterraneus ponticus*), Flathead mullet (*Mugil cephalus*), Atlantic bonito (*Sarda sarda*), Bluefish (*Pomatomus saltatrix*);

demersal fish species: Red mullet (*Mullus barbatus*), Piked dogfish (*Squalus acanthias*), Thornback ray (*Raja clavata*), Turbot (*Scophthalmus maximus*), Gobies nei (Gobiidae).

Bulgarian fishing fleet also exploits the rapana snail (Rapana venosa).

The total catch of fish and other aquatic organisms in the Black Sea by the Bulgarian fishing fleet is 9507,6 tons. The most of the vessels with length overall less than 12 m are mainly engaged in small-scale fishing with gillnets (anchored). Vessels with length overal more than 12 m use mainly pelagic trawl for fishing as their preferred gear type.

There are quotas for two species in Bulgaria, turbot and sprat. The Black Sea TAC (quota regime) was introduced in 2008, following the accession of Bulgaria and Romania to the European Union (EU). For the year 2013 the quotas were 43.2

Table 25.1 Fishing activity of vessels with same Loa for 2011, 2012 and 2013 (NAFA 2013)

	Loa	<6 m			6–12 m			12–18 m			18–24 m			24–40 m		
Active vessels	Year	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013
	Number	343	375	399	586	728	725	52	56	55	16	19	13	12	11	12
	Days at sea*	4409	4512	5059	8170	9391	9795	2725	3163	3489	950	1170	1290	2045	1881	2002
Inactive vessels	Number	431	429	304	883	746	534	12	14	14	10	6	10	0	0	0

*"Days at sea" as defined in Decision 2010/93/EU

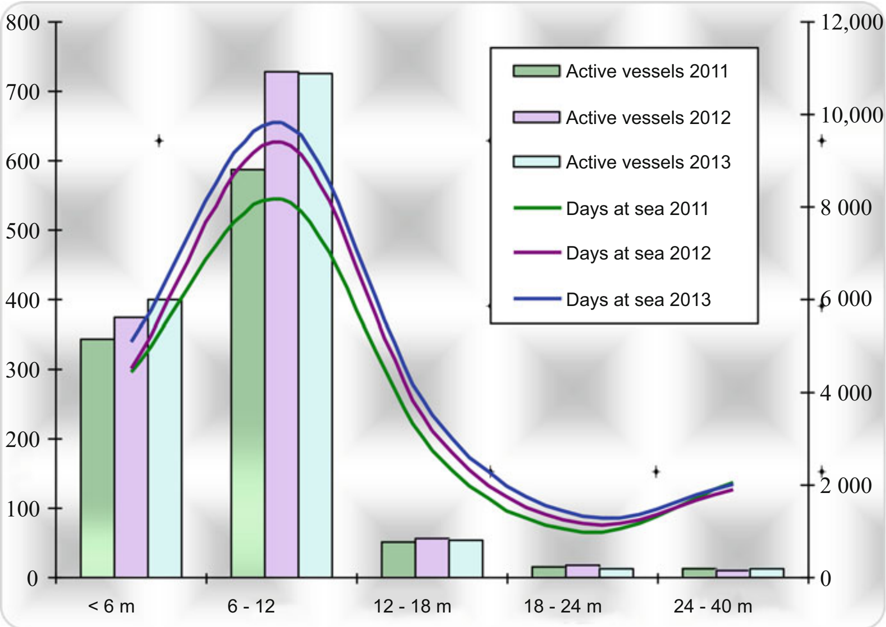


Fig. 25.3 Number of active vessels and days at sea for 2011, 2012 and 2013 (NAFA 2013)

tonnes for turbot and 8032.5 tonnes for sprat. In 2013 the turbot catches are 39.6 tonnes and sprat catches are 3784 tonnes.

Detailed information on the catches of the main fish species and other aquatic organisms in the Black Sea are presented in the tables below (Tables 25.2 and 25.3).

25.2.1 Development in Fleet

The development of the Bulgarian fishing fleet from 1st January 2007 to 31st December 2013 is presented in the Table 25.4 and Figs. 25.4 and 25.5. As it is visible, the number of registered vessels has been reduced with 20% for 2007 and from 2011 to 2013. As a whole the Bulgarian fishing fleet reduced both in tonnage and in power in all fleet segments.

25.3 Management Instruments

The catch of fish species and other aquatic animals by any kinds of bottom trawling and dredging gears and devices is banned for the whole Black Sea territorial waters except in cases of conducting of scientific investigation, for which a special

Table 25.2 Catches of main species in the Black Sea in 2013 (NAFA 2013)

Main target species	FAO code	<6 m	6–12 m	12–18 m	18–24 m	24–40 m	Total 2013
European sprat	SPR	50,024.8	77,022.3	365,390	472,831	2818.9	**3,784.2**
Mediterranean horse mackerel	HMM	18,616.9	80,480.1	78,388.9	47,209	460,682	**271,376.9**
Atlantic bonito	BON	1428.1	4702.9	0.0	0.0	0.0	**6131.0**
Bluefish	BLU	7623.3	10,729.3	9420.7	2648.0	18,603	**49,024.3**
Flathead grey mullet	MUF	5085.3	3474.5	0.0	0.0	470.0	**9029.7**
Red mullet	MUT	2038.4	19,989.2	136,262.9	62,859.5	35,625	**256,775**
Picked dogfish	DGS	4063.0	10,202	15,377.3	1139.6	165.0	**30,947.7**
Turbot	TUR	514.6	13,419.6	18,044	4800.4	2798.4	**39,577**
Rapana snail	RPN	327,927.5	1,697,259.5	1,966,266.5	764,588	62,969	**4,819,061.5**
Gobies nei	GPA	34,108	39,831.2	53.0	0.0	8.0	**74,001**
Thornback ray	RJC	25.0	13,330.7	30,321.7	10,846.2	1591.1	**56,114.7**
Silversides nei	SIL	3690.4	5445.0	0.0	500.0	160.0	**9795.4**

Table 25.3 Catches of main species in the Black Sea for the period 2007–2013 (NAFA 2013)

Main target species	FAO code	Catch in 2007	Catch in 2011	Catch in 2012	Catch in 2013
European sprat	SPR	2985	3958	2836	3784
Mediterranean horse mackerel	HMM	116	395	381	271
Atlantic bonito	BON	895.0	8257.0	96	6131.0
Bluefish	BLU	8218.9	30	551	49
Flathead grey mullet	MUF	5844.9	15	25	9029.7
Red mullet	MUT	13	177	132	257
Picked dogfish	DGS	24	82	29	31
Turbot	TUR	67	38	36	40
Rapana snail	RPN	4310	3119	3794	4819
Gobies nei	GPA	74	850	90	74
Thornback ray	RJC	36	93	69	57
Silversides nei	SIL	10	17	28	10

permission from the authorities/Fisheries and aquaculture act/is needed (Raykov 2006; NAFA 2013).

The fishermen using turbot nets are obliged to fit them with devices for radio-resound protection of dolphins. The catches of fish and other aquatic animals by any kind of pelagic trawling gears in the coastal zone is prohibited, as follows (EAFA, Fisheries and Aquaculture act):

from cape Sivriborun to the river Kamchiya outflow – in 3 mile zone
from the river Kamchiya outflow to the cape Emine – in 1 mile zone;
to the line of cape Emine – Nessebar lighthouse;
to the line of Nessebar lighthouse – village Chernomorets, south cape;
From the c. village Chernomorets to the Rezovska river outflow – in 1 mile zone.

The fisheries by any kind of fishing gears are prohibited completely in the places of flow of warm waters of Electrical Power-stations. The zones of artificial installations (farms) for mussels, considered to 100 m from their constructions are declared as fish farming waters and zones of natural reproduction of local fish species. In such zones the catch of fish and other aquatic animals by all fishing gears is prohibited.

(f) During the fishing season for horse mackerel (*Trachurus mediterraneus*), considering from 15th September to 15th November fishery banned zones: from (a) to (e), are opened only for scads fishing with allowable by catch not exceeding more than 5%.
(g) All fishery activities with all kind of gears are prohibited in the radius of 500 m area of Thermo Electrical Power Stations warm water inflow into the Varna lake system.

Table 25.4 Development of Bulgarian fishing fleet (NAFA 2013)

	31.12.2007			31.12.2011			31.12.2012			31.12.2013			Change in comparison with 2007		
	Vessels	GT	kW	Vessels	GT	kW	Vessels	GT	kW	Vessels	GT	kW	Vessels (%)	GT (%)	kW (%)
Under 6 m	845	601	6594	773	554	5987	805	582	6507	700	516	6044	−17	−14	−8
6–12 m	1595	3464	42,173	1464	3164	40	1466	3129	40	1249	2653	34	−22	−23	−19
12–18 m	66	1273	8625	62	1200	8403	64	1227	8853	60	1182	9163	−9	−7	6
18–24 m	29	1309	4819	25	1104	4119	20	890	3714	22	927	4539	−24	−29	−6
24–40 m	12	1586	3304	12	1351	3069	11	1234	2848	12	1310	3510	0	−17	6
Total	**2547**	**8233**	**65,515**	**2336**	**7373**	**61,307**	**2366**	**7061**	**61,366**	**2043**	**6587**	**57,383**	**−20**	**−20**	**−12**

Fig. 25.4 Capacity in gross tonnes 2007–2013 (NAFA 2013)

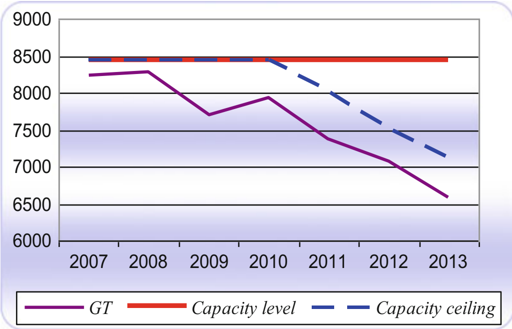
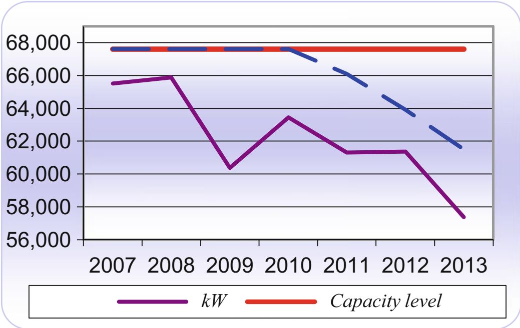


Fig. 25.5 Capacity in kW 2007–2013 (NAFA 2013)



Processing facilities are 26 situated in Varna and Burgaz mainly and one in Shoumen. Sea snail processing company, situated near Varna, produces over 1000 t/year frozen meat for export to Corean/Japan market.

Ordinance № 37/10Nov. 2008 and m.3., al.1 from FAA the mesh sizes of the gears for different fish species have been established:

During the prohibition period for turbot, commercial fishery for shad (*Alosa* spp.) should be fulfilled by one layer nets with minimum mesh size not less than 36 mm;

Commercial fishery for Gobies should be carried out with net gears with mesh size of the net not less than 22 mm;

With Council regulation 1139/2008, quota for turbot fishery (50:50, Bulgaria and Romania) has been established with minimum mesh size of the gillnets: 400 mm;

The prohibition period from 15April to 15 June. According to the same regulation, the shared quota has been established in the limits of 12,750 t in the EU waters of Black sea;

National plan for control of catch and landings of turbot in 2010 has been approved by the Ministry of Agriculture and Forestry on 10th of February, 2010.

25.3.1 Socio-economic Context

In compliance with the Operational Program “Fisheries sector development” for Programming period 2007–2013, Priority axis 1 “Measures for adaptation of the fishing fleet”, Measure 1.1. “Public aid for permanent cessation of fishing activities” the decrease of the capacity will be achieved, based on the national plans for adjustment of the fishing effort in direction of restructuring of the fishing fleet and conservation of its sustainable management, in compliance with the principles of the Common Fisheries Policy.

From the applied Table 25.5 with implementation of the scheme for withdrawing from exploitation of vessels from the Bulgarian fishing fleet is obvious, that Bulgaria makes efforts for withdrawing from exploitation of vessels in the segments 6–12 m, 12–18 m and 18–24 m. Implementation of Fishing Efforts Adjustment Plans is summarized in Table 25.5.

25.3.2 Impact on Fishing Capacity of Effort Reduction Schemes

During 2013, as a result of application of FEAP 39 fishing vessels were scrapping, respectively, suspended licenses with public aid (Table 25.6 and Fig. 25.6), 87.20% in segments 6–12 and 12–18, the priority fishing for turbot. In conclusion from the presented data it may be considered, that from adoption of FEAP the Republic of Bulgaria made the necessary effort for reduction of the pressure on the populations of the quoted species and for the restructuring of its fishing fleet. The result of permanent cessations of fishing activities of the vessels in segments between 6 and 12 m, and between 12 and 18 m is the reduction of pressure on the stocks, and from the other side is a key point for improvement of the state of the whole population (Table 25.6).

25.4 Compliance with Entry/Exit Scheme and with Level of Reference

The capacity of the Bulgarian fishing fleet on 1 January 2007: GT07 = 8448 GT and kW07 = 68,304 kW (Table 25.7).

Each entry (or increase in tonnage or engine power) in the fleet register was covered by the removal of at least the same amount of the fleet. So Bulgaria can ensure that at all times the fishing capacity of its fishing fleet in tonnage (GT) and power (kW) is equal or less than the fishing capacity at its accession date as

Table 25.5 Implementation of Fishing Efforts Adjustment Plans (FEAP) to 31/12/2013 Date of adoption of FEAP: 23.12.2010, revised: 19.10.2011, revised: 18.05.2012 (NAFA 2013)

	BG fleet 31.12.2009			in %		Implementation			%	
Fleet segments	N of vessels	KW	GT	KW (%)	GT (%)	N of vessels	KW	GT	KW (%)	GT (%)
LOA: <6	708	5462.35	507.20	−20	−20	4	19.49	2.43	−0.36	−0.48
LOA: 6 < 12	1392	37.160	2985.48	−30	−30	33	1707.957	219.26	−4.60	−7.34
LOA: 12 < 18	65	9106.23	1290.00	−30	−30	21	2143.767	344.24	−23.54	−26.69
LOA: 18 < 24	28	4773.66	1253.40	−40	−40	9	1201.92	400.56	−25.18	−31.96
LOA: 24 < 40	13	3877.50	1665.00	−40	−40	2	1029.65	431.36	−26.55	−25.91
Total	2206	60.4	7701.08			69	6102.78	1397.85	−10.11	−18.15

Source: NAFA

Table 25.6 Implementation of Fishing Efforts Adjustment Plans (FEAP) for 2013 (NAFA 2013)

Fleet segments	Implementation			%	
	Number of vessels	KW	GT	KW (%)	GT (%)
LOA: <6	4	19.49	2.43	−0.36	−0.48
LOA: 6 < 12	23	1168.14	159.81	−3.14	−5.35
LOA: 12 < 18	11	1125.727	183.47	−12.36	−14.22
LOA: 18 < 24	1	99.29	73.00	−2.08	−5.82
LOA: 24 < 40	0	0	0.00	0.00	0.00
Total	**39**	**2412.65**	**418.71**	**−4.00**	**−5.44**

Source: NAFA

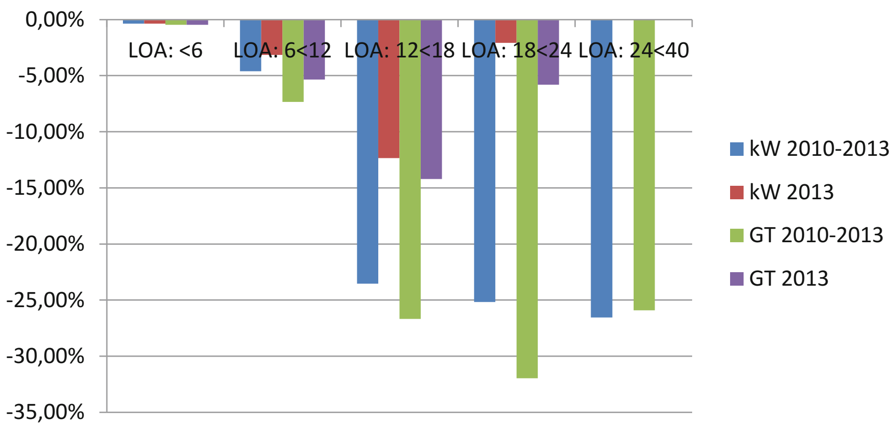


Fig. 25.6 Reduction of Bulgarian fishing fleet in kW and GT (NAFA 2013)

Table 25.7 Calculation of the baselines (GT_{07} and kW_{07}) on 01/01/2007 (NAFA 2013)

GT_{FR}	GT_1	GT_2	GT_3	GT_4	GT_{07}		kW_{FR}	kW_1	kW_2	kW_3	kW_4	kW_{07}
8147	301	0	0	0	8448		64,924	2683	0	0	0	67,607

adjusted, according to the provisions of Article 8 of Regulation (EC) 1013/2010 and Article 23 of Regulation (EC) 1380/2013 (Tables 25.8 and 25.9).

25.5 Economic Indicators

For calculating the economic indicators the used data is from questionnaires for economic statistics collected under DCF. The economic variables are recalculated for the entire fleet.

Table 25.8 Information for capacity of the vessels, which was entered/excluded from the FR for the period 2007–2013 (NAFA 2013)

Entry/Exit regime		GT							kW						
		2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013
ENTRY	Vessels' entered the FR after excluding of the vessels	3	3	86	328	217	338	583	55	50	420	3894	1412	3099	6284
	Vessels' entered the FR after the accession date based on an administrative decision	86	44	171	–	–	–	–	700	401	1582	–	–	–	–
	Total	**89**	**48**	**257**	**328**	**217**	**338**	**583**	**756**	**451**	**2002**	**3894**	**1412**	**3099**	**6284**
EXIT	Financed with public aid	–	–	–	–	442	537	419	–	–	–	–	1514	2176	2413
	Financed without public aid	2	5	830	97	344	116	640	164	85	7449	883	1932	868	7843
	Total	**2**	**5**	**830**	**97**	**785**	**653**	**1059**	**164**	**85**	**7449**	**883**	**3446**	**3044**	**10,256**

Table 25.9 Management of the entry/exit regime on 31 December 2013 (NAFA 2013)

		GT		kW	
1	Capacity of the fleet on 01/01/2007	$\mathbf{GT_{FR}}$	8147	$\mathbf{kW_{FR}}$	64,924
2	Capacity level for the application of the entry-exit regime	$\mathbf{GT_{07}}$	8448	$\mathbf{kW_{07}}$	67,607
3	Entries of vessels of more than 100 GT financed with public aid	$\mathbf{GT_{100}}$	0	$\mathbf{kW_{100}}$	0
4	Other entries or capacity increases (not included in 3 & 5)		1872		17,786
5	Increases in tonnage GT for reasons of safety	$\mathbf{GT_{S}}$	0		0
6	**Total entries (3 + 4 + 5)**		1872		17,786
7	Exits before 1/1/2007 financed with public aid	$\mathbf{GT_{a1}}$	0	$\mathbf{kW_{a}}$	0
8	Exits after 1/1/2007 financed with public aid	$\mathbf{GT_{a2}}$	1398		6103
9	Other exits (not included in 7 and 8)		2034		19,224
10	**Total exits (7 + 8 + 9)**		3432		25,327
11	Power of engines replaced with public aid conditional to power reduction		0	$\mathbf{kW_{r}}$	0
12	**Capacity of the fleet on 31/12/2013 (1 + 6–10)**	$\mathbf{GT_{t}}$	6587	$\mathbf{kW_{t}}$	57,383
13	**Fleet ceiling on 31/12/2013**		**7106**		**61,504**

Line 4 is calculated as: 4 = (12–1) + 10 – (3 + 5)
Line 13: Ceiling GT = 2–35% 3–98.5% 7–96% 8 and kW = 2–35% 3–7 – 8–20% 11

25.5.1 Return on Investment (ROI)

ROI is an indicator, which shows the return rate of the investments, made during the year. Values of ROI for segments 6–12 and 24–40 shows that extraordinary profits are being generated which contribute to net profit's values of these segments (Table 25.10).

The value of ROI for the segment 12–18 indicates that in the long term the segment is overcapitalized and therefore economically inefficient. Incomes from the activity of vessels in this segment are close in value to the cost declared.

Table 25.11. shows the values of the indicator ROI for the period 2009–2013. The results of the indicator for 2013 calculated according to Guidelines for the analysis of the balance between fishing capacity and fishing opportunities according to Art 22 of Regulation (EU) No 1380/2013 of the European Parliament and the Council on the Common Fisheries Policy (COM(2014) 545 final). Data on direct income subsidies are excluded from the calculation.

Ratio between current revenue and break-even revenue (CR/BER).

For 2013 the indicator CR/BER is calculated in the short and long term (Table 25.12.)

In the short term, the results shows that all segments are profitable and they are able to cover their costs (fixed costs, variable costs, capital costs). The indicator CR/BER for all segments is above 1. The highest value of the indicator CR/BER is for the segment 24–40. In view of the long-term viability in the calculation of CR/BER also include opportunity costs. In this case, the results for all segments are

Table 25.10 Return on investment (ROI) (NAFA 2013)

Values for 2013 year (€'000)	Fleet segment 0–6	Fleet segment 6–12	Fleet segment 12–18	Fleet segment 18–24	Fleet segment 24–40
Income from landings + other income[a]	227.5	1099.24	1370.04	702.81	1531.09
Crew costs + unpaid labour costs + fuel costs + repair & maintenance costs + other variable costs + non variable costs	161.87	618.41	1279.33	570	854.61
Net profit	65.62	480.84	90.71	132.81	676.48
Fleet capital asset value (vessel replacement value + estimated value of fishing rights)	994.98	3689.50	4759.04	1394.53	4480.35
ROI	**6.6%**	**13.03%**	**1.91%**	**9.52%**	**15.10%**
ROI- risk free long term interest rate[b]	**0.91%**	**7.37%**	**−3.78%**	**3.83%**	**9.41%**

[a]Data on direct subsidies are excluded from the calculation
[b]Average risk free long term interest rate for Bulgaria for the period 2008–2012 (source: European Central Bank) – 5.69%

Table 25.11 Return on investment (ROI) from 2009 to 2013 (NAFA 2013)

Year	Segment				
	0–6	6–12	12–18	18–24	24–40
2009	0.12	0.66	0.07	0.43	0.26
2010	0.11	0.09	0.11	−0.01	0.07
2011	0.45	0.10	−0.01	−0.06	−0.06
2012	0.04	−0.47	1.02	1.55	1.05
2013 (%)	**6.6**	**13.03**	**1.91**	**9.52**	**15.10**

closer to 0 as the lowest value of CR/BER shows a segment 12–18. This result shows that in long-term, the sector would not be profitable.

Indicator values for CR/BER for the period 2009–2013 are presented in Table 25.13. When analyzing the data should be taken into account that only the results from 2013 were obtained following the recommendations of Guidelines for the analysis of the balance between fishing capacity and fishing opportunities according to Art 22 of Regulation (EU) No 1380/2013 of the European Parliament and the Council on the Common Fisheries Policy (COM(2014) 545 final) (NAFA 2013).

Table 25.14 presents the subsidies granted to each fleet segment for the period shown.

Table 25.12 Ratio of Current revenue to Break-even revenue (CR/BR) (NAFA 2013)

Values for 2013 year (€'000)	Fleet segment 0–6	Fleet segment 6–12	Fleet segment 12–18	Fleet segment 18–24	Fleet segment 24–40
1. Current revenue (CR) = Income from landings + other income[a]	227.5	1099.24	1370.04	702.81	1531.09
2. Fixed costs = Non variable costs + depreciation	25.38	71.97	33.67	14.47	16.22
3. Variable costs = Crew costs + unpaid labour costs + energy costs + repair & maintenance costs + other variable costs	136.49	546.44	1245.66	555.53	838.39
4. BER = 2/(1–[3/1])	63.45	143.11	370.92	69.05	35.85
Cr/BER = 1/4	**3.59**	**7.68**	**3.69**	**10.18**	**42.7**
CR/BER[b]	**0.02**	**0.03**	**0.005**	**0.02**	**0.03**

[a]Data on direct subsidies are excluded from the calculation
[b]adding opportunity costs to fixed costs

Table 25.13 Ratio of Current revenue to Break-even revenue (CR/BR) from 2009 to 2013 (NAFA 2013)

	Segment				
Year	0–6	6–12	12–18	18–24	24–40
2009	2.87	8.12	5.27	9.19	14.9
2010	3.82	5.3	2.49	1.73	1.37
2011	5.29	10.08	2.21	1.16	0.64
2012	1.98	3.82	10.33	14.69	16.24
2013	**3.59**	**7.68**	**3.69**	**10.18**	**42.7**

Table 25.14 Direct subsidies from 2008 to 2013 (€'000) (NAFA 2013)

	Segment				
Year	0–6	6–12	12–18	18–24	24–40
2008–2011	[a]	[a]	[a]	[a]	[a]
2012	166.86	30.17	266.89	0.52	169.25
2013	58.68	0,06	0	15,19	0

[a]For the period 2008–2011 it has no data available

25.6 Institutional and Organizational Context of SSF: Capacity for Collective Action and Influence on Governance Arrangements

25.6.1 Summary of the Strengths and Weaknesses of the Fleet Management System

According to the national legislation all fishing vessels used for commercial fishing, should be first registered in the fishing vessels register, kept by Executive Agency "Maritime administration" (the Bulgarian authority/institution, responsible for the technical characteristics and condition of the vessels) and in the fishing vessels register, kept by the National Agency of Fisheries and Aquacultures (the Bulgarian authority/institution, responsible for the control of the fishing activities).

Basic principle in the management of the Bulgarian fleet is that the fishing capacity, being a composition of the gross tonnage and the power of the vessels may never be increased before the taking out of the same or greater fishing capacity from the Bulgarian fishing fleet.

The quantity of the catches, which is not assimilated in the Bulgarian fleet is due mainly to the small fishing vessels under 12 m, which represent over 90% of the whole Bulgarian fleet and perform small-scale fisheries alongside the coast. A big part of these vessels almost do not perform fishing activities.

In order to overcome this problem during 2012 were made corrections in the national legislation that allowed NAFA to undertake effective measures against the non-active fishing vessels. An opportunity was created for the cessation of the functions of the issued license for commercial fishing when no fishing activities are performed during two following years. The released capacity afterwards remains in favour of the state. As a result of this measures from the register of the fishing vessels during 2013 are taken out a big number of fishing vessels – total of 392 – a big part of them because of lack of fishing activities.

25.6.1.1 Weaknesses

- Limited human resources, participating in the management of the fleet in Bulgaria;
- Difficulties in the analysis of the fishing labour because of the great number of vessel, which are engaged in mixed maritime fisheries (under 12 m), namely catches of several fish species at one and the same time with different fishing gear during the year;
- Lack of automatic system for management of the fishing fleet;
- Lack of separate fish markets, the existence of small places for taking out of fish and the fact, that the bigger part of the sailing vessels are smaller than 12 m, create difficulties in the preciseness of there taking out and monitoring;
- The lack of joint researches with Romanian scientists of the stocks of sprat and turbot in international waters during 2012 and 2013 had a negative impact on the collection of more precise information for the availability of fish resources from these species in the Black sea.

25.6.1.2 Strengths

- The assimilated corrections in the national legislation, which allow to undertake effective measures against non-active fishing vessels, which are already applied;
- According to the latest corrections of the Fisheries and Aquacultures Act from 2013 our fishermen are obliged to become legal entities or sole proprietors until

the end of 2014. This will allow the collection of more precise and exhaustive economic information for the state of the fishing fleet of the Republic of Bulgaria;

– In Bulgaria there is one authority, which is responsible for the management of the resources in the fisheries regions and the fishing fleet and which provides the accurate and permanent maintenance of the fleet register, performs complete monitoring and the whole necessary information, related to the fleet management;
– The existence of administrative measures against the illegal, unreported and unregulated fisheries through the application of point system for serious infringements, where it is possible to come to the confiscation of the issued commercial fishing permit.

Plan for the improvement of the fleet management system:

With undertaken changes in the legal provisions were introduced measures, aiming to improve the fleet management system: application of points system for serious infringements in case of illegal, undeclared and unregulated fishing, as well as the definition of order for certification and check of the power of the engines of the fishing vessels, entered in the fishing vessels register.

Considering the low economic profitability of the small fishing vessels, NAFA plans to continue the taking out from the register of the non-active sailing vessels from the Bulgarian fishing vessels register, keeping to the requirements of the acting legislation and to change them with bigger sailing vessels (over 12 m), because these vessels are more active.

During 2013 is worked on the development and operation of Electronic Reporting System (ERS) (according to the requirements of (EO) 1224/2009) for the sailing vessels with length equal or greater than 12 m. This system shall facilitate the improvement of the control in the fishing regions and shall decrease the administrative burden, changing the documents on paper (the fishing logbook and the declaration of origin for the catches) and provide precise and fast recording and submitting of the information according to the requirements of Regulation

Information about the general level of keeping to the instruments of the fleet policy:

The fleet is managed through a system of commercial fishing permits, as it is laid down in the Fisheries and Aquacultures Act. The order and conditions for issuance of the commercial fishing permit, special permit and certificate for acquired right for assimilation of resource of fish and other water organisms are determined keeping to the requirements of the legislation of the European Union, according to the provision of article 17, paragraph 7 of the Fisheries and Aquacultures Act.

During 2013 were made changes in the existing secondary legal basis, based on the requirements of Regulation (EC) 1224/2009, through which were regulated the order and conditions for certification and check of the engine power of the fishing vessels.

The method for application of point system for serious infringements is applied in the national legislation through the issued by the Minister of Agriculture and

Foods Ordinance 3 from 19.02.2008 for creation of Community system for application of point system for serious infringements according to Regulation (EC) 1005/2008 of the Council from 29.09.2008 for creation of Community system for preventing, deterring and eliminating of the illegal, undeclared and regulated fishing, for amendment of regulations (EIC) 2847/93, (EC) 1936/2001 and (EC) 601/2004 and for repealing of regulations (EC) 1093/94 and (EC) 1447/1999 (NAFA 2013).

In 2013 were made efforts for additional elaboration of the Electronic Reporting System (ERS), which gives evidence for the fishing and the issuance of documents according to Regulation (EC) № 1224/2009 and Regulation (EC) № 404/2011. It is worked for the building of links for the submission of data from this system to the European Commission (NAFA 2013).

In 2013 was issued Ordinance 3 from 19.02.2013 for the application of point system for serious infringements in the context of Regulation (EC) 1005/2008 of the Council from 29.09.2008 for creation of Community system for the prevention, deterring and eliminating of the illegal, unregulated and unreported fishing, for amendment of regulations (EC) № 1093/94 and (EC) № 1447/1999.

With this ordinance is envisaged opportunity when a certain number of points are accumulated for temporary or permanent confiscation of the certificate of the rights of the masters of fishing vessels. With Ordinance 5 from 8.10.2013 issued by the minister of agriculture and food and minister of transport were determined the order and conditions for the certification and check of the engine power of the fishing vessels, entered in the fishing fleet vessels register of the Republic of Bulgaria. According to this ordinance a fishing vessel which engine power exceeds the registered power in the commercial fishing permit, may not perform fishing activities.

Also in 2013 was prolonged the term, in which the persons exercising commercial fishing should register themselves as legal entities or sole proprietors. This term was prolonged to 31.12.2014.

25.6.1.3 Indicators

In accordance with the guidelines for an improved analysis of the balance between fishing capacity and fishing opportunities, Bulgaria calculated the technical and economic indicators for 2013 as outlined below. The indicators were based on data collected under the framework of Data Collection Programme for 2013 and NAFA's information-statistical system.

Technical indicator: Ratio between days at sea and maximum days at sea

The technical indicator in relation to efforts of Bulgarian fishing fleet is based on the fishermen's obligation to fill in a fisheries logbook for every fishing trip. The assessment of the technical indicator was made according to the Guidelines and covers all active vessels (during 2013). Active vessels are licensed to fish and reported at least 1 day at sea in the reference year. Inactive vessels (due to repair of the vessel, sale and etc.) may or maybe not licensed to fish, but did not report any time in the sea and no landings during the reference year.

Some of the vessels are only used for tourism of the time and as a result there are significant differences between the fishing days of ships from one segment.

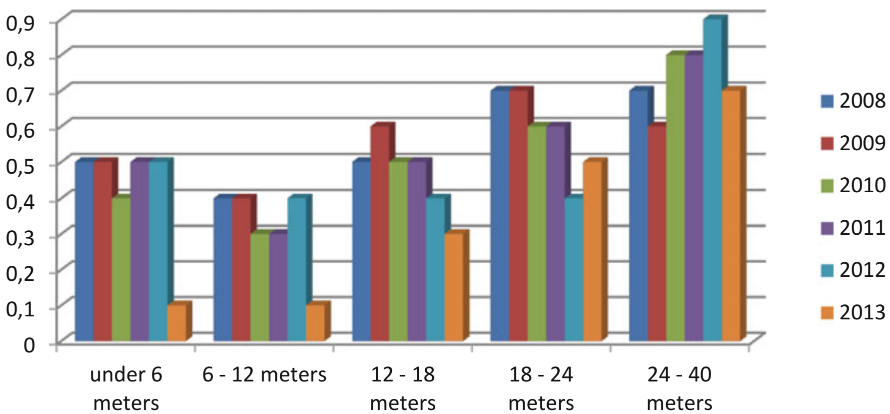
The detailed information calculated for each fleet segment (LOA) contains:

– Capacity values (kW & GT);
– Current GTdays and kWdays at sea;
– Maximum days at sea;
– Theoretical maximum days at sea;
– Technical indicator (observed);
– Technical indicator (theoretical) (Fig. 25.7).

As it is visible, the technical indicator values for 2013 calculated on the basis of the observed max indicated a decrease in most segments (LOA under 6, 6–12 m, 12–18 m and over 24–40 m) in comparison with previous years. A slight increase in capacity utilization observed on vessels with LOA 18–24 m, and exceeds the level of 2012, as a result of the increased fishermen activity despite of the difficult economic situation in the country. The lowest values of the indicator we have in two of the smaller segments (vessels under 6, 6–12 m).The fact that they constitute a significant part of the Bulgarian fleet (96%) and carried out mainly small-scale coastal fishing, explains the high fluctuation in the behaviour of fishermen.

Detailed information on the number of inactive vessels by fleet segment for 2011, 2012 and 2013 is presented in the Table 25.15.

Figure 25.8 presents the ratio between inactive vessels and the total number of fishing vessels in each fleet segment (LOA). As is apparent from the figure above the number of inactive vessels, which constituted unused capacity, decreased in the



* *The calculations are made taking into account the average technical indicator (observed)*

Fig. 25.7 Capacity utilization per segment for 2008–2013 (NAFA 2013)

Table 25.15 Proportion of inactive vessels in the total fleet for 2011, 2012 and 2013 (NAFA 2013)

Loa	<6			6–12 m			12–18 m			18–24 m			24–40 m		
Year	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013
Inactive vessels	431	429	304	883	746	534	12	14	14	10	6	10	0	0	0
Total vessels	773	805	700	1464	1466	1249	62	64	60	25	20	22	12	11	12

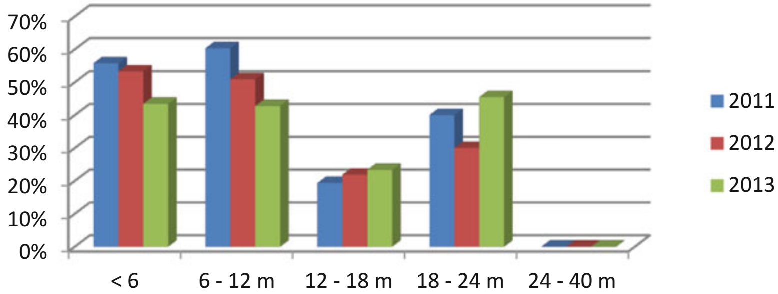


Fig. 25.8 Percentage of inactive vessels (NAFA 2013)

fleet segments under 12 m (96% of Bulgarian fleet). Analysis of the period 2008–2013 shows that the overall trend is improving or at worst maintain the level of capacity utilization, which means that Bulgaria's efforts to achieve a balance between fishing capacity and fishing opportunities are in the right direction.

25.7 Biological Indicators

The Bulgarian marine fisheries are performed in Black Sea. From the catches of fish, only the turbot species (*Scophthalmus maximus*) and sprat (*Sprattus sprattus*) are subject to quotas and are included in the National data collection program (NDCP), use and management of the data in the Fisheries sector. The applied quotas are precautionary, because it is not possible their biomass to be calculated for the whole water basin of the Black Sea. During 2013 allocated national quota at the rate of 43.2 t from turbot and sprat – 8032.5 t.

The necessary biological information for 2013 was not collected due to failure to conduct research surveys in the Bulgarian Black Sea (according implementation of NDCP). Consequently, the biological indicators – *Sustainable harvest indicator* and *Stocks-at-risk indicator* were not calculated (Table 25.16).

25.7.1 Policy Context

The term "management" usually is interpreted as series of regulatory measures introduction in the fishery practice with no doubt, positive influence on general marine living resources condition. On another hand, similar restrictions could not lead conceptually to the "management policy" if they are not systemized with clearly formulated aims and prerogatives. In the presence of introduced "closed area", "closed season", "minimum mesh size" and other regulations, altogether all

Table 25.16 Biological indicators (NAFA 2013)

National data	Year											
	2008		2009		2010		2011		2012		2013	
Species	Turbot (TUR)	Sprat (SPR)	Turbot (TUR)	Sprat (SPR)	Turbot (TUR)	Sprat (SPR)	Turbot (TUR)	Sprat (SPR)	Turbot (TUR)	Sprat (SPR)	Turbot (TUR	Sprat (SPR
Quota, t	50[a]	15,000[b]	50[a]	12,750[b]	46[a]	12,750[b]	43.2[a]	8032.5[a]	43.2[a]	8032.5[a]	43.2[a]	8032.5[a]
Total catch, t	54.7094	4300.0363	52.07445	4541.348	46.24314	4039.966	37.7468	3957.895	36.362	2836.219	39.577	3784.192
Biomass, t	1966.18[c]	32,718.3[c]	1555.94[c]	41,761.398[c]	633.120[d]	75,080.20[d]	263.29[d]	48,201.7[d]	191.48[d]	–	–	–
Recommended TAC	Average 75[c]	Average 13,746.57[c]	Average 85[c]	11,469.9[c]	Average 71.08[d]	12,500[d]	–	–	–	–	–	–
Days at sea	850	2320	763	2598	1099	2548	1320	2905	1961	2319	–	–
National F_t	0.15[c]	0.479[c]	0.15[c]	0.479[c]	0.2[d]	0.5[d]	0.2[d]	0.5[d]	0.15[d]	–	–	–
National F	0.0255	0.139	0.033	0.010	0.073	0.053	0.143	0.081	0.188		–	–
F/F_t	0.17	0.291	0.22	0.20	0.37	0.106	0.715	0.162	1.25		–	–
National F Recommended TAC	0.731	0.313	0.613	0.396	0.6505	0.323	–	–	–	–	–	–
F/F_t	4.87	0.653	4.08	0.826	3.25	0.646	–	–	–	–	–	–

NB:

[a]Bulgaria's quota according to Regulation (EU) № 1579/2007, Regulation (EU) № 1139/2008, Regulation (EU) № 1287/2009, Regulation (EU) № 1004/2010, Regulation (EU) № 1256/2010, Regulation (EU) № 5/2012, Regulation (EU) № 1261/2012

[b]EC's quota

[c]Source of data: Institute of Oceanology – BAS, Bulgaria

[d]Source of data: Institute of Oceanology – BAS, Bulgaria; National Institute for Marine Research and Development, Romania

these measures could not serve as restrictions over the yield capacity, i.e. could not influence the fishing effort.

The main priority in such a conception is a precautionary approach and responsible fishery practice in force. It could "work" properly with quota principle introduction, together with more effective system control. It is hard for the any single country to follow these regulations and it is harder for all Black Sea countries to do so, because they are exploiting resources from shared fish stocks. In order to have an effective management on these stocks (Caddy 2008), joint stock assessment is needed (Leonart 2004). On this basis the allocation of the catches for the separate Black Sea country could be established. Unfortunately, due to the different reasons, for the time being this is impossible. Hence, it could be assumed that management of the marine living resources shall be fulfilled in its incomplete form, under the national jurisdiction prescript, as they are. In the very concrete case with Bulgaria, it is more properly to put the accent on the separate regulations of the fishery, instead of its integral management. These regulations concerns in very small extension the shared fish stocks, which are exploited without control, because of the restriction measures absence. Much more different is the attitude concerning the so called "domestic fish stocks" (turbot and sprat, mainly) with some elements of management applied. But even such a scheme in force remains imperfect, because of the insufficient control. Present policy regarding Bulgarian marine fishery is orientated to the production mainly, as far as the fish protein in the country is not corresponding (adequate) to the demands. Average fish consumption from any kind of sources amounts to 3.5 kg/per capita1 to 5.5 kg/per capita (2014).[1,2] Indicated production orientated marine fishery, is stimulated by the lack of adequate management rules of the fishing activities. In the present acting fishery policy of the Bulgaria some ecological aspects exist, as endangered species conservation, included in the Red book of the Republic of Bulgaria, according to the requirements of the CITES for trade with rare and endangered species, ban of the bottom trawling activities with view benthic communities conservation and etc.

Present Fishery and Aquaculture Act (FAA) was adopted in 2001 by the Bulgarian parliament and published at State Gazette on 24th April the same year. After that the Act has been amended six times (at the time of pre-accession period for membership in EU negotiations, 2005–2006) for the adoption the legislation of the community in the scope of fisheries. With the last changes, we can assume that the Act is harmonized in the maximum possible extent with "Acquis Commmuniautare of the EU. Nevertheless, the term "management" is used only in the second chapter title, which in fact regulates (stipulates) administrative procedures for formulation and compilation of the National Program of Fishery and Aquaculture, to gain professional fishing rights and etc., but do not consider questions on management in its specific aspects. In the other chapter of the FAA (Section 4) the requirements regarding fisheries resources conservation are presented, including scientific research on the fish stock condition,

[1]National statistical Institute Statement (2002).

[2]Expert assessments.

temporary fishing prohibitions, bottom trawling ban, minimum allowable lengths, without mention fishing effort as a management instrument.

To the FAA, as secondary legislation, on ministerial level the following ordinances have been published:

- Ordinance on the rules and procedure of keeping the fishing logbook and issue and submission of landing declaration (SG, № 106 from 7.12.2001), NAFA 2001;
- Ordinance on the rules and procedure for first sale of fish and other aquatic organisms;
- Ordinance on the rules and procedure of use and maintenance of the system for monitoring and control of the fishing vessels, introducing the requirements of EC Regulation № 2244/2003;
- Ordinance on the content and procedure of keeping the registers which introduces the provisions of EC Regulation №26 from2004;
- Ordinance on the rules and procedure for recognition of organizations which produce fish and other aquatic organisms and inter-branch organizations;
- Ordinance №7/27.01.2006. In force from 17.02.2006.Conditions and order of use, support and preservation of the surveillance and control system of the fishing vessels and onboard equipment;
- FAA,2001 – Changes and additions concerning: licenses, prohibitions, regulations and control of fishing vessels and stationary fishing gears from 01.01.2007 according to obligations of Bulgaria to follow CFP of EU without transition period taken into account.

FAA, 2001 and 2012 amendments Art.35(4) The gears using electric current, shotguns, harpoons could be used for scientific purposes with special permission issued by the Minister;

Art.35(5) Minister of Agriculture and Food, on the base of Executive Director of NAFA defines the zones free of Beam-trawling;

Art.35(6) In such zones is forbidden the fishery of vessels without special surveillance equipment on board;

Art. 36(1) Additional nets are forbidden for use in case they have mesh size less than stipulated in Art.15 (1) FAA.

There is ordinance in force of Ministry of Internal Affairs which specify introduction of the obligations of the Border Police to carry out control on fishing vessels in accordance with the Fishery and Aquaculture Act (NAFA 2001).

25.8 Legal Framework

Ministry of Agriculture and Food Supply is the main governmental institution, responsible for putting in practice the FAA (NAFA 2001). In accordance with this act, responsible minister of Agriculture and Food Supply is eligible to regulate all administrative and organization procedures in the scope of fisheries, including:

- Conditions and regulations;
- Licenses system and registration;
- Regulation on obligations, functions and rights of the governmental bodiesp responsible for the law implementation;
- Secondary legislation endorsement.

In accordance with the Law, Scientific-technical and administrative council of fisheries and aquaculture has been created. Its members belong to the different scientific organizations in the sphere of fisheries. The minister is a chairman of the appointed council.

By his authority, the minister delegates the task on the operative activity, development and management of the fishery to the National Agency for Fishery and Aquaculture (NAFA).

This juridical body is on budgetary support and works under the regulations, ratified by the Ministerial council of Bulgaria. One of the main prerogatives of the National executive agency is the elaboration and execution of the National Program for Fishery and Aquaculture, appointed for 7 years period. In the frame of these activities, National agency is responsible to apply measures as regards biodiversity conservation, creation and support the information-statistical system and quota allocation – obligations of the MS under international regulations and contracts. This kind of quota allocation is not established yet, since lack of TAC's and quotas as management tools in the Black Sea region exist concerning "shared fish stocks".

In accordance with the administrative division of functions in the country, 27 branches function in subjection of NAFA. Branches in Varna, Bourgas and Dobrich are situated close to the Black Sea coast (to observe FAA implementation). NAFA is not juridical dependant on other legal norms. Some requirements under the environment protection legislation exist as regards conservation of rare and endangered species. Yearly prohibitions for commercial fishery in coastal areas (1–3 nm from the shore) are brought into line with Ministry of Environment and Water.

25.9 Looking to the Future

25.9.1 Critical Point of View

1. The reform of CFP stipulate to the member states multi-annual management of the fish stocks and ecosystem approach by application of long-term plans and guarantees for sustainability according to the precautionary approach (Raykov and Bikarska 2011). None of these restrictions has its reflection in FAA, and the turbot population has decreased significantly and the species is faced to the collapse and extinction. Simultaneously, the condition of the most of the commercial species is unknown. This would have serious lost also from economical point of view;

2. Discard ban. The changes of CFP make the member states to equip the fishing vessels in order to lead the necessary full documentation of all activities on board and fish processing, and the control over the rules for landings of the total catch;
3. Profitability of the fishing sector increase trough concessions for the fishing vessel over 12 m LOA and for all vessels with towing gears;
4. Support for the small scale fishery, near the coast;
5. Scientific base improvement. Member states must collect, support and change scientific data, regarding fish stocks and the influence of the fishery. National strategies and programmes for scientific research and innovations must be created;
6. More rights to the sector and more information for the consumers;

Problems to be solved:

1. The determination of resource abundance and productivity;
2. The relation of that productivity to rates and methods of exploitation;
3. The evaluation of management options and distribution of benefits, consistent with sustainable utilization, and the interrelationships between biological resources and variation in the physical environment;
4. How to prevent appearance of new threatened species and to halt losses of currently known threatened species and destruction of their habitats?
5. How to increase the number and improve management of protected areas with particular attention to marine protected areas? Transboundary Marine protected areas designation and management.
6. How to restore and rehabilitate damaged areas of previously high biodiversity value?

25.10 Conclusions

Present policy regarding Bulgarian marine fishery is orientated to the production mainly, as far as the fish protein in the country is not corresponding to the demands. Indicated production orientated marine fishery, is stimulated by the lack of adequate management rules of the fishing activities. Taking into consideration the entire existent EU regulations and national legislation in force regarding the small scale fisheries, wider environmental, economic and social aspects in a balanced manner should be regarded.

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Chapter 26
Conservation Status of the Fish Fauna in the Danube Delta Marine Zone

Carmen Georgeta Nicolae, Magda Ioana Nenciu, Valodia Maximov, Dana Popa, Monica Marin, and Mihaela Ivancia

Abstract Establishing the necessary measures for the conservation of habitats and species of the Marine Zone of the Danube Delta (ROSCI 0066) is based on the assessment of their current conservation status. Conservation measures instituted aimed at maintaining or restoring the species and habitats for which the site was designated, at an appropriate stage of conservation. The marine protected area ROSCI 0066 (overlapping the Danube Delta – marine zone) is a national protected area within the Natura 2000 European ecological network (Habitats Directive 92/43/EEC, Romanian Government Emergency Ordinance 57/2007, Minister's of Environment, Water and Forests Order no. 46/2016), and also has the status of Ramsar and UNESCO site. The overall assessment of the conservation status of marine species and habitats derived from Annex E (V) matrix of the EC official reporting format. It was performed for marine fish species of Community interest, whose presence is certain and confirmed by research in the marine protected area's perimeter. According to the results, *Alosa immaculata* Bennet, 1835 (Pontic shad) and *Alosa tanaica* Grimm, 1901 (Black Sea shad) have a favorable conservation status; *Huso huso* Linnaeus, 1758 (Beluga) and *Acipenser stellatus* Pallas, 1771 (Starry sturgeon) have an unfavorable conservation status – inadequate U1, while *Acipenser gueldenstaedtii* Brandt and Ratzeburg 1833 (Danube sturgeon) – unfavorable conservation status – bad U2. Assessing the conservation status of marine fish species contributes to the development of good management measures for biodiversity conservation in the marine protected area (MPA).

C.G. Nicolae • D. Popa • M. Marin
University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest 011464, Romania
e-mail: carmennicolae19@yahoo.com

M.I. Nenciu (✉) • V. Maximov
National Institute for Marine Research and Development "Grigore Antipa" Constanta, 300 Mamaia Blvd, Constanta 3 RO 900581, Romania
e-mail: magdalena.nenciu@gmail.com

M. Ivancia
"Ion Ionescu de la Brad" University of Agricultural Sciences and Veterinary Medicine of Iasi, 3 Mihail Sadoveanu Alley, Iasi 700490, Romania

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Keywords Ichthyofauna • Conservation status • Management • MPA • Sustainability

26.1 Aims and Backround

The Danube Delta is the second largest river delta in Europe. The Romanian Danube Delta Biosphere Reserve (580,000 ha) is situated northwest of the Black Sea in Eastern Europe. The area was created to conserve its diversity, both biological and cultural (Navodaru et al. 2008). It has a triple international conservation designation: UNESCO World Heritage Sites, Biosphere Reserve since 1990 and Ramsar site due to its importance for migratory birds. At EU level, the Danube Delta is recognized as part of Natura 2000 network for the great diversity of birds listed on the Birds Directive, as well as for the habitats and species listed on the annexes of Habitats Directive. The following Natura 2000 sites are overlapping the area: ROSPA 0031 Danube Delta and Razelm – Sinoie Lagoon System, ROSPA 0076 Black Sea, ROSCI 0065 Danube Delta, and ROSCI 0066 Danube Delta – marine zone.

The latter protected site, ROSCI 0066 Danube Delta – marine zone, is the focus of this research, and corresponds to the geographical unit coastal zone of the Black Sea, from the outflows of the Danube – Chilia Branch (north) down to Cape Midia (south), up to the 40 m isoline to the east (Minister's of Environment, Water and Forests Order no. 46/2016).

The overall evaluation of the conservation status of marine species and habitats in the analysed site derived from Annex E (V) matrix of the European Commission official reporting format. This paper presents the results for marine fish species of Community interest, whose presence is certain and confirmed by research in the MPA perimeter (Table 26.1).

Given the particular conditions of the Danube Delta marine zone, the fish fauna is highly diversified, compared to the other MPAs located along the Romanian coast, 70 fish species being identified. This site is important both for migrant species (shads and sturgeons), which use it during their passage to/from the Danube and for all marine fishes, being the main spawning and foraging area (Nicolae et al. 2014) The five Community importance fish species inventoried (two shads and three sturgeons) are briefly described below.

Family Clupeidae

Pontic shad – *Alosa immaculata* (Bennett, 1835) (Fig. 26.1)

Table 26.1 Marine fish species inventoried in the Danube Delta – marine zone (ROSCI0066)

Scientific name	Habitats Directive Annex/GEO 57/2007	Population size	Occurrence in the biogeographic region according to MO no. 2387/2011 (amending MO 1964/2007)	Certain presence based on field inventory
Order Clupeiformes, Family Clupeidae				
Alosa immaculata (Pontic shad)	Annex II, V/Annex 3, 5a	X	PON, MBLS	YES
Alosa tanaica (Black Sea shad)	Annex II, V/Annex 3, 5a	X	PON, MBLS	YES
Alosa maeotica (Azov shad)	Annex II, V/Annex 5a	X	Not mentioned	Uncertain[a]
Order Acipenseriformes, Family Acipenseridae				
Acipenser sturio (Sturgeon)	Annex II, IV/Annex 5[a]	X	PON – Extinct	NO
All species:	Annex V/Annex 5a	X	Not mentioned	YES
Huso huso (Beluga)				
Acipenser gueldenstaedtii (Danube sturgeon)				YES
Acipenser stellatus (Starry sturgeon)				YES
Acipenser nudiventris (Fringebarbel sturgeon)				Uncertain[b]
Acipenser ruthenus (Sterlet sturgeon)				Uncertain[b]

[a]The Azov shad (*A. maeotica*) has not been reported in the lagoons and coastal lakes in the past 50 years, its last reporting dating back to 1968, in Lake Razelm. Thus, records of *A. maeotica* in Romanian fishery statistics should be reconsidered
[b]Occurrence uncertain within the boundaries of ROSCI 0066 and not confirmed by field research or historical data

Fig. 26.1 Pontic shad – *Alosa immaculata* (Photo NIMRD)

Synonyms

Caspialosa pontica Eichwald, 1838
Clupea eichwaldi Grimm, 1901
Alosa pontica Antipa, 1906
Caspialosa pontica hypselocephala Isachenko, 1925
Alosa kessleri pontica Svetovidov, 1952
Alosa (Caspialosa) pontica Banarascu 1964

Distribution A Ponto-Caspian relic, this fish is often encountered in the western part of the Black Sea. For spawning, it migrates into the Danube and Dniester. The specimens east of the Dniester, which go up the Dnieper for spawning, are considered by Pavlov (1953) a distinct geographical breed (*Alosa pontica borysthenis*), a little studied subspecies, similarly to the specimens in the Azov Sea and Don river (Navodaru and Maximov 2014). Pontic shads winter at great distances from the shore.

Sizes Maximum 50 cm; common 15–34 cm.

Biology and Ecology Marine gregarious species, the Pontic shad performs long migrations (currently up to the Iron Gates II Dam on the Danube) (Radu et al. 2011), winters in the sea and spawns in rivers. It spends winters at great distances from the shore, off Ukrainian coasts. The spawning migration occurs from south to north, along the Bulgarian and Romanian coasts, up to the Danube mouth, and going up the river. Migration starts in spring (late February, early March), at water temperatures of 4–5 °C, reaching the peak in April (at 9–13 °C) and sometimes last until August (22 °C). Spawning takes place in the Danube, upstream of km 180 (between Calarasi and Braila, but shads can reach up to the Iron Gates II Dam). After spawning, adult Pontic shads return to the sea, at relatively great depth, beyond 55 m. The newly hatched fingerlings flow with the stream towards the sea, remaining for a long time off the river mouth. Pontic shad mainly feeds on fish, which make up to 70–75% of its diet (anchovies, other shads, sprat – in the sea, and Cyprinids – in rivers). The rest comprises crustaceans – *Crangon*, *Upogebia, Idothea* – and gammarids (Zaharia et al. 2013).

Fishery Pontic shad is fished using pound nets, shad gillnets and beach seines (Radu et al. 2011).

Commercial Importance High value as food source, with very tasty meat. Pontic shad is marketed fresh, salted, smoked and canned (Navodaru and Maximov 2014).

Black Sea shad – *Alosa tanaica* (Grimm, 1901) (Fig. 26.2)

Synonyms

Clupea caspia Eichwald, 1938
Alosa caspia Eichwald, 1938
Clupea tanaica Grimm, 1901
Alosa nordmanni Antipa, 1906
Clupea macedonica Vinciquerra, 1921
Caspialosa knipowitscha Ilyin, 1927
Caspialosa caspia persica Il'in, 1927
Alosa bulgarica Drensky, 1934
Caspialosa tanaica palaeostomi Sadowsky, 1934
Alosa alosa bulgarica Svetovidov, 1952
Caspialosa caspia salina Svetovidov, 1952
Alosa alosa macedonica Svetovidov, 1952

Distribution Black Sea shad is widely distributed in the western part of the Black Sea, inhabiting the Romanian, Bulgarian, Russian, Ukrainian and Anatolyan coasts. In the Danube, it is encountered up to Iron Gates II; in the Dnieper, up to the Rapids, and at the Dniester's outfalls. It also occurs in the Sea of Azov and the Caspian Sea, often migrating in the Danube, Dniester and Dnieper (Navodaru and Maximov 2014).

Sizes Maximum 23 cm; common 9 cm–18 cm.

Biology and Ecology A euryhaline species, Black Sea shad winters in the Sea. It occurs in spring in the coastal area, in mixed shoals with the other related species, at a water temperature of 6 °C. Some of the individuals go up the Danube, the other remain at the outfalls. Spawning takes place in late April – early June. The retreat of fingerlings and adults into the sea occurs during August–September (Zaharia et al. 2013).

Fishery Black Sea shad is fished using pound nets, shad gillnets, beach seines and mid-water trawl (Radu et al. 2011).

Fig. 26.2 Black Sea shad – *Alosa tanaica* (Photo NIMRD)

Commercial Importance Tasty meat, comparable to the Pontic shad. It is marketed fresh, salted and smoked.

Family *Acipenseridae*

In the Black Sea, the family *Acipenseridae* is represented by two genera: *Huso* and *Acipenser*. While species in the genus *Huso* have a large mouth shaped as a crescent moon, occupying almost the entire width of the lower surface of the head, species in the genus *Acipenser* have a suitably large transversal mouth, occupying only part of the lower surface of the head. The vast majority of species, subspecies and ecological or intraspecific forms of sturgeons are characterised by migratory life. Sturgeon migration is carried on long distances along the seabed (Maximov et al. 2014).

In the marine zone of the Romanian Black Sea coast, three species of the family *Acipenseridae* were documented: beluga (*Huso huso*), Danube sturgeon (*Acipenser guldenstaedtii*) and starry sturgeon (*Acipenser stellatus*). Monitoring was also performed for *Acipenser sturio* (European sea sturgeon), but no individual was reported.

Genus *Huso*

Beluga – *Huso huso* (Linnaeus, 1758) (Fig. 26.3)

Synonyms

Acipenser huso Linnaeus, 1758
Huso huso Berg, 1904
Huso ichthyocolla Bonaparte, 1846
Acipenser vallisnerii Molin, 1853
Huso huso ponticus Salnikov and Maleatzky, 1934

Distribution Marine anadromous species, distributed in the Black, Caspian and Adriatic Seas and the rivers that flow into them. Beluga is frequently encountered in

Fig. 26.3 Beluga – *Huso huso* (Photo NIMRD)

the north-western Black Sea and all over the Romanian coast (Paraschiv et al. 2006).

Sizes The largest sturgeon in Romanian waters. Usual size 4–6 m and 100–250 kg. Maximum 9 m (Maximov and Zaharia 2010).

Biology and Ecology Being a marine anadromous species, the beluga lives solitary and only in winter it forms larger groups. Migration into the Danube starts in January, when there is an early spring, and late March, when there is a late spring, at a water temperature of 4–5 °C. The highest intensity of spring migration is reached in March or April; in June, migration ceases and resumes in autumn, reaching the peak in October–November, after which it stops.

The existence of two migration periods made some authors assume the existence of two sympatric breeds, the spring and autumn ones, while others believe that specimens migrating in spring are older and their gonads started maturing in the sea; females migrating in spring have stage IV gonads, while those migrating in autumn usually have gonads in stage III (Zaharia 2013).

Gonad maturation in young specimens occurs in the river during winter. Spawning takes place for all individuals in spring, from April until mid-June, with a peak in May; the optimal temperature for spawning is around 15–17 °C.

Belugas reach sexual maturity at 12–14 years (males) and 14–16 years (females). The breeding grounds are located at 4–20 m water depth, on rocky or rough bottoms, with crevices that shelter the eggs and hatchlings against predation by gobies. After spawning in the river, belugas return to the sea, where they disperse, living on rocky bottoms at 50–70 m depth (sometimes beyond 100 m). Fingerlings slowly travel towards the sea, along the river bottom, halting in various sites with proper conditions, where large sturgeon fingerlings agglomerations are found. The retreat into the sea occurs in July–September.

Initially, juveniles remain in the brackish waters off the Danube mouths and only later travel to deeper waters, spreading across the entire Romanian continental shelf. During their time in the Danube, beluga fingerlings mainly feed on gammarids, other crustaceans and insect larvae. In the sea, mysidaceans and lalaemonids are dominant.

Specimens larger than 20 cm start feeding of fish. Adult belugas feed mainly on fish (80%), in the Danube on Cyprinds and in the sea on gobies, red-mullet, turbot, anchovies, crustaceans (*Crangon*), mollusks (*Modiola)* and algae. Feeding is very weak in winter. Belugas are the most long-lived sturgeon species, usually living up to 30–60 years, but they can reach 100 (Radu et al. 2012).

Fishery Belugas are fished using sturgeon hooked lines and other stationary fishing gears and, incidentally, using the trawl. Currently, in Romania there is a ban on commercial beluga fishery until 2020, confirmed by the annual Prohibition Orders (currently Order no. 154/2016).

Commercial Importance The beluga is the most valuable sturgeon species, its meat being extremely tasty (fresh, refrigerated, frozen, salted, smoked, canned). Its eggs (caviar) are highly valuated, being marketed fresh or salted (Maximov et al. 2014).

Genus *Acipenser*

Danube sturgeon – *Acipenser gueldenstaedtii* (Brandt and Ratzeburg 1833) (Fig. 26.4)

Synonyms

Acipenser güldenstadtii Berg, 1911
Acipenser güldenstadtii var.colchica V. Marti, 1940
Acipenser güldenstadtii colchicus Berg, 1948

Distribution This species is abundant in the Black and Azov Seas, also occurring in the Caspian Sea, but it is absent from the Mediterranean Sea. Being a migrant species, Danube sturgeon swims up the rivers which flow into the above mentioned sea basins (Paraschiv et al. 2006).

Biology and Ecology Danube sturgeon is a marine benthic species, which migrates into rivers. Spring migration begins after the beluga's and lasts from February–March until August–September/November. Unlike the beluga, in autumn there is a larger number of young individuals whose gonads are not yet mature and accomplish this process in the Danube. Some isolated individuals migrate in between the two proper migration periods. Similarly to the beluga, the young specimens which migrate in autumn do not display a special biology, but are simply younger individuals. Sexual maturity is reached at 8–12 years (males) and 13–15 years (females). Danube sturgeons live up to 40–50 years. The spawning period and grounds are the same as for the beluga, thus hybridization often occurs. After spawning, adults return into the sea, inhabiting at great depths, 60–70 m, along turbot and thornback ray. Fingerlings slowly swim towards the sea and mix with other sturgeon species. Part of the juveniles remain in the Lower Danube until reaching 1–2 years of age. Danube sturgeon fingerlings prefer feeding on small oligochaete worms, while adults feed mainly on

Fig. 26.4 Danube sturgeon – *Acipenser gueldenstaedtii* (Photo NIMRD)

mollusks (*Nassa, Cardium, Mactra*), crustaceans (*Portunus arcuatus*) and less on fish. In the Danube, Danube sturgeons feed on ephemeroptera (*Palingenia, Polymitarcis*) and other insect larvae, crustaceans and fish. Danube sturgeon has a slow growth rhythm, reaching at 20 years of age 170 cm and 35 kg (Maximov and Zaharia 2010).

Fishery Danube sturgeons are fished with hooked lines, gillnets, pound nets and bottom trawls (Maximov et al. 2014). Currently, in Romania there is a ban on commercial Danube sturgeon fishery until 2020, confirmed by the annual Prohibition Orders (currently Order no. 154/2016).

Commercial Importance After the sterlet, Danube sturgeon has the tastiest meat (16% fats) and is marketed fresh, refrigerated, frozen, salted, smoked, canned. Danube sturgeon caviar is consumed fresh or salted (Radu et al. 2012).

Starry sturgeon – *Acipenser stellatus* (Pallas, 1771) (Fig. 26.5)

Synonyms

Acipenser stellatus stellatus Pallas, 1771
Acipenser helops Pallas, 1811
Acipenser stellatus iliricus Brusina, 1902

Distribution Anadromous migrant species, the starry sturgeon is distributed in the Black Sea, Azov Sea, northern Caspian Sea and their tributaries. It was also reported in the Adriatic Sea (Paraschiv et al. 2006).

Biology and Ecology Starry sturgeons are a pelago-benthic species, regularly swimming towards the surface at night in search of food. They spend most of their life in the sea, at smaller depths compared to belugas and Danube sturgeons, often coming near the coast in summer and returning back to 80–100 m in autumn. Young specimens are encountered in large numbers close to the shoreline, especially off the Danube mouths and Lake Razelm. Spring migration into the Danube begins after the beluga and Danube sturgeon, in April or May, at a water temperature of 8–10 °C. The second migration period sometimes starts in June, usually in

Fig. 26.5 Starry sturgeon – *Acipenser stellatus* (Photo NIMRD)

August, and lasts until September–October, being more intensive than the first. Specimens migrating in summer-autumn have non-maturated gonads, while spring migrants are already able to spawn. Starry sturgeons reach sexual maturity at 5 years (males) and 7 years (females). Spawning occurs in April and May, at water temperatures of 8–15 °C, having the same spawning grounds as the beluga and Danube sturgeon. Fingerlings swim to the sea partly in July–August, partly in September, forming agglomerations on the way. Some juveniles remain in the Lower Danube until reaching 2 years of age. Large agglomerations of starry sturgeon juveniles form off the Danube mouths. Fingerlings feed on chironomid, tricopter and ephemerid larvae, crustaceans. As they grow, juveniles start feeding on mollusks. Adults feed on mollusks, crustaceans and fish. Growth rhythm varies from one river to another. Thus, the best growth is recorded by starry sturgeons migrating in the Don River (1 year – 30 cm, 2 years – 60 cm, 4 years – 80 cm, 10 years – 120 cm) (Maximov and Zaharia 2010)

Fishery Starry sturgeons are caught with hooked lines, gillnets, pound nets and bottom trawl. Currently, in Romania there is a ban on commercial starry sturgeon fishery until 2020, confirmed by the annual Prohibition Orders (currently Order no. 154/2016).

Commercial Importance The meat is tasty, but not comparable to Danube sturgeon. It is marketed fresh, refrigerated, frozen, salted, smoked or canned, and eggs are eaten fresh or salted.

26.2 Experimental

The general assessment of the conservation status of the five target species is derived from Annex E of the official reporting format. The results of assessing the “Favourable Conservation Status ”(FCS) are given using the four available categories: **Favourable (FV), Unfavourable-Inadequate (U1), Unfavourable-Bad (U2)** and **Unknown (XX)**. For graphical representation, each class is colour coded, green for Favourable, amber for Unfavourable-Inadequate’, red for Unfavourable-Bad and grey for unknown. Assessments are qualified with a plus or minus to indicate a trend (improving or declining) (Mihailescu et al. 2015).

The data and information on the geographical distribution of the marine fish species were collected during various research surveys at sea, carried-out with NIMRD’s “Steaua de Mare 1” rrsearch vessel, and from fishing points located along the Romanian coast, during 2012–2014. The perimeters were selected so as to be representative for each habitat type and species of interest. The monitoring fishing was made during 2012–2014 by vessel (“Steaua de Mare 1”, equipped with pelagic/demersal trawl gears – Fig. 26.6 left) and by pneumatic boat, for specialized shad and sturgeon gillnet fishing (Fig. 26.6 right).

Four complex scientific surveys were performed, during which 52 pelagic/demersal hauls were made, namely a fishing effort of 52 h of trawling and more

Fig. 26.6 Survey fishing using the demersal trawl (*left*) and gillnets (*right*) (Photo NIMRD)

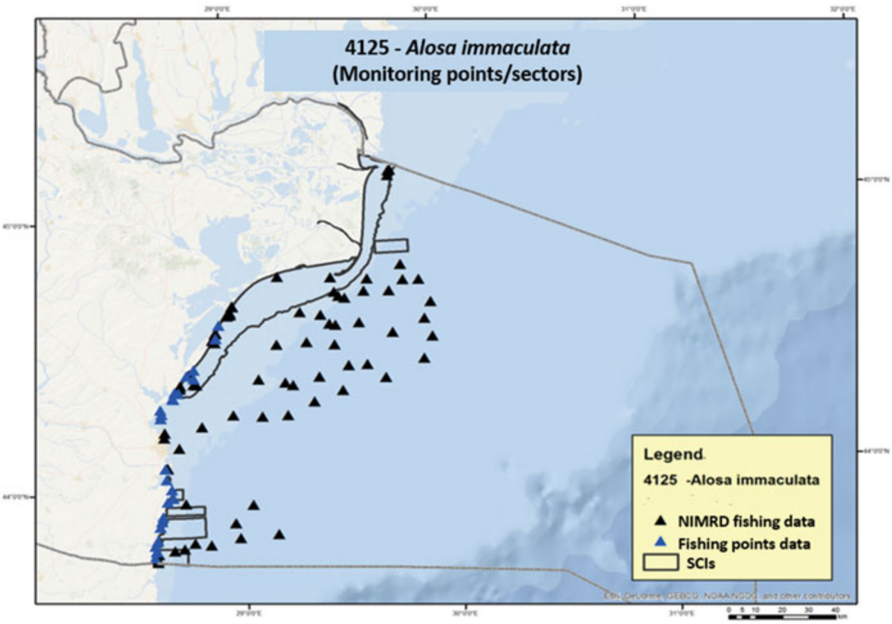

Fig. 26.7 Monitoring points for Pontic shad (MBLS)

than 1400 h – fishing effort with gillnets (4 strings with 4 gillnets each, 400 m long/each, mesh size ranging between 28 ÷ 36 Φ).

The monitoring points in the Black Sea biogeographic region (MBLS) of the Danube Delta marine zone are shown in Figs. 26.7, 26.8, 26.9, 26.10 and 26.11 below.

Additional investigations were performed in the Pontic biogeographical region (PON) and the areas covered are shown in Figs. 26.12, 26.13, 26.14, 26.15 and 26.16.

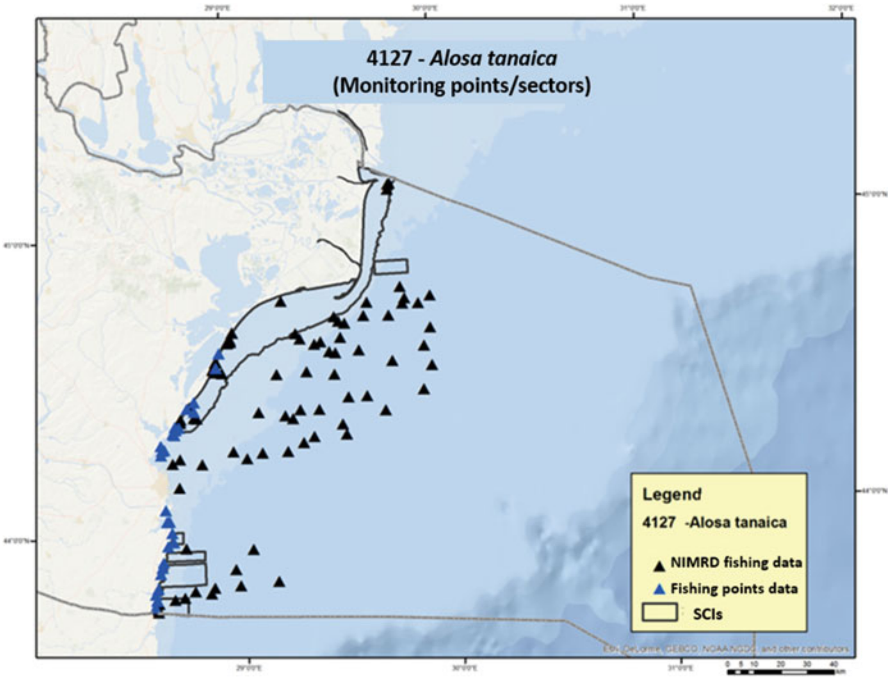

Fig. 26.8 Monitoring points for Black Sea shad (MBLS)

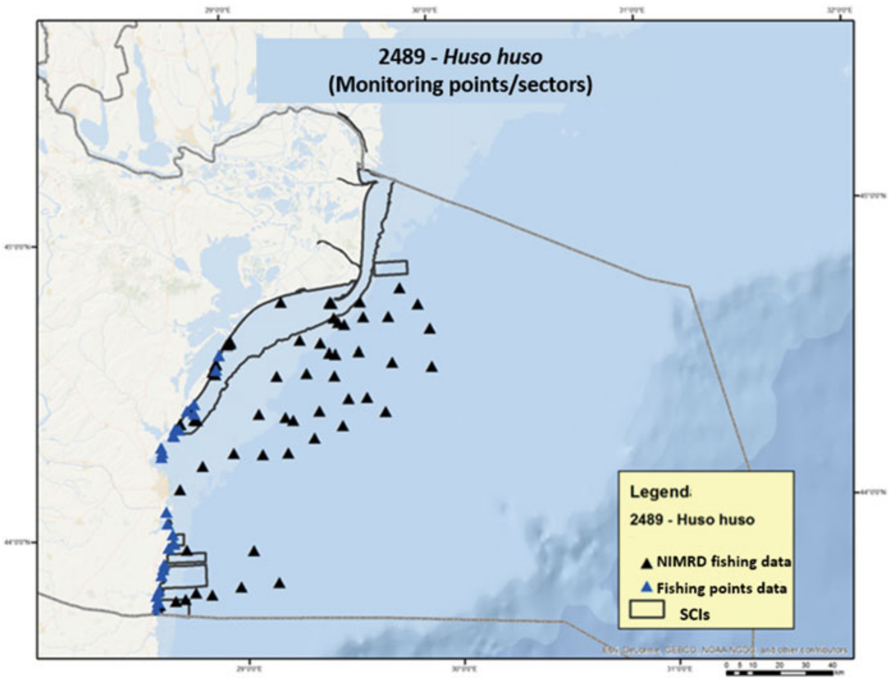

Fig. 26.9 Monitoring points for Beluga (MBLS)

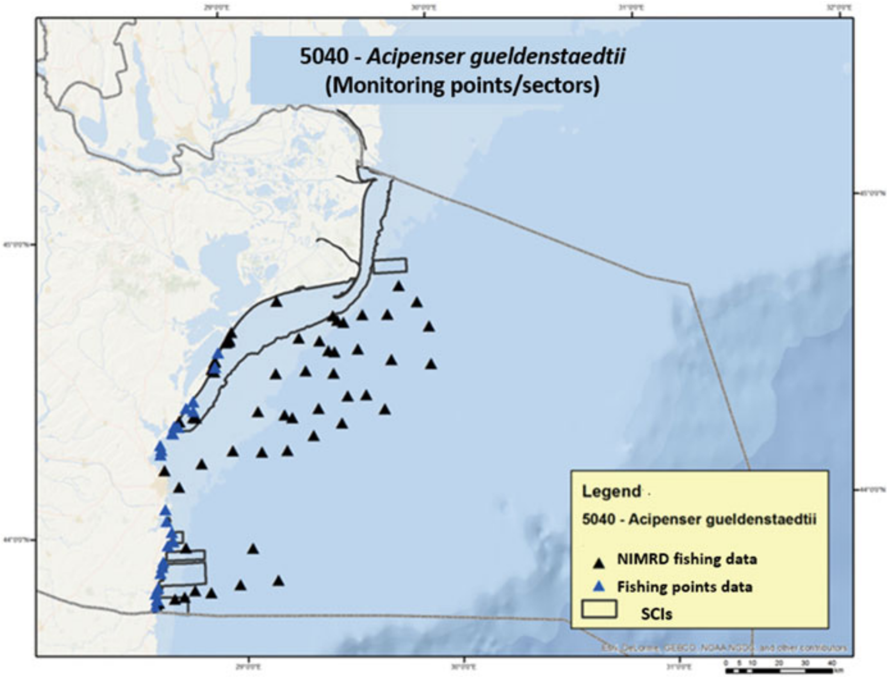

Fig. 26.10 Monitoring points for Danube sturgeon (MBLS)

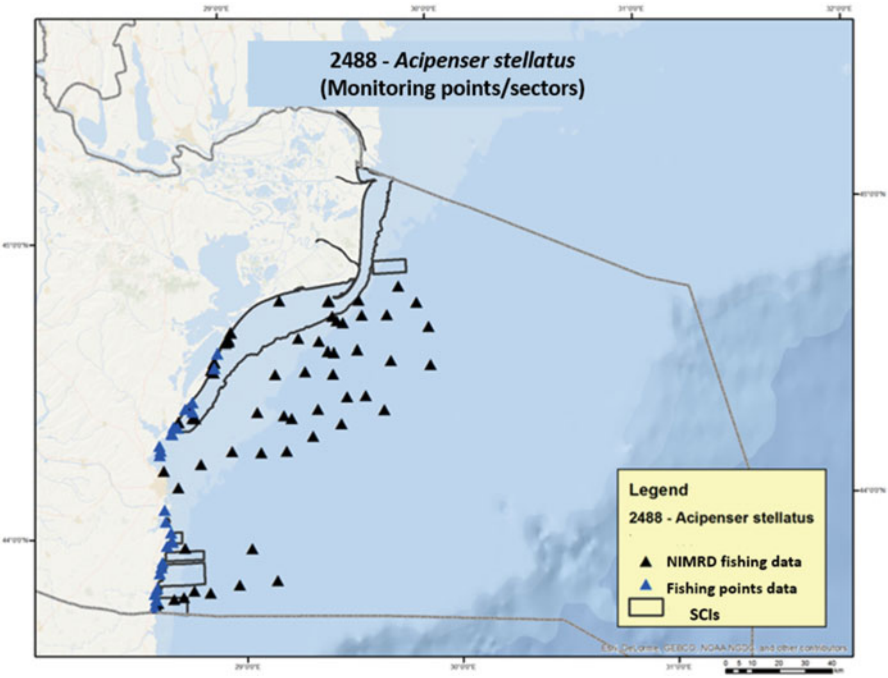

Fig. 26.11 Monitoring points for starry sturgeon (MBLS)

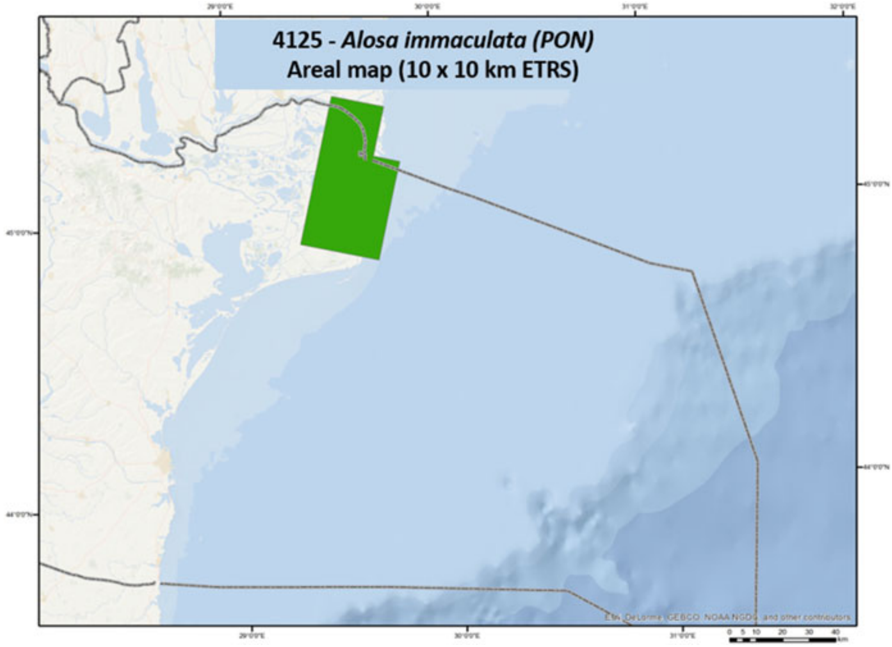

Fig. 26.12 Monitoring points for Pontic shad (PON)

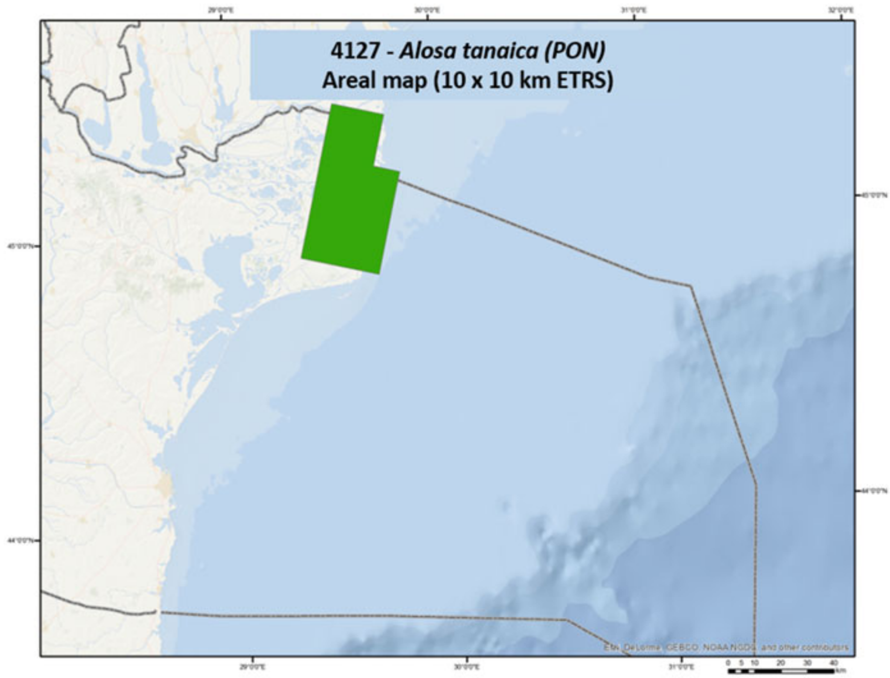

Fig. 26.13 Monitoring points for Black Sea shad (PON)

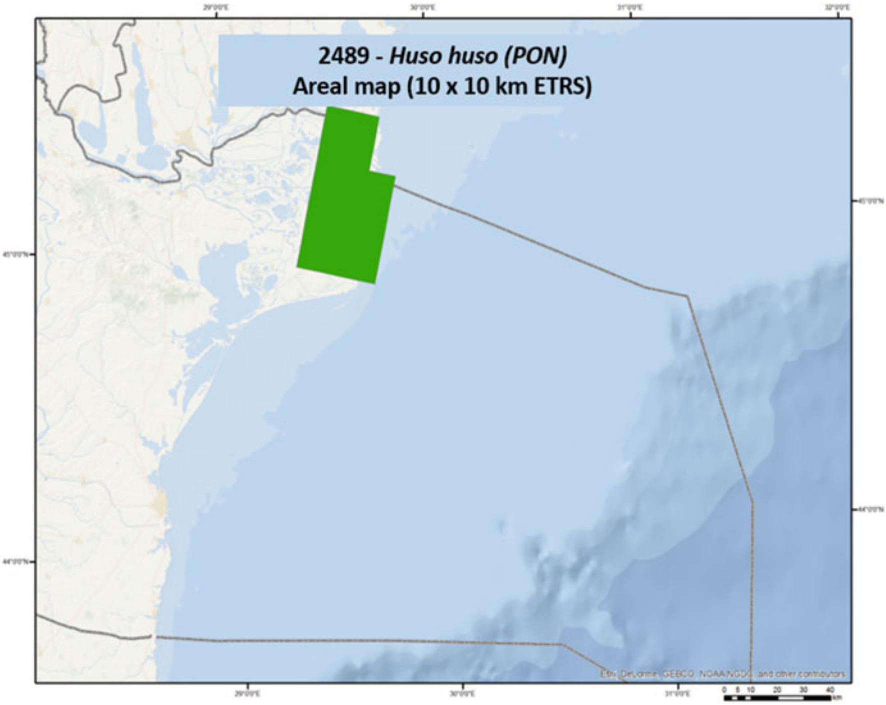

Fig. 26.14 Monitoring points for beluga (PON)

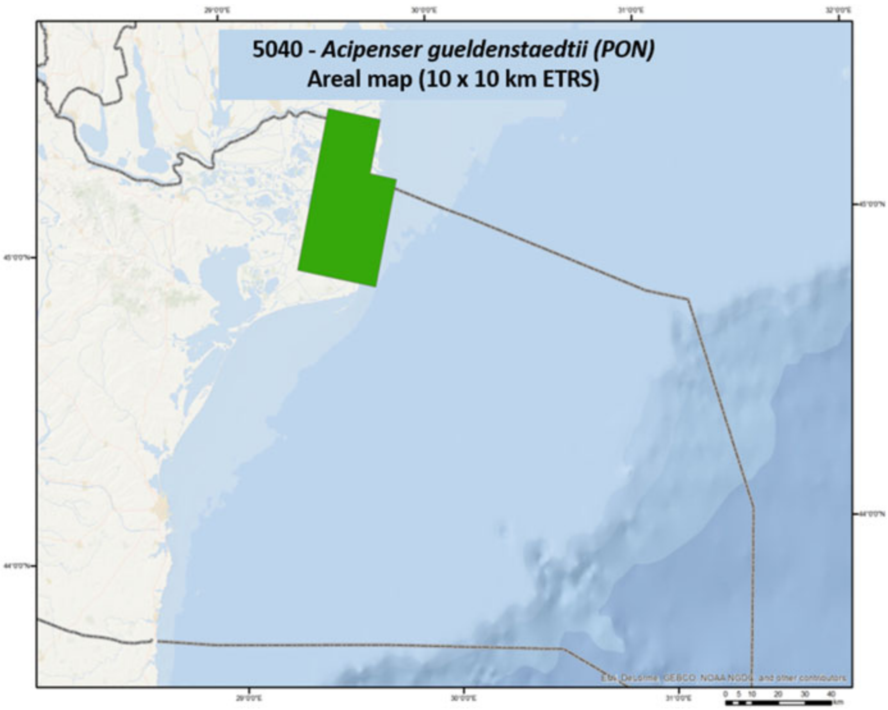

Fig. 26.15 Monitoring points for Danube sturgeon (PON)

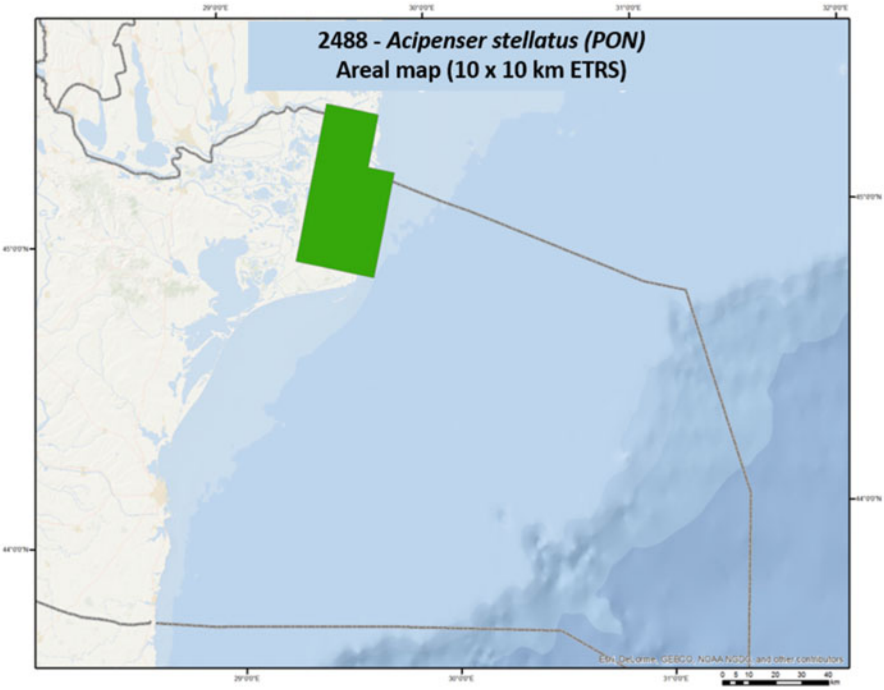

Fig. 26.16 Monitoring points for starry sturgeon (PON)

26.3 Results and Discussion

The investigations performed allowed us to draw-up maps comprising the distribution of the five marine fish species whose presence was confirmed within ROSCI 0066, in both biogeographic areas covered (Pontic/PON and Black Sea/MBLS) (Mihailescu et al. 2015).

Alosa immaculata
Pontic shad was the species permanently recorded in catches made during the scientific fishing surveys. The largest number of shads were caught in the Sulina area (more than 30%), followed by Sachalin (around 18%), Periboina (around 18%), Zatoane, Perisor and Sf. Gheorghe (around 8% each).

This species was also reported in the other sectors of ROSCI 0066, but in small numbers Chituc (around 2%), Gura Portitei (around 2%), Periteasca (around 1%) and Vadu (around 1%) (Figs. 26.17 and 26.18).

Applying the methodology for reporting under Article 17 of the Habitats Directive, it resulted that the overall conservation status for the species ***A. immaculata* (Pontic shad)** in the marine zone of the Danube Delta (ROSCI 0066) is **favourable (FV)** (Table 26.2), status which applies for the entire Romanian coastal area.

Alosa tanaica

Black Sea shad was the species most frequently caught during the monitoring research surveys, its distribution covering all 10 perimeters of the site ROSCI 0066. The highest number of individuals was caught in the Zatoane and Sachalin perimeters (almost 26% each), Sulina (around 18%), Sf. Gheorghe (around 16%) and Perisor (around 8%).

Even though in small numbers, Pontic shad was also caught in the other perimeters of the MPA, namely Periboina (around 1%), Chituc (around 1%), Periteasca, Gura Portitei and Vadu (less than 1%) (Figs. 26.19 and 26.20).

According to Table 26.3 and after applying the methodology for reporting under Article 17 of the Habitats Directive, it resulted that the overall conservation status for the species ***A. tanaica*** **(Black Sea shad)** in the marine zone of the Danube Delta (ROSCI 0066) is **favourable (FV)**, status which applies for the entire Romanian coastal area.

The conservation status for the other shad species reported in ROSCI 0066, namely Azov shad (*Alosa maeotica*, Grimm, 1901) is unknown due to lack of data. The species has not been reported in the lagoons and coastal lakes for about 50 years, its last record being in Lake Razelm in 1968. Under such circumstances, records in Romanian fishery statistics for the past 5 years should be reconsidered (Mihailescu 2015).

Moreover, during the Biogeographical Seminar for the Black Sea marine region (Brindisi, Italy, 15–17 June 2010), it was proposed to remove this species from the reference list, due to the following accounts: *A. maeotica* is a non-anadromous species, rather stenohalyne, living in the brackish Black Sea coastal waters. It does not enter the Danube or the Delta like the other shad species, but it remains in the estuarine waters off the Danube mouths and rarely penetrates the Razelm-Sinoie Lagoon System.

The morphological differentiation from *A. immaculata* is made by the number of gill spines, the scales of the ventral area (quite larger and sharper in *A. maeotica*) and the eyes (larger) (Banarascu 1964). These criteria are very week, mainly for species with high morphological variability. In addition, a recent study (Mezhzherin et al. 2009) on the allozyme variability in *A. immaculata*, *A. maeotica* and *A. caspia*, based on the analysis of 19 enzyme loci and a series of loci coding structural proteins in the muscle, showed a high degree of monomorphism and the absence of any differentiation between the alleles of the three taxa, thus confirming that they belong to the same species. Thus, the three forms are just eco-phenotypes of the same species (*A. immaculata*), phenomenon which often occurs in anadromous fish, and must not be considered different species (Mezhzherin et al. 2009).

Huso huso

During the monitoring period of marine fish species, the occurrence in catches of the beluga was very scarce throughout 1 year (in 2012 only 5 individuals were caught by scientific fishing, of which 4 were tagged and released into the sea).

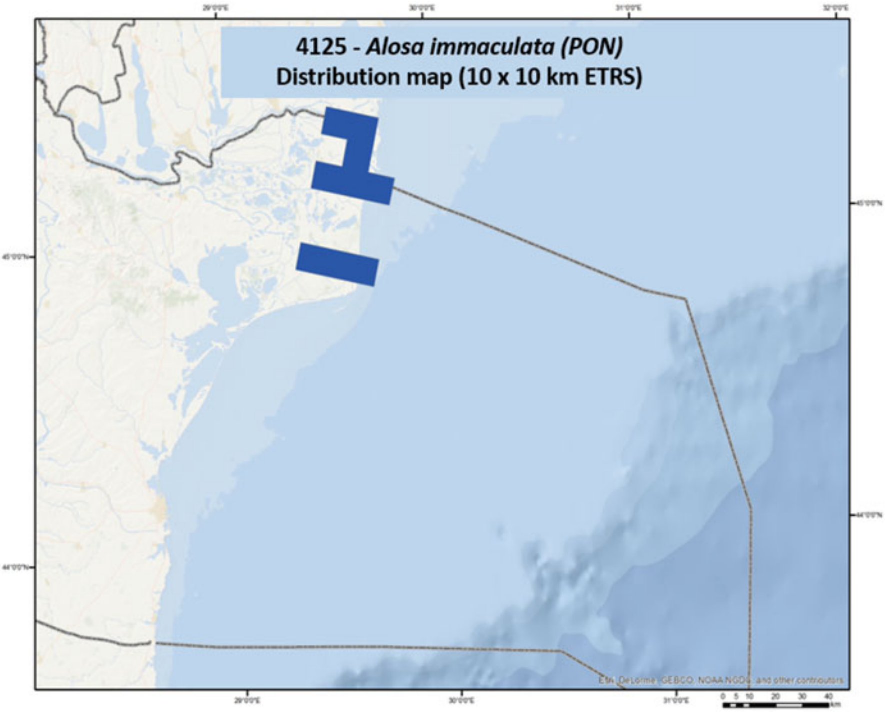

Fig. 26.17 Distribution map of Pontic shad in the Pontic biogeographic region of the Danube Delta – marine zone (ROSCI 0066)

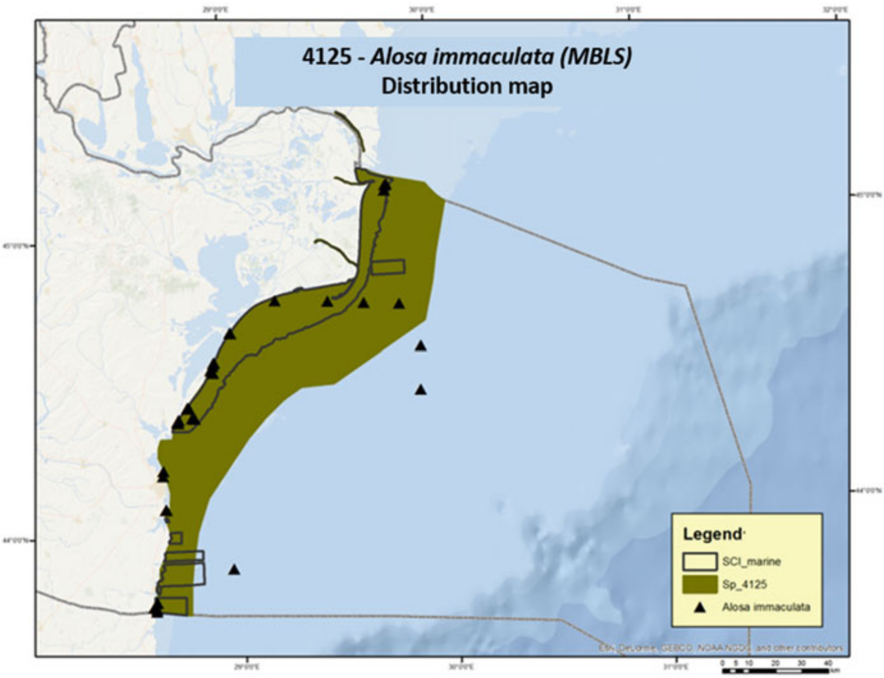

Fig. 26.18 Distribution map of Pontic shad in the Black Sea biogeographic region of the Danube Delta – marine zone (ROSCI 0066)

Table 26.2 General assessment matrix for the conservation status of *Alosa immaculata* (Pontic shad)

Parameter	**Conservation status**			
	Favourable (green)	**Unfavourable-Inadequate (amber)**	**Unfavourable-Bad (red)**	***Unknown (insufficient information for an accurate assessment)***
Range	Stable (loss and expansion in balance) or increasing and not smaller than the "favourable reference range".			
Population	Population above "favourable reference population" and reproduction, mortality and age structure not deviating from normal (if data available).			
Habitat for the species	Area of habitat is sufficiently large (and stable or increasing) and habitat quality is suitable for the long term survival of the species			
Future prospects (as regards to population, range and habitat availability)	Main pressures and threats to the species not significant; species will remain viable on the long-term			
Overall assessment of CS s	**FV**			

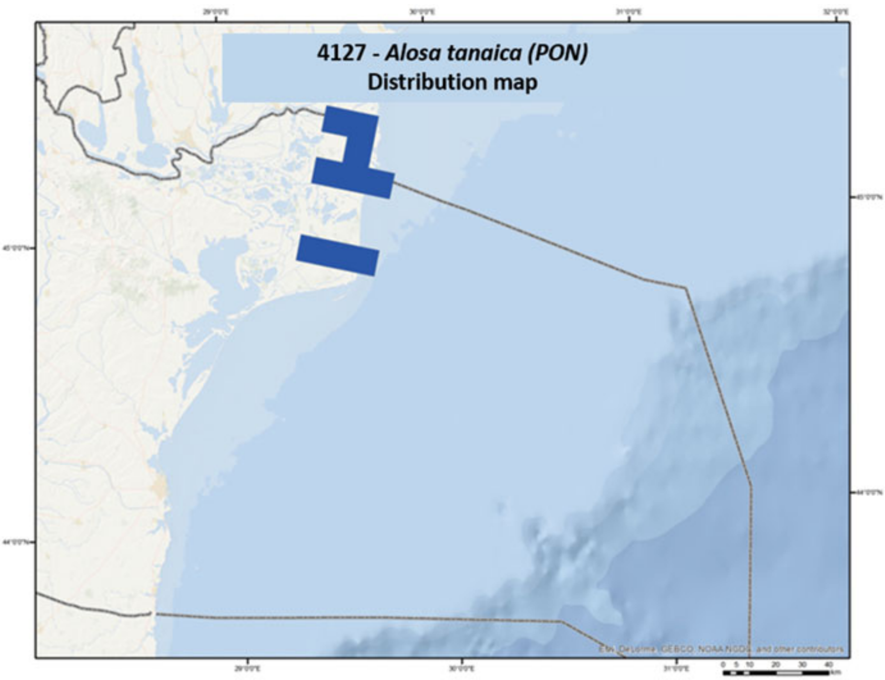

Fig. 26.19 Distribution map of Black Sea shad in the Black Sea biogeographic region of the Danube Delta – marine zone (ROSCI 0066)

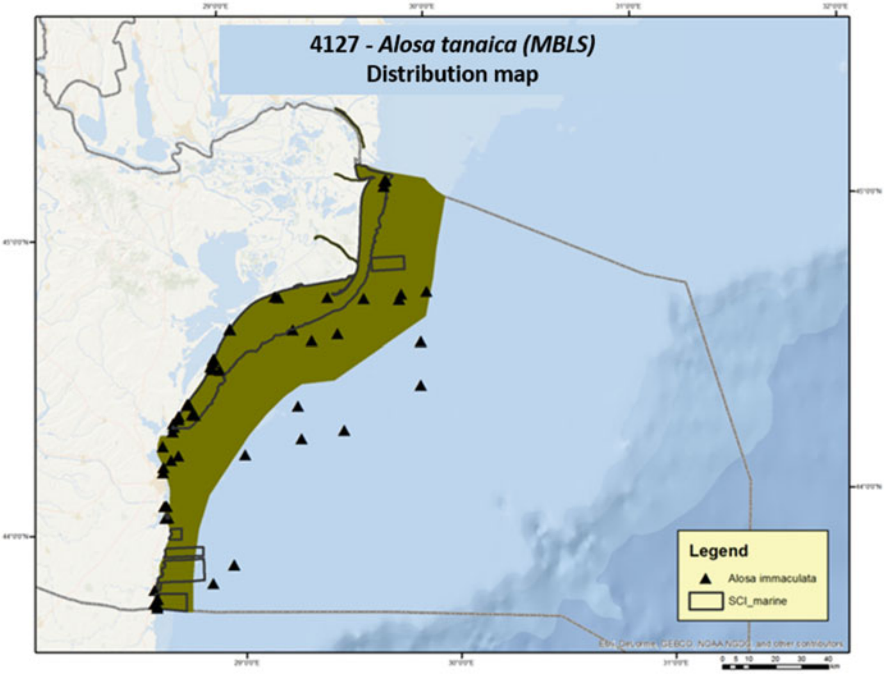

Fig. 26.20 Distribution map of Black Sea shad in the Black Sea biogeographic region of the Danube Delta – marine zone (ROSCI 0066)

Table 26.3 General assessment matrix for the conservation status of *Alosa tanaica* (Black Sea shad)

Parameter	**Conservation status**			
	Favourable (green)	**Unfavourable-Inadequate (amber')**	**Unfavourable-Bad (red)**	***Unknown (insufficient information for an accurate assessment)***
Range	Stable (loss and expansion in balance) or increasing and not smaller than the "favourable reference range".			
Population	Population above "favourable reference population" and reproduction, mortality and age structure not deviating from normal (if data available).			
Habitat for the species	Area of habitat is sufficiently large (and stable or increasing) and habitat quality is suitable for the long term survival of the species.			
Future prospects (as regards to population, range and habitat availability)	Main pressures and threats to the species not significant; species will remain viable on the long-term.			
Overall assessment of CS s	**FV**			

However, despite its scarcity, *H. huso* was caught in every season, mainly when fishing with a mid-water/demersal trawl (Figs. 26.21, 26.22 and 26.23).

Moreover, the verbal information collected from local fishermen operating in the fishing points located within the boundaries of the MPA confirmed the occurrence of beluga, especially young specimens, frequently in the Zatoane – Sf. Gheorghe perimeter, at depths ranging between 5–20 m.

The overall assessment of the conservation status for the species ***H. huso*** **(beluga)** occurring in Danube Delta – marine zone, applying the methodology for reporting under Article 17 of the Habitats Directive, indicates a **Unfavourable-Inadequate U1+ conservation status,** which also applies to the entire Romanian marine zone (Table 26.4).

The main issue for beluga is the pressure caused by illegal fishing, both in the Danube River and the Black Sea, in spite of the moratorium in force banning commercial fishing (2006–2015, extended until 2020). However, as future prospects for the species, it is expected that continuing the restocking program and the regulation of sturgeon fishing will result in a medium and long-term recovery of the beluga population population in the north-western Black Sea.

Acipenser gueldenstaedtii

Of the three species at the Romanian Black Sea coast, the Danube sturgeon recorded the scarcest presence (during scientific fishing in 2012, for instance, only one specimen was caught in summer). This reflects the loss of more than 1% of the Danube sturgeon population per year during 2000–2006.

Similarly to the beluga, however, local fishermen have reported its presence in several sectors of the MPA (Figs. 26.23 and 26.24).

After applying the methodology for reporting under Article 17 of the Habitats Directive, the overall assessment for the species ***A. gueldenstaedtii*** **(Danube sturgeon)** resulted as **Unfavourable-Bad U2+**, which is also applicable for the entire Romanian marine zone (Table 26.5). Similarly to the beluga, the pressure caused by illegal fishing in the Black Sea and the Danube strongly affects the NW Black Sea population, which is affected by the Alee Effect (adult Danube sturgeon stocks dropped below the critical threshold, which in most areas hinders/makes impossible the recruitment from natural breeding).

Fortunately, it is estimated that continuing the restocking program and the regulation of sturgeon fishing rights will generate the circumstances for a recovery of the population, but not immediately and only on the long-term.

Acipenser stellatus

The starry sturgeon was the most frequently encountered species in catches achieved during the scientific fishing surveys, covering all sectors of the Danube Delta – marine zone (ROSCI 0066). The highest number of *A. stellatus* were caught in the Sachalin perimeter (60% of the catches), followed by Zatoane (around 25%), Sulina and Perisor (around 4%) and Sf. Gheorghe, Periboina, Chituc and Vadu (around 1% each) (Figs. 26.25 and 26.26).

Applying the methodology for reporting under Article 17 of the Habitats Directive, the overall assessment of the conservation status for the species ***A. stellatus***

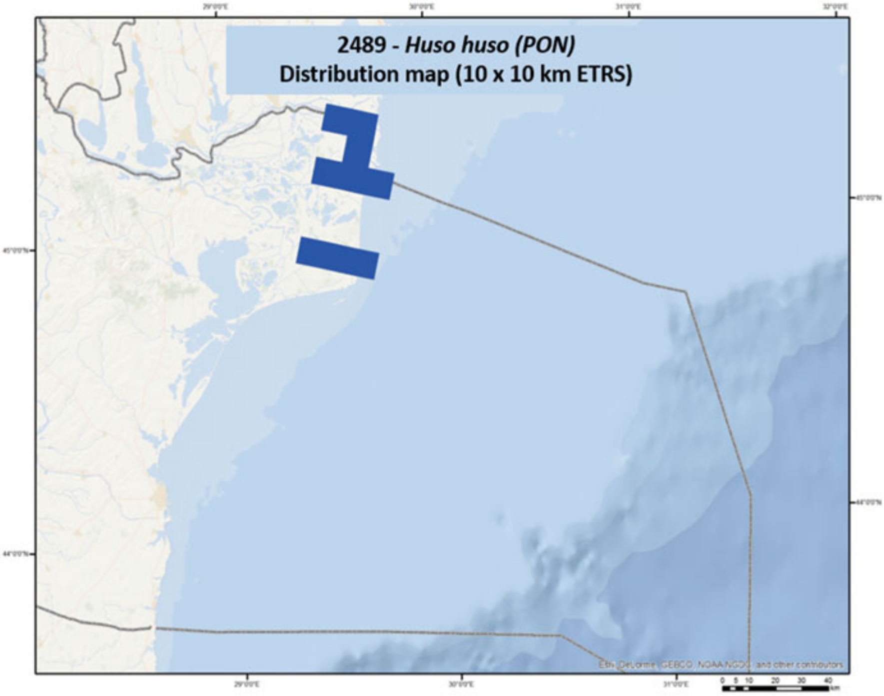

Fig. 26.21 Distribution map of beluga in the Pontic biogeographical region of the Danube Delta – marine zone (ROSCI 0066)

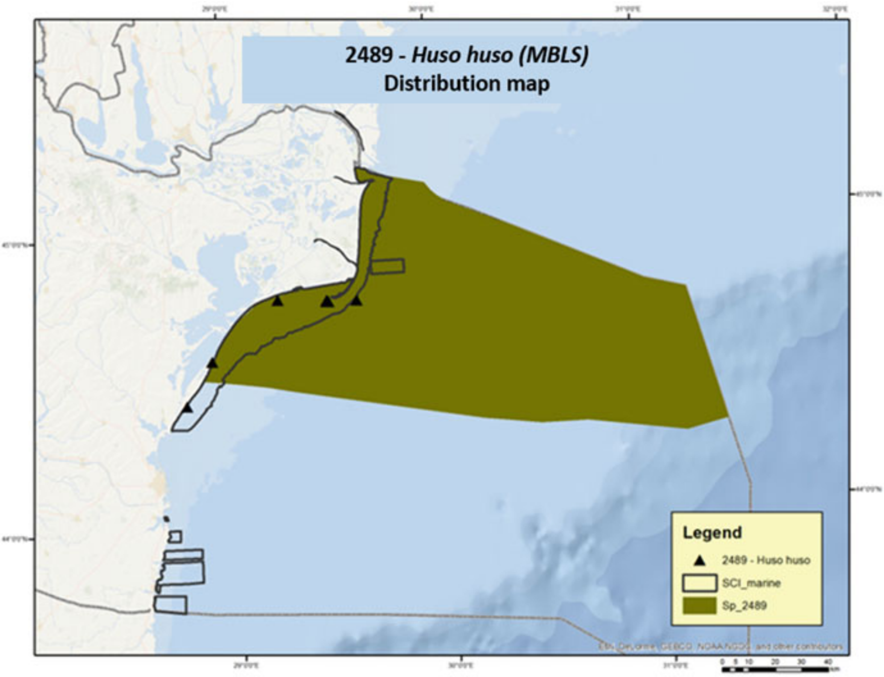

Fig. 26.22 Distribution map of beluga in the Black Sea biogeographical region of the Danube Delta – marine zone (ROSCI 0066)

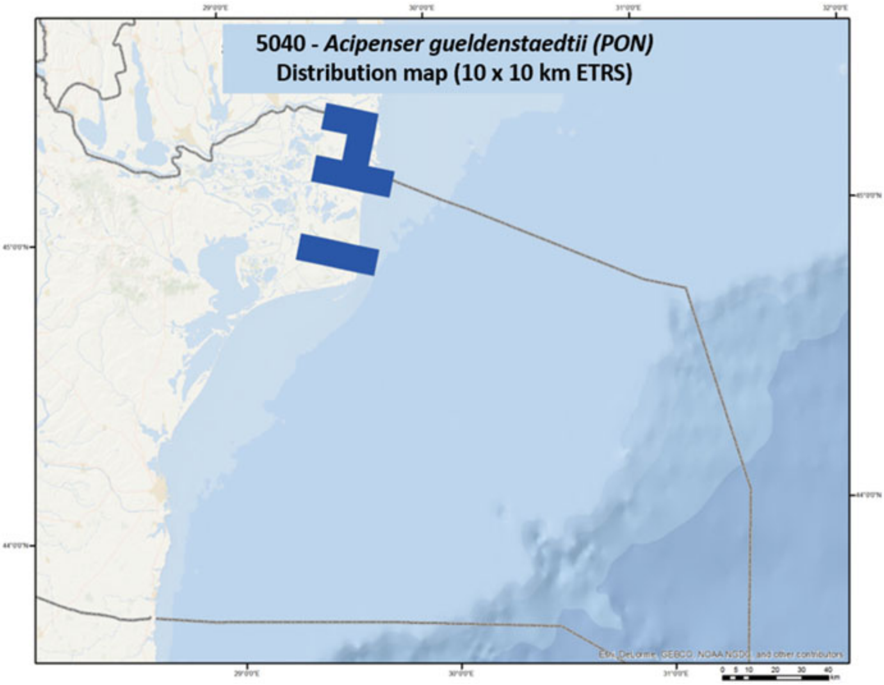

Fig. 26.23 Distribution map of Danube sturgeon in the Pontic biogeographical region of the Danube Delta – marine zone (ROSCI 0066)

(starry sturgeon) occurring in Danube Delta – marine zone indicates a **Unfavourable-Inadequate U1+ conservation status,** which also applies to the entire Romanian marine zone (Table 26.6).

As for the beluga and Danube sturgeon, the main concern for starry sturgeon is the pressure caused by illegal fishing, both in the Danube River and the Black Sea, in spite of the moratorium in force banning commercial fishing (2006–2015, extended until 2020). Future prospects for the species indicate that it is expected that continuing the restocking program and the regulation of sturgeon fishing will result in a medium and long-term recovery of the population in the north-western Black Sea.

26.4 Conclusions

Applying the methodology for reporting under Article 17 of the Habitats Directive, we concluded that the overall conservation status for the two shad species, ***A. immaculata*** **(Pontic shad)** and ***A. tanaica*** **(Black Sea shad),** in the marine

Table 26.4 General assessment matrix for the conservation status of *Huso huso* (beluga)

Parameter	Conservation status			
	Favourable (green)	**Unfavourable-Inadequate (amber)**	**Unfavourable-Bad (red)**	***Unknown (insufficient information for an accurate assessment)***
[a]Range	**FV** The marine range of the population is not smaller than the "favourable reference Range".			
Population of NW Black Sea and Lower Danube		**U1+** The conservation status of the population is inadequate, but there is a moratorium in force banning commercial fishing (2006-2015, extended until 2020), as well as a restocking program of the Lower Danube with fingerlings obtained by artificial breeding of wild spawners.		
[b]Foraging habitats of juveniles and adults	**FV** The area of the foraging habitats of juveniles and adults is large enough and the habitat quality is adequate for the long-term survival of the species.			
Future prospects (as regards to population, range and habitat availability)		**U1x** The pressure caused by illegal fishing in the Black Sea and the Danube strongly affects the NW Black Sea population.		
Overall assessment of CS		**U1+** It is estimated that continuing the restocking program and the regulation of sturgeon fishing rights generate the circumstances for a **medium and long-term recovery of the population.**		

[a]The current population range covers the entire Lower Danube
[b]The wintering habitats at sea are outside the boundaries of ROSCI 0066. The wintering habitats in the river, spawning and foraging of early life stages and fingerlings are in the Lower Danube

zone of the Danube Delta (ROSCI 0066), is **favourable (FV),** status which applies for the entire Romanian coastal area.

For sturgeon species, however, the assessment showed that there are serious reasons for concern. The conservation status for the species ***H. huso* (beluga)** and ***A. stellatus* (starry sturgeon)** resulted **Unfavourable-Inadequate U1+,** which also applies to the entire Romanian marine zone. The main concern for beluga

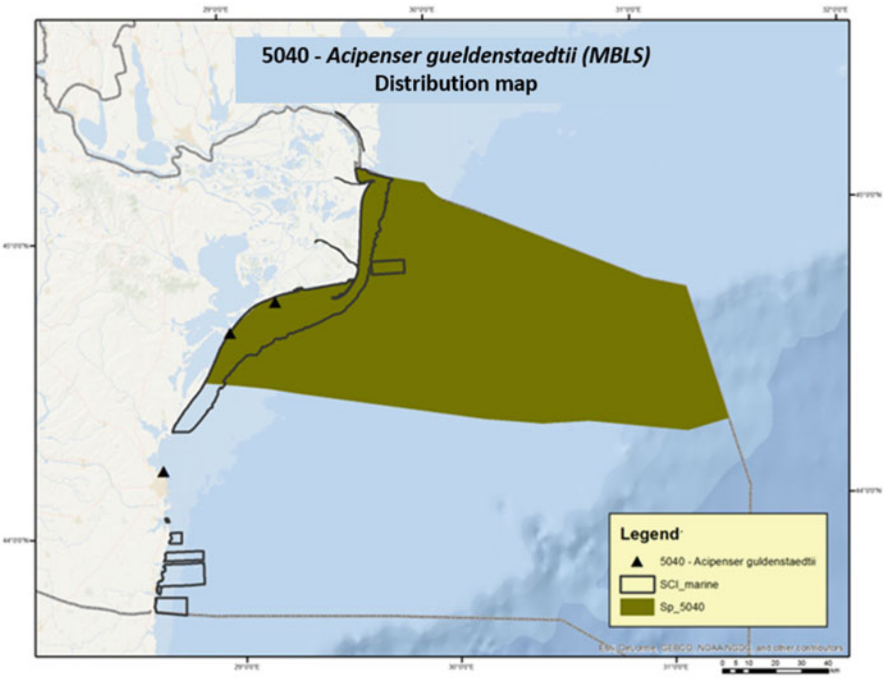

Fig. 26.24 Distribution map of Danube sturgeon in the Black Sea biogeographical region of the Danube Delta – marine zone (ROSCI 0066)

and starry sturgeon populations is the pressure caused by illegal fishing, both in the Danube River and the Black Sea, in spite of the moratorium in force banning commercial fishing (2006–2015, extended until 2020). However, it is expected that continuing the restocking program and the regulation of sturgeon fishing will result in a medium and long-term recovery of the beluga and starry sturgeon populations in the north-western Black Sea.

The worst conservation status was recorded by far for ***A. gueldenstaedtii*** **(Danube sturgeon)**, namely **Unfavourable-Bad U2+**, which is also applicable for the entire Romanian marine zone. As for the other two sturgeons species monitored, the pressure caused by illegal fishing in the Black Sea and the Danube strongly affects the NW Black Sea population, which is additionally affected by the Alee Effect (adult Danube sturgeon stocks dropped below the critical threshold, which hinders/makes impossible the recruitment from natural breeding).

Fortunately, continuing the restocking program and the regulation of sturgeon fishing rights generate the circumstances for a recovery of the Danube sturgeon population on the long-term.

Given the anadromous character of both shads and sturgeons, the fishery management of these species can only be made correlated among the two significant habitats they populate (sea and river), and also taking into account the MPA status of the zone. Several studies have been performed in recent years (after the inclusion

Table 26.5 General assessment matrix for the conservation status of *Acipenser gueldenstaedtii* (Danube sturgeon)

Parameter	**Conservation status**			
	Favourable (green)	**Unfavourable-Inadequate (amber)**	**Unfavourable-Bad (red)**	***Unknown (insufficient information for an accurate assessment)***
[a]Range	**FV** The marine range of the population is not smaller than the "favourable reference Range".			
Population in the NW Black Sea and the Lower Danube.			**U2+** Large decline: Equivalent to a loss of more than 1% per year during 2000-2006, as resultimg from the sharp drop of catches and recruitment from natural spawning in the river. There is a moratorium in force banning commercial fishing (2006-2015, extended until 2020), as well as a restocking program of the Lower Danube with fingerlings obtained by artificial breeding of wild spawners.	
[b]Foraging habitats of juveniles and adults	**FV** The area of the foraging habitats of juveniles and adults is large enough and the habitat quality is adequate for the long-term survival of the species.			
Future prospects (as regards to population, range and habitat availability)			**U2x** The pressure caused by illegal fishing in the Black Sea and the Danube strongly affects the NW Black Sea population. Population conservation is affected by the Alee Effect (adult Danube sturgeon stocks dropped below the critical threshold, which in most areas hinders/makes impossible the recruitment from natural breeding).	
Overall assessment of CS			**U2+** It is estimated that continuing the restocking program and the regulation of sturgeon fishing rights generate the circumstances for a **medium and long-term recovery of the population.**	

[a]The current population range covers the entire Lower Danube
[b]The wintering habitats at sea are outside the boundaries of ROSCI 0066. The wintering habitats in the river, spawning and foraging of early life stages and fingerlings are in the Lower Danube

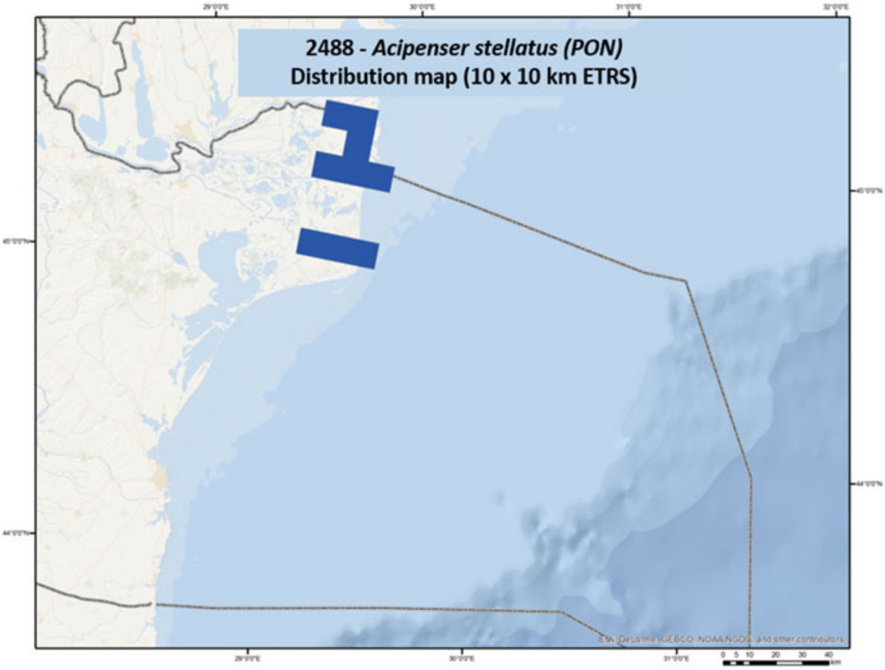

Fig. 26.25 Distribution map of starry sturgeon in the Pontic biogeographical region of the Danube Delta – marine zone (ROSCI 0066)

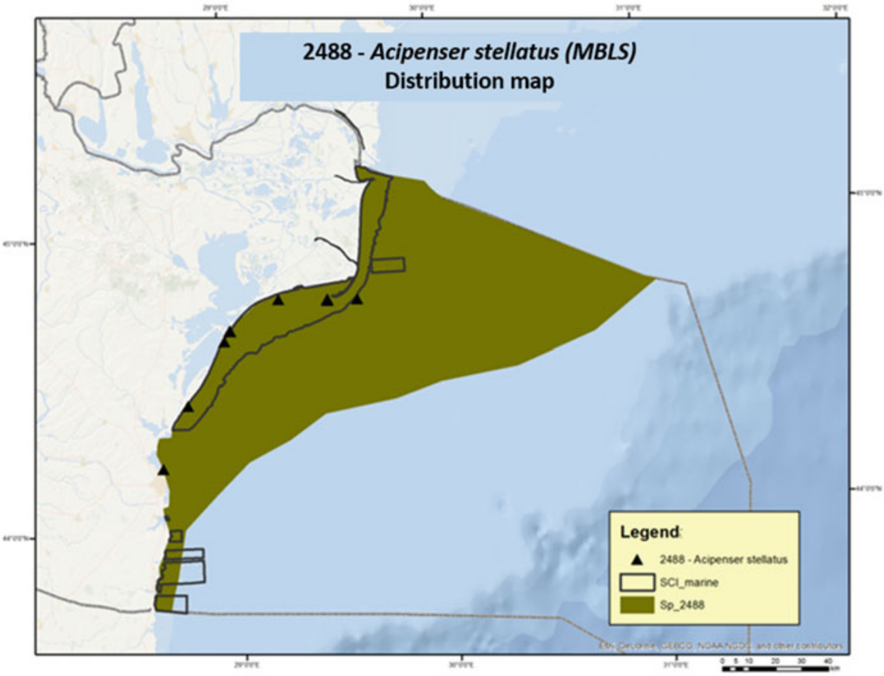

Fig. 26.26 Distribution map of starry sturgeon in the Black Sea biogeographical region of the Danube Delta – marine zone (ROSCI 0066)

Table 26.6 General assessment matrix for the conservation status of *Acipenser stellatus* (starry sturgeon)

Parameter	Conservation status			
	Favourable (green)	**Unfavourable-Inadequate (amber)**	**Unfavourable-Bad (red)**	***Unknown (insufficient information for an accurate assessment)***
[a]**Range**	**FV** The marine range of the population is not smaller than the "favourable reference Range".			
Population of NW Black Sea and Lower Danube		**U1+** The conservation status of the population is inadequate, but there is a moratorium in force banning commercial fishing (2006-2015, extended until 2020), as well as a restocking program of the Lower Danube with fingerlings obtained by artificial breeding of wild spawners.		
[b]**Foraging habitats of juveniles and adults**	**FV** The area of the foraging habitats of juveniles and adults is large enough and the habitat quality is adequate for the long-term survival of the species.			
Future prospects (as regards to population, range and habitat availability)		**U1-** The pressure caused by illegal fishing of juveniles and adults off the Danube mouths and adults in the Black Sea strongly affects the NW Black Sea population.		
Overall assessment of CS		**U1+** It is estimated that continuing the restocking program and the regulation of sturgeon fishing rights generate the circumstances for a **medium and long-term recovery of the population.**		

[a]The current population range covers the entire Lower Danube
[b]The wintering habitats at sea are outside the boundaries of ROSCI 0066. The wintering habitats in the river, spawning and foraging of early life stages and fingerlings are in the Lower Danube

on Romanian MPAs in the Natura 2000 European ecological network) on the reconciliation between fisheries and marine protected areas such as the marine zone of the Danube Delta (ROSCI 0066) (Zaharia et al. 2010, 2012, 2014; Nicolae et al. 2011). The enforcement of the moratorium banning sturgeon fishery until 2020 is a crucial tool for the recovery of sturgeon populstions in the north-western Black Sea, yet involving all stakeholders in the region must not be overlooked. Any potential management measure of both shads and sturgeons in the Danube Delta – marine zone (ROSCI 0066), as Community importance species, should be fitted into the Integarted Management Plan of the Danube Delta Biosphere Reserve, in an attempt to manage the conservation of species at a larger scale.

26.5 Acknowledgement

This paper is based on the results obtained in the frame of the projects "Monitoring the conservation state of species and habitats in Romania pursuant to Article 17 of the Habitats Directive" (SMIS-CSNR 17655) and "Management measures for the marine site (SCI) Natura 2000 ROSCI0066 Danube Delta-Marine area" (SMIS-CSNR Code 17162), funded through the Operational Sectorial Program Environment (SOP Environment), Priority Axis 4.

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Chapter 27
Assessment of Cetacean Population Abundance at the Romanian Black Sea Coast in 2013

George Ţiganov, Cristian-Sorin Danilov, Magda Ioana Nenciu, Eugen Anton, and Aurel Năstase

Abstract The aim of this study was to describe the marine mammal sighting and abundance related to the distribution in front of the Romanian Black Sea coast, for the year 2013. The assessment of cetacean populations, according to the working methodology used regionally and internationally, imposed the necessity of observations both on shore (seashore, port protection dikes etc.) and at sea, on board vessels and boats. In order to obtain data and information on the population status of marine mammals from the Romanian Black Sea coast, a monitoring plan was drawn-up, aiming at increasing the knowledge of the abundance of cetaceans in the Black Sea, towards the sustainable protection and conservation of the sensitive habitats and species.

Keywords Black Sea • Strandings • Marine mammals • Abundance

27.1 Aims and Backround

Black Sea cetaceans play a major role in the ecological balance of the marine ecosystem, being top predators (Radu et al. 2012). Due to this position in the food chain, they are very sensitive to ecological conditions and in direct competition with anthropogenic activities (Radu and Anton 2014).

The current delicate state of the Black Sea cetacean populations, represented by the three species: common dolphin - *Delphinus delphis ponticus*, bottlenose dolphin - *Tursiops truncatus ponticus* and harbor porpoise - *Phocoena phocoena relicta,* has required research aiming at obtaining information on the populations existing in the coastal and offshore zone, and several studies have been

G. Ţiganov (✉) • A. Năstase
DDNIRD – Danube Delta National Institute for Research and Development, 165 Babadag Street, Tulcea, Romania
e-mail: gtiganov@alpha.rmri.ro; george.tiganov@ddni.ro

C.-S. Danilov • M.I. Nenciu • E. Anton
NIMRD – National Institute for Marine Research and Development "Grigore Antipa", 300 Mamaia Blvd, Constanta, Romania

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performed (Anton et al. 2002; Anton 2006; Anton et al. 2006, 2012; Radu et al. 2012). The study of marine mammals requires a temporal continuity, because of the complex and systematic research that needs to be carried-out in order to establish the species composition, distribution, occurrence frequency and abundance (Anton et al. 2008).

Apart from these population parameters of marine mammals, the interaction between cetaceans and fisheries is an issue of great concern (Anton et al. 2010; Radu and Anton 2014). Fisheries may affect significantly the conservation state of cetacean populations, by causing accidental death due to capture or entanglement in gillnet-type fishing gear. For such reasons, with the view to protecting marine mammal populations, research has been carried-out to establish technical solutions aimed at reducing accidental by-catches reported in gillnet-type fishing gear (Anton et al. 2013).

The aim of this study was to outline the recent marine mammal sighting and abundance related to the distribution in front of Romanian Black Sea coast in 2013.

27.2 Experimental

Assessing cetacean populations, in full compliance with the working methodology used regionally and internationally (Birkun et al. 2014), imposed the need to have observations both from the shore (seashore, protection dikes etc.) and offshore, on board of vessels and boats.

Depending on where the observations were made, the monitoring activity of marine mammals can be divided as follows:

– Monitoring observations at sea;
– Terrestrial monitoring observations from shore.

The marine mammal observation area ranged between Sulina (north) and Vama Veche (south), from shore to the 90–100 m isoline (Fig. 27.1).

The coordinates delimiting each of the three monitoring zones and the area covered for each sector are given below:

Southern Area
SW: 43,044′11″ lat. N and 28,035′07″ long. E;
SE: 43,040′04″ lat. N şi 29,052′59″ long. E;
NW: 44,010′48″ lat. N şi 28,040′46″ long. E;
NE: 44,006′38″ lat. N şi 30,015′28″ long. E;
Area covered = 6085 km^2

Central Area
SW: 44,010′48″ lat. N and 28,040′46″ long. E;
SE: 44,006′38″ lat. N and 30,015′28″ long. E
NW: 44,038′10″ lat. N and 28,059′12″ long. E;
NE: 44,033′19″ lat. N and 30,055′22″ long. E;
Area covered = 7769 km^2

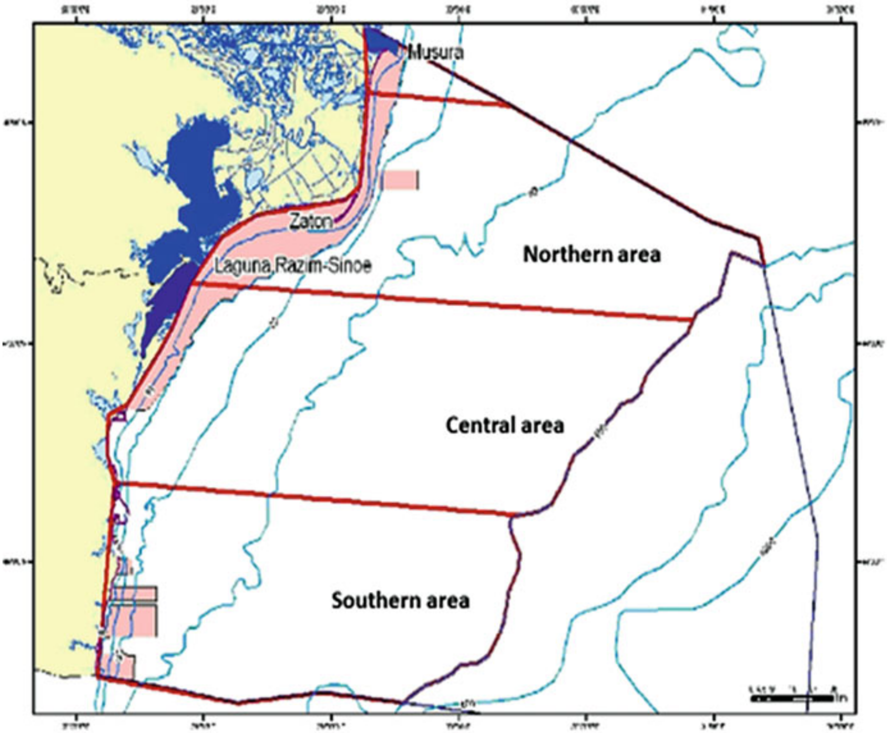


Fig. 27.1 Map of the observation area

Northern Area
SW: 44,038′10″ lat. N and 28,059′12″ long. E;
SE: 44,033′19″ lat. N and 30,055′22″ long. E;
NW: 45,010′10″ lat. N and 29,046′42″ long. E;
NE: 44,044′18″ lat. N and 31,010′48″ long. E;
Area covered = 6210 km^2

In order to obtain data and information regarding the status of the cetacean populations from the Romanian coast of the Black Sea, a monitoring plan was drawn-up. For each type of observation, the monitoring was detailed and includes both a spatial distribution of the points and routes of observation and a temporal distribution (periodicity, time line).

The actions provided for in the monitoring plan are:

– Identification of observation sectors and possible observers and collaborators;
– Distribution of recording sheets to observers and collaborators from fishing points, Coast Guard, Administration of the Danube Delta Biosphere Reserve etc.;
– Bimonthly surveys along the coastline to observe cetaceans close to the shore;

Fig. 27.2 Boat used for dolphin observations

– Data collection and observations of the collaborators on the presence of marine mammals in the area;
– Observation on board of vessels/boats of cetacean groups, in the coastal and offshore zone.

The monitoring of marine mammals at sea was carried out by boat (Fig. 27.2) and using the "Steaua de Mare 1" research vessel (Fig. 27.3). Monitoring at sea was made during calm sea, as it allows the location of individuals at great distances from the survey vessel.

27.3 Results and Discussion

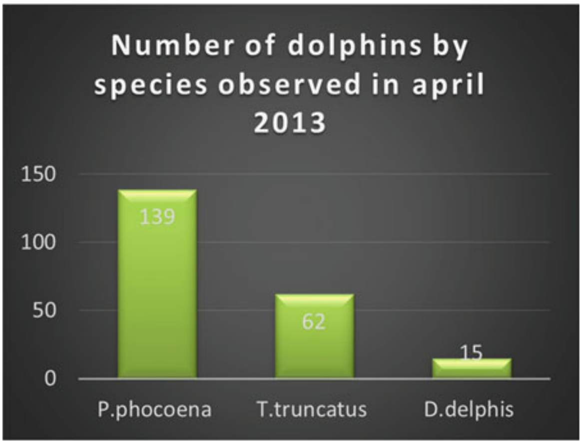
In April–May 2013, observations at sea were performed with the "Steaua de Mare 1"research vessel, aiming at tracing individuals or groups of dolphins.

Observations made in April resulted in a recorded number of 216 marine mammals, represented by the three reported species (Fig. 27.4). The distribution in the three sectors of the Romanian coastline is presented in Fig. 27.5.

The area in which the observations were carried out in April was about 3204 km^2 and represented 17% of the total surface taken into account (19,299 km^2) for the purpose of estimating marine mammal abundance. By means of extrapolation, it was estimated that the number of cetaceans present in the offshore area in April, on the total surface taken into account, ranged between 88 (*D. D. ponticus*) and 817 individuals (*P. P. relicta*), with a total of 1270 specimens (Fig. 27.6).

Fig. 27.3 "Steaua de Mare 1" research vessel

Fig. 27.4 Total number of cetaceans by species (by vessel, April 2013)



Observations made in May resulted with recording a number of 156 marine mammals, represented by the three species, as shown in (Figs. 27.7, 27.8, and 27.9).

The area in which the observations were carried out in May was about 1922 km^2 and represented 10% of the total surface taken into account (19,299 km^2) for the purpose of estimating marine mammal abundance. By means of extrapolation, it was estimated that the number of cetaceans present in the offshore area in May, on the total surface covered, ranged between 290 individuals (*D. D. ponticus*) and 740 individuals (*P. P. relicta*).

Observation from boats at the Romanian coast was done with the "Marsuin" speedboat in May 2013, aiming at tracing individuals or groups of cetaceans which prefer areas closer to the coast. Observations made in May resulted in recording a

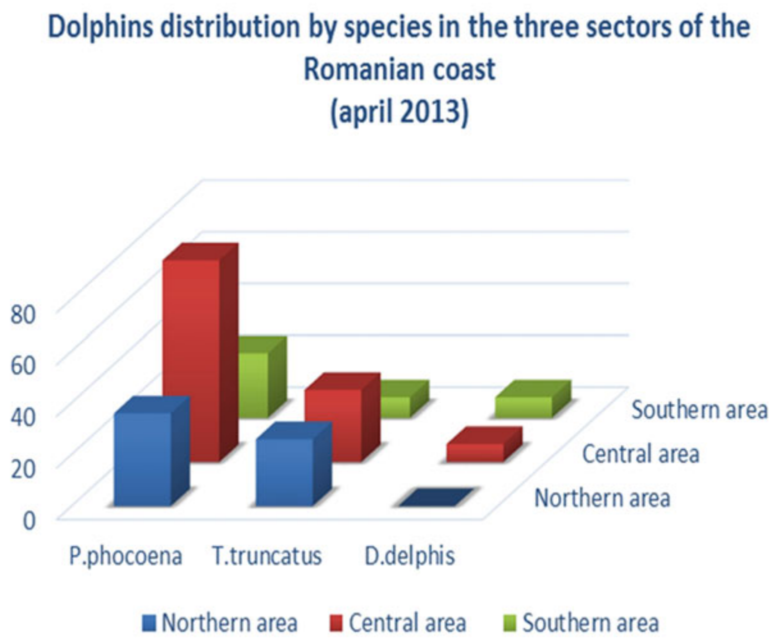


Fig. 27.5 Cetacean distribution by species and sectors (by vessel, April 2013)

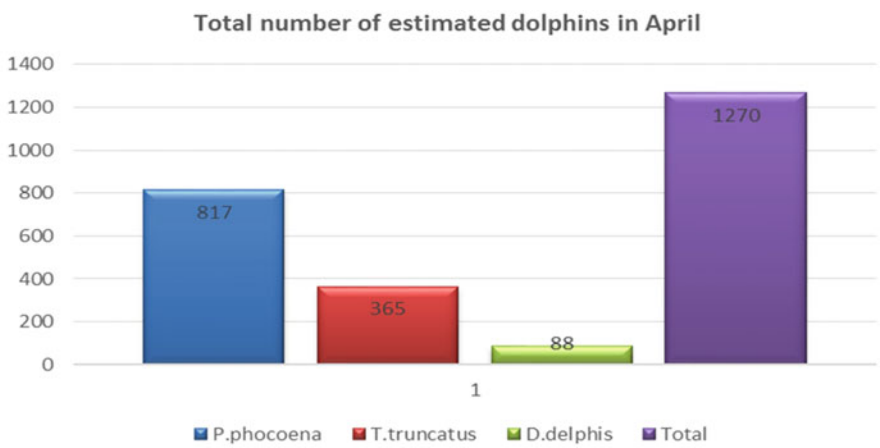


Fig. 27.6 Total number of estimated cetaceans in April 2013 (by vessel)

number of 43 marine mammals, represented by the three species (Fig. 27.10), with the highest number sighted in the central area (*T.T. ponticus*) (Fig. 27.11).

Compared with the situation during observations carried out with the vessel in the offshore area, the number marine mammals observed from the boat relates to a

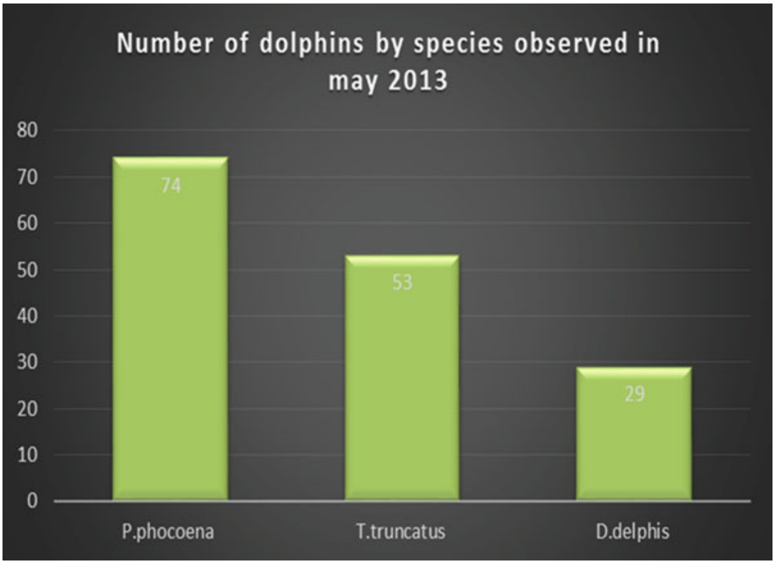
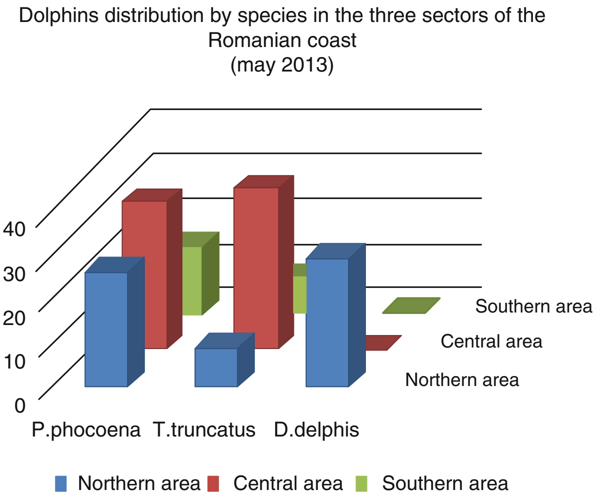


Fig. 27.7 Total number of cetaceans by species (by vessel, May 2013)

Fig. 27.8 Cetacean distribution by species and sectors (by vessel, May 2013)



much smaller surveyed area. However, marine mammals were well represented, with the exception of *P.P. relicta*.

The area in which the observations were carried out in May 2013 by boat was about 765 km^2 and represented 31% of the total surface area taken into account (2450 km^2) for the purpose of estimating cetacean abundance. By means of extrapolation, it was estimated that the number of marine mammals present in the

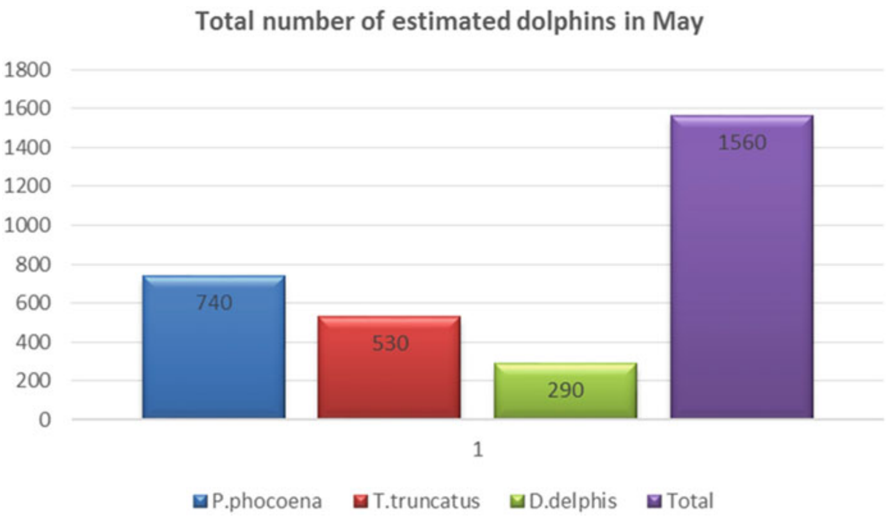


Fig. 27.9 Total number of estimated cetaceans in May 2013 (by vessel)

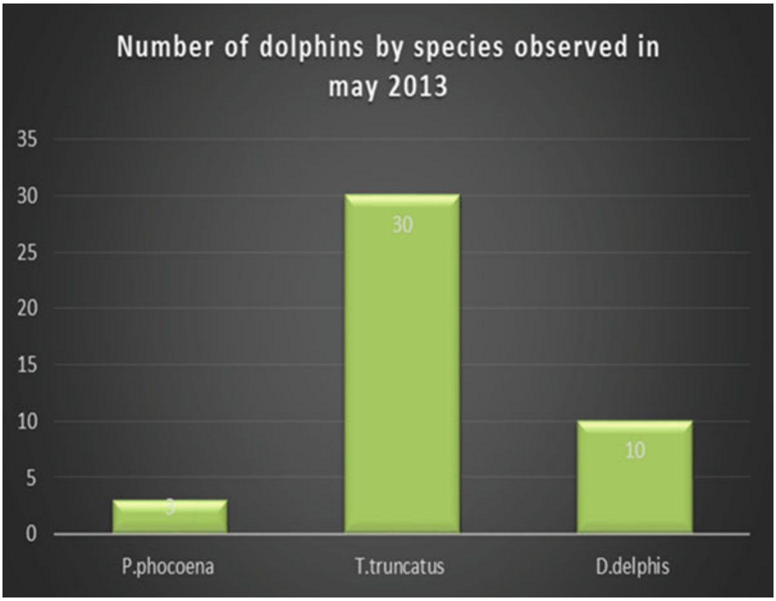


Fig. 27.10 Total number of cetaceans by species (by boat, May 2013)

coastal area in May, on the total surface taken into account, ranged from only 10 individuals (*P*. *P*. *relicta*) to 97 individuals (*T*. *T*. *ponticus*) (Fig. 27.12).

The observations carried out on board of vessels and boats from the coastline to the offshore zone generated data and information about cetacean abundance along

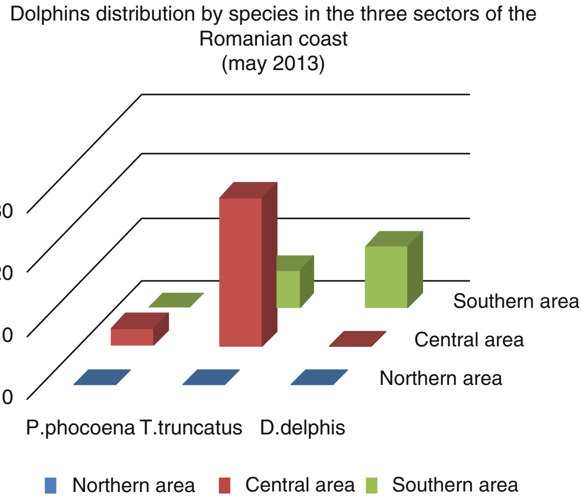


Fig. 27.11 Cetacean distribution by species and sectors (by boat, May 2013)

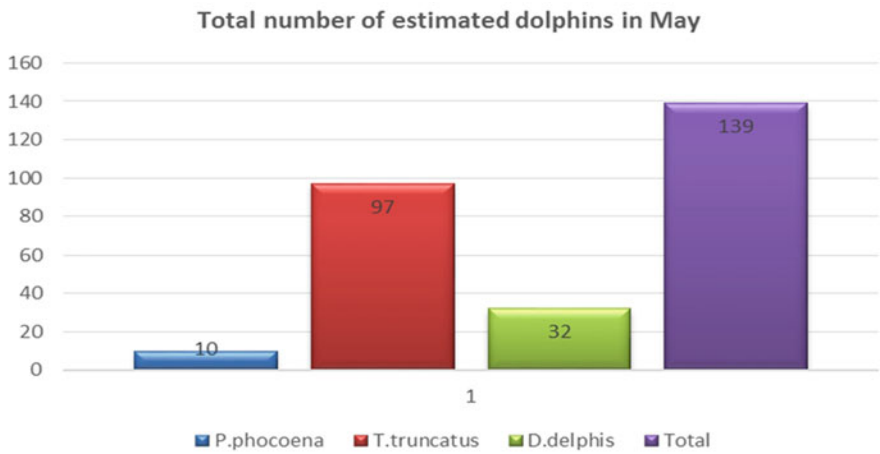


Fig. 27.12 Total number of estimated cetaceans in May (by boat)

the Romanian Black Sea coast. The results indicate a slight increase of marine mammals' number as hydroclimatic conditions improved. Thus, in May, due to warmer weather and the presence of a greater diversity of pelagic fish species, the main food source for dolphins, more *T.T. ponticus* and *D.D. ponticus* indivuiduals were sighted approaching the coast.

Although the observations carried-out over only 2 months (April and May) are not sufficient to establish the population status of marine mammals from the Romanian coast, an estimation of their relative abundance was made, and the figures indicate a total number of 1706 individuals in spring 2013. The distribution by species showed that the harbor porpoises recorded the highest numbers of

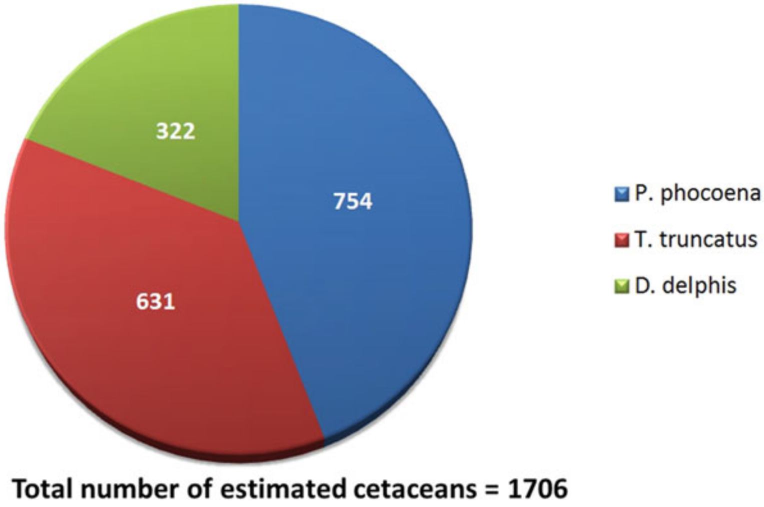


Fig. 27.13 Total number of estimated marine mammals (spring 2013) and distribution by species

individuals (754), followed closely by bottlenose dolphins (631). Fewer common dolphins were sighted (only 322, half compared to the other two species), which can be explained by their predilection for the open sea, compared to the other two more coastal species (Fig. 27.13).

27.4 Conclusions

Compared with the situation recorded as a follow-up of the last assessment carried out during the period 2001–2004 (when a total number of 1800 individuals was estimated for the Romanian coastal watets), the number of estimated cetaceans in the first semester of 2013 maintained a close value (1710 individuals), especially if we take into account the fact that the maximum peak of cetacean presence was registered then in the first months of the second semester (from July to September, when there is an increase in the number and biomass of fish species in the Romanian coastal area). The monitoring of marine mammals in the area close to the shore pointed-out that they prefer areas where fish form feeding agglomerations and their migration routes, respectively (Radu et al. 2012).

Cetaceans are the top predators of the food chain in the Black Sea and their presence in different shares is related with the food source (fish), which form aggregations under the influence of biological and hydroclimatic factors. As such, cetaceans occur infront of the Romanian coast in March–April, along with the beginning of the spawning migration of shads and turbot. The peak of their occurrence is usually during June–September, after that their number sharply decreases until mid December (in correlation with the wintering migration of fish).

In conclusion, a non-uniform distribution of marine mammals in the Romanian coastal sector resulted, with more individuals reported in the central and northern part of the coast, mainly determined by the presence of fish agglomerations.

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Chapter 28
The Black Sea Dolphin Nephron Studied by Romanian Nobel Laureate George Emil Palade

Vasile Sârbu, Raluca Melihov, and Daniel Ovidiu Costea

Abstract George Emil Palade was awarded the Nobel Prize in Physiology and Medicine, with Albert Claude and Christian de Duve for cell fractions and the most important discovery: the ribosome, (corpuscula of Palade responsible for cellular proteins synthesis), mitochondria and reticulum endoplasmic. In 1975 Palade was elected Honorary member of the Romanian Academy.

The scientific biography of Palade started in 1940 in Carol Davila Medical University with research of morphology and physiology of Dolphin Kidney.

As a student G. E. Palade was fascinated by Professor Francisc Iosif Rainer (Anatomy and Anthropology), Andre Boivin (Biochemistry) and Gr. T. Popa.

The doctoral thesis of G.E. Palade under the coordination of Fr. Rainer was about anatomical structure and physiology adaptation of dolphin kidney, the adaptation from terrestrial to sea life. The doctoral thesis of G. E. Palade remains unknown and outclassed by his research, considering "mile-stones" in cell biology. The dolphin kidney, dissected in 1939 by G. E. Palade, exists in the Anatomy Laboratory of Medical Faculty (Carol Davila University Bucharest).

We present here his medical history which started with a research of macroscopic and microscopic structures of dolphin kidney, adaptation like member and affections of nephrons. Palade thesis confirmed his hypothesis and Rainer's that dolphins descend from terrestrial mammal, although further adapted to the see life having short urinary tubs.

Keywords Palade • Dolphin nephron • Marine life • Adaptation

V. Sârbu (✉)
Academy of Romanian Scientists, Bucharest-Constanta, Romania
e-mail: vasilesarbu_cta@yahoo.com

R. Melihov • D.O. Costea
Ovidius University of Constanta, Constanta, Romania
e-mail: ralucamelihov@gmail.com; danielocostea@gmail.com

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28.1 Introduction

The dolphin has a number of anatomical and physiological features associated with aquatic living. He is a marine mammal and evolved from terrestrial mammals in last 50 million years.

Dolphins evolved in:

- Swimming, locomotion and jumping in the water;
- Thermoregulation;
- Orientation in the ocean;
- Adaptation of the deep diving (Berta et al. 2006).

28.1.1 Swimming Adaptation

- Hydrodynamic body (fusiform body shape – Raynolds);
- Maximal propulsion and minimal drag;
- The surface area of marine mammal is 23% less than the terrestrial mammals, obtained by having no hide limbs and have caudal flukes;
- Dolphins have a smooth teguments and less hair (sometimes born with hair around bears, less this hair, retains hair follicles);
- Legs diminished absorbed into the body (the ancestor of the dolphins once lived on land 50 million years ago. For new efficient locomotion, the limbs modified for propulsion and balance;
- Dolphin is the fastest agile swimmer in the world (Iftimovici 2007).

28.1.2 Thermoregulation (Heat Conservation)

- In the context of aquatic life, the dolphin has a fatty layer of blubber (under the skin which conserves body centrally while allowing the periphery to remain cold).
- Dolphins have a large body with small surface (for adaptation including decrease of surface area and increase in internal volume).
- Dolphins have warm blood, therefore they have to keep the body temperature.
- Dolphins reduce the amount of their blood when they go in contact to areas with cold water (complex circulation system in intermits is used to conserve and dissipate heat) (Lockyer 1991).

28.1.3 Orientation in the Ocean – Sensory Adaptation – Communication

- Dolphins communicate underwater with sound by echolocation, transmitting sounds and receiving echoes (Raynolds, Scheffer) – Sea Grant Alaska Mammal Adaptation.
- Dolphins emit a focused heam 1000 quickly of high frequency, by passing air from the body nares through the phonic lips.
- Dolphin has a very large brain (i.e. 2000 g). When a dolphin sleeps, only half of its brain is asleep. It swims up to the surface of the water to take a breath. A portion of the brain is still alert.
- Dolphins are often very social animals, known to help each other when one of the group is injured.
- Dolphin often hunts together and also participate migrations, in a group or individually. Echolocation is important because the dolphin needs to hunt; the night or in turbid as deep water.
- Dolphin brains process information with a very high learning ability.
- They mate for breeding but also for pleasure. The male has 3–4 females around him.
- Dolphin is a highly intelligent creature, often performing acrobatic figures above the water surface (Marine Mammals).

28.1.4 Deep Diving

- Marine mammal lungs are smaller that human but they use oxygen more efficiently up to 70% better.
- Dolphin has bright blood volume to 10–12% from his body weight.
- Dolphin have greater oxygen retention.
- Increased myoglobin make.
- High tolerance to lactic acid and carbon dioxide.
- Lungs and ribs are collapsible.
- Nitrogen absorption is limited.
- Dolphin have the capacity to reduced heart rate (bradycardia <40/min).
- Increased the amount of oxygen stored in their intern tissues.
- For prolonged submersion (hypoxia – 15–20 min under water) the dolphin can access substantial reserves of glycogen that supports for anaerobic glycolysis.
- Reduced blood flow to non vital organs.
- High hemoglobin in blood (Nicolici-Schultz and Neculae).

28.2 Material and Method

The dolphins for Palade's research were *Delphinus delphis ponticus*. They live in the Black Sea, have 1.5–1.8 m length and weight of 55–60 kg. They are part of the mammals with teeth. Living 20–22 years old and in 1940 when Palade has achieved his research on the Black Sea, living 1,5-2 million dolphins; in 1965 there were 300,000 and in 1980 about 50,000.

In the Black Sea in 1995–1998 lived 1500–3000 dolphins (in the past 50 years their numbers had decreased by 13–16 times). For hunting dolphins, Palade turned in 1938 after graduating maritime research at the Marine Zoological Station at Agigea, later on temporary belonging to the Romanian Institute of Marine Research, where he distinguished himself by contemporary research biologist Dr. Bologa. Palade was helped by then-Director, Dr. I. Popovici and Mueddin Efendi, to hunter the dolphins in Rize Anatolia. The hunting expeditions in the Black Sea were attended by collegues from University, D. Vereanu and I. Juvara, brightest future teachers in Bucharest and Professor Francisc I. Rainer, supervisor of his PhD thesis. In 1938 they hunted two dolphins and in 1939 – 14 dolphins, with Isticlar Turkish boat. This boat was used for hunting dolphins in the Caliacra area for their fat, to be sold in Germany where they used to prepared margarine. The kidneys of dolphins aboard, were preserved in formaldehyde, formalin-alcohol, and so on, and the lobules in Suza mixtures (Heidenhain) and Zenkel.

Parts for cytological research they have fixed in osmic acid, Champy, Cesa-Bianca, Flemming and Hermann mixtures, specifically in 1938–1940 period.

Palade has injected blood vessels with Prussian blue, and ureters with ink of China. Renal tubules was not injected because ink of China entered into the lymphatic system. Then he collected blood and urine samples for biochemical research.

28.2.1 Working Hypothesis

Excretory system of the dolphin has value not only by removal of the metabolic waste from body, but also in maintaining a constant internal environment. Terrestrial mammals were part of the function of excretion and through the lungs (H_2O, CO_2), skin (water, salts, etc.) which were not retained at dolphins (aquatic mammal without sweat glands, with rare breathing). Dolphins retain an increased amount of water. Therefore, Palade assumed that dolphins kidney should increase the yield of excretion. Wanted to verify how and therefore changed the architecture and function of renal excretion if there is an abundant filtering and an intense reabsorption (Ludwig's and Cuslini hypothesis). Previous studies were done on terrestrial mammals or frog (Richards).

28.2.2 *Work Method*

Palade viewed the nephrons that were reconstituted by inclusion in paraffin sections at 10 microns, then Mallory staining. First images were increased 700 times and performed by successive overlapping sections 800 image of a nephron. Unifying sectioned pieces on a table stand with some vertical rods he managed to replicate the spatial form of a nephron.

28.3 Palade's Research Results

Dolphins kidney has a considerable number of lobes with small dimensions, called renal rencul. The average size of dolphin's kidney is: 14 cm length, 7 cm diameter, 4 cm thickness, 125 cc volume, 130 g weight. It looks like a grape with "bean stuffed".

From rencul leaves a system of converging channels ending with right and respectively left ureteral. Kidney arteries enters the upper pole. Each rencul has his artery. A kidney has an average of 500 lobes (rencul) measuring 8–12 mm and have weight 0.25–0.36 g. Rencul has a 1.8 mm thick cortical and medullary has thickness of 3 mm. The total area of cortical is increased by the fragmentation of kidney in renculi. Dolphins kidney urinary tubules are short and rencul dividing lead to the existence of many nephrons compared to terrestrial mammals (Figs. 28.1, 28.2, 28.3, 28.4 and 28.5).

Fig. 28.1 The dolphin kidney dissected by G. E. Palade (1940) Anatomy Laboratory, Faculty of Medicine Bucharest

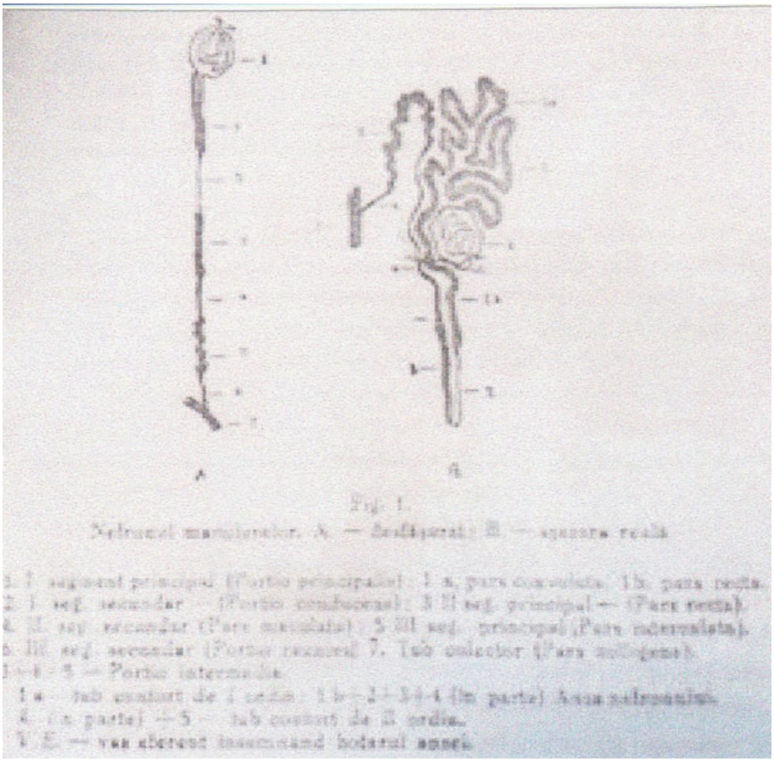

Fig. 28.2 The nephron of mammal kidney (From G. E. Palade's thesis, Bucharest 1940)

On the anterior (front) surface of the left kidney there can be seen several intertwined renculi and two trigeminal renculi (Palade 1940).

Dolphins nephron resembles in shape to that of terrestrial mammals. Dolphins nephrons are shorter than in humans. The road from glomerule (filter area) until the collector channel, therefore the tubular or resorption area, is 3 times as short as in humans. Dolphins surface of the tubular resorption is 7.23 times smaller compared with filtration surface (glomerular) (Reynolds and Rommel 1999).

Terrestrial mammals tubular surface is 13–15 times higher to resorb water. In birds this index is 23 times higher and at the reptile is very high. They have maximum tubular resorption (recovers almost all the water). They can live in dry places while the dolphin was adapted to the abundance of water:

- Increased filtration area (3 m^2);
- Increased number of nephrons (22.000.000);
- Decreased resorption surface (21 m^2) (Scheffer 1976).

As Physiology:

- Blood urea has reached 1,83 gr ‰;
- Non-protein nitrogen 0.968 gr ‰;

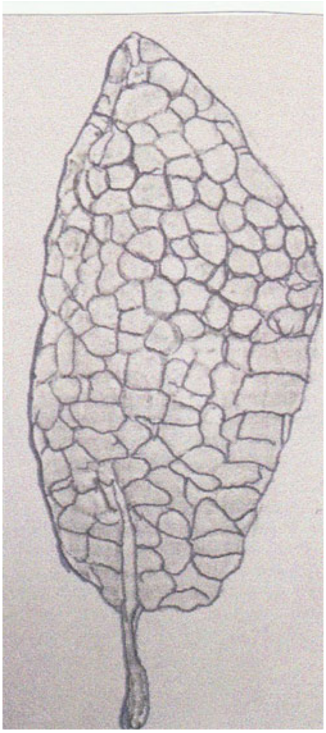

Fig. 28.3 Dolphin kidney – outward appearance

- Creatinine with high level;
- In urine: urea increased 33 times compared to blood value and creatinine increased 66 times;
- Concentration of urine is 1040;
- Nephron segment with resorption activity is lower (36% compared with terrestrial mammals where is 70–80% of tube) (The Structure and Adaptation to Living Marine).

28.4 Conclusions

1. Dolphins kidney it's like a "bunch" being composed from approximately 500 lobes. This increases cortical surface about 960 cm^2.
2. Nephron number of a middle rencul is 21.000 with a total of 22 million for both kidneys.
3. Glomerulus has 130/100 microns, and the renal tube measures 18.57 mm.

Fig. 28.4 Dolphin kidney – Branch artery and common ureter. In the cranial pole – vascular hilum with the renal artery. In the caudal pole – common uterer

4. Dolphin renal tube is shorter in the intense resorptive activity zone than that of terrestrial mammals.
5. Dolphins glomerular filtration is more intense (abundant), followed by resorption less intense compared to terrestrial mammals.

In conclusion, in his doctoral thesis held in 1940 at Bucharest University, G. E. Palade, demonstrated that the excretory system of the dolphin has adapted to life marine mammal by the several kidney lobules in his anatomy, the large number of nephrons (2 millions) and by their morphology and physiology (shorter and less water reabsorption). The thoroughness of the research since then has essentially the image of the later famous research, from US.

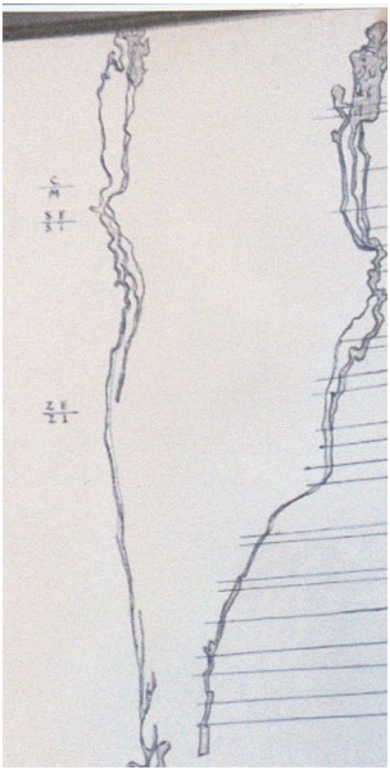

Fig. 28.5 Urinifer tubule rebuilt. *Left*: projection; *Right*: *C* cortical, *M* medullary, *E. Z.* external zone, *I. Z.* internal zone, *E. S. L.* external striae layer, *I. S. L.* internal striae layer

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Chapter 29
Effect of Water Different Salinity on the Morphology of *Kudoa nova* (Myxosporea: Kudoidae) Spores: Experimental Study

Violetta Yurakhno

Abstract It has been shown for the first time in experiment, that placing of marine species myxosporean *Kudoa nova* spores into fresh water influences negatively their construction and preservation in the case, when spores are in cysts, isolated from muscles and put to refrigerator. The percent of anomalous spores in these cysts at the 34-th day of experiment reached 87%, deformation or destruction of 48% of spores was observed already at third day. By 20-th day of experiment majority of spores and polar capsules darkened, polar filaments in such spores did not shoot being placed to 8% solution of KOH. If cysts of *K. nova* were placed into sea water and kept in the refrigerator percentage of anomalous spores made only 2–6%. But if the spores of the given myxosporean species were contained in muscle tissue and kept in waters of different salinity under natural weather conditions, then in the fresh water abnormal spores maximal share was of 17% and in the sea water – 20%.

Keywords *Kudoa nova* • Muscles • Fish • Spores construction and preservation • Experiment • Different salinity of water

29.1 Introduction

When we studied the Black Sea and the Sea of Azov fish myxosporeans we paid attention to the fact that common in the sea waters species *Kudoa nova* Naidenova, in Naidenova, Schulman, Donets, 1975 (Myxosporea: Kudoidae) either was not met at all or was represented singularly in material from the regions undergoing strong desalination. For example according to N. N. Naidenova (1974) and to our expedition researches in summer 1997–1998 this parasite species was absent in gobies, caught in the Taganrog gulf of the Sea of Azov, to which Don river inflows. In the

V. Yurakhno (✉)
A. O. Kovalevsky Institute of Marine Biological Research RAS, Nakhimov Ave, 2, Sevastopol 299011, Russia
e-mail: viola_taurica@mail.ru

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Sivash gulf of the Sea of Azov it has been started in autumn and winter, 2010–2011, that in periodically desalinated by the rice checks waters close to Mysovoye and Chaykino villages all the studied round gobies *Neogobius melanostomus* were free of *Kudoa nova*, and in sand goby *N. fluviatilis* this parasite species was found only once (Yurakhno and Gorchanok 2011). In summer 2011–2012 we observed in the Black Sea estuary zone of Dnieper river and in Bug and Wisla rivers an absence of myxosporeans in parasite fauna of round goby *N. melanostomus,* racer goby *N. gymnotrachelus*, sand goby *N. fluviatilis* and western tubenose goby *Proterorhinus semilunaris*. *K. nova* was met only once in round goby caught near Ochakov, where we observed periodic approach of the sea waters to the firth (Kvach et al. 2014). This may testify to the fact that in the zones of considerable inflow of fresh waters either possible intermediate hosts of the given myxosporeans species are absent or extremely low water salinity is destructive for its spores. To reveal survival of myxosporeans *Kudoa nova* spores when kept in different salinity waters in summer 2014 we fulfilled an experiment (Yurakhno 2015).

29.2 Material and Methods

On June 19, 2014 fresh fish (25 specimens of round goby, general length 12,7–24,0 cm), caught in the Sea of Azov near Zolotoye village and strewed with ice was transported from Kerch to Sevastopol. On June 20 the first parasitologic analysis of sample has been conducted. 48% of 15,5–24,0 cm gobies appeared to be infected; from their muscle tissue *K. nova* cysts of 0,25–0,70 mm × 1,0–4,0 mm size have been isolated. By 30 cysts of the given parasite were put into Petri dishes (60 ml water volume) with sea water (from bay near institute, salinity 17,6‰) and fresh water (from source of Maximova dacha, 0,22‰ salinity), filtered through double layer of the filtering paper; then dishes were put into refrigerator (with water temperature of +16 °C). The remaining muscle tissue from 12 infected fishes was placed into closed crystallizers (water volume 1,5 l), filled with salt and fresh water, and then placed to the window-sill in a deep niche behind the window (with water temperature at the day time in shadow +18 °C). To struggle with fungi and bacteria we added to water antibiotics with doses of 1 g of penicilline and 1 g of streptomycine for 1 l of water (Zavyalov 2007; Adroher et al. 2004 etc). Percentage of anomalous spores was counted, as a rule, from observations of more than 200–300 spores in fresh water smears.

29.3 Results

At the beginning of experiment the share of anomalous (deformed) *K. nova* spores made 2%.

On June 23 and 25 (at the third and fifth days of experiment, correspondingly) we conducted the first studies of *K. nova* spores in artificially created conditions. It appeared that in the fresh water there was considerably greater number of anomalous (deformed – with changed form of valves, with shift of polar capsules from their axes to chaotic placing) spores – from 12 to 48% in the refrigerator and from 9 to 17% under the street temperature (Table 29.1).

The anomalous spores number in the sea water in refrigerator made 4–6%, while in crystallizers behind the window their share made 4–10%. In the water media, contained in refrigerator (with water temperature + 16 °C) microflora practically was not developed, while with water temperature + 18 °C in crystallizers behind the window there was great number of bacteria in water (Figs. 29.1, 29.2, 29.3 and 29.4).

On June 30, at the tenth day of experiment we observed in the fresh water in refrigerator already 67% anomalous spores, while in the sea water in refrigerator there were only 2% of such spores. In the crystallizers under natural weather conditions we observed 11% of anomalous spores in the fresh water and 20% in the brine.

On July 4, at the 14-th day of experiment we noted in the fresh water in refrigerator 38% ugly spores and in the brine again only 2%. In the crystallizers under natural weather conditions we observed in the muscles of gobies from the fresh water 13% of anomalous spores, in the sea water spores were not found and only mass of Protozoa and bacteria was observed.

On July 10, at the 20-th day of experiment we fixed in the refrigerators in fresh water 64% of anomalous spores, in the sea water still low magnitude (3%). Great number of darkened parasite spores with dark polar capsules began to be met. In the crystallizers under the street temperature muscles in the fresh and sea water represented slimy mass in which spores were not revealed.

On July 18, at the 28-th day of experiment in the refrigerator in fresh water we found 83% ugly spores and in the sea water only 4%. Most of anomalous spores were of dark colour. Placing such spores into 8% alkaline solution KOH has shown that in such spores extrusion of the polar filament does not take place for many hours.

On July 24, at 34-th day of experiment *K. nova* spores were found only in the fresh water in refrigerator. The share of anomalous spores reached 87%.

Thus it has been revealed that already at the third day of experiment a bit less than a half of spores in cysts which were put into fresh water had anomalous construction. To the 34-th day a number of such ugly forms grew to 87%. The most comfortable conditions were created in cysts placed to the sea water in refrigerator, where to the contrary number of normal spores made from 94 to 98% along the period of experimental studies, which lasted for more than a month. As for cysts in muscles, here their location in the host tissues in a definite biochemical medium played great role in preservation of spores. In such case a number of anomalous spores in the fresh and sea water under the street temperature was correlative and quite not high – in the fresh water it varied from 9 to 17%, in the sea water – from 4 to 20%.

Table 29.1 Correlation of share (%) of *Kudoa nova* normal and anomalous spores kept in different conditions with different water salinity

		In fresh water in cysts in refrigerator		In sea water in cysts in refrigerator		In fresh water in muscles tissue in weather conditions		In sea water in muscles tissue in weather conditions	
Date	Day	Anom. spores	Norm. spores	Anom. spores	Norm. spores	Anom. spores	Norm. spores	Anom. spores	Norm. spores
23.06.14	3	48	52	6	94	9	91	10	90
25.06.14	5	12	88	4	96	17	83	4	96
30.06.14	10	67	33	2	98	11	89	20	80
04.07.14	14	38	62	2	98	13	87		
10.07.14	20	64	36	3	97				
18.07.14	28	83	17	4	96				
24.07.14	34	87	13						

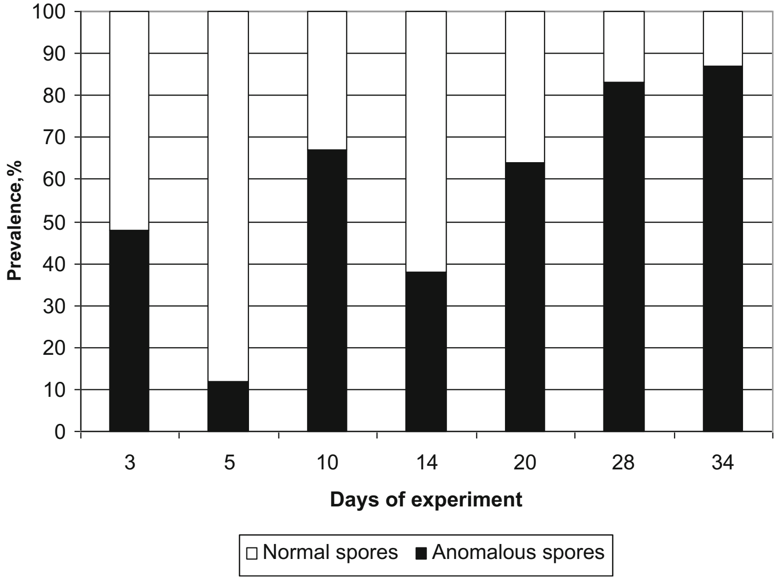

Fig. 29.1 Percent correlation of anomalous and normal spores of *Kudoa nova* in cysts, placed into fresh water and kept in refrigerator

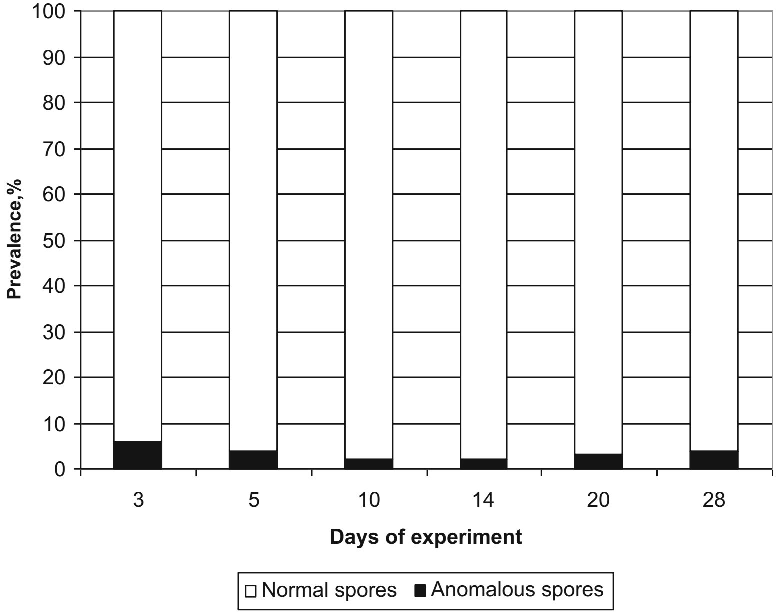

Fig. 29.2 Percent correlation of anomalous and normal spores of *Kudoa nova* in cysts, placed into the sea water and kept in refrigerator

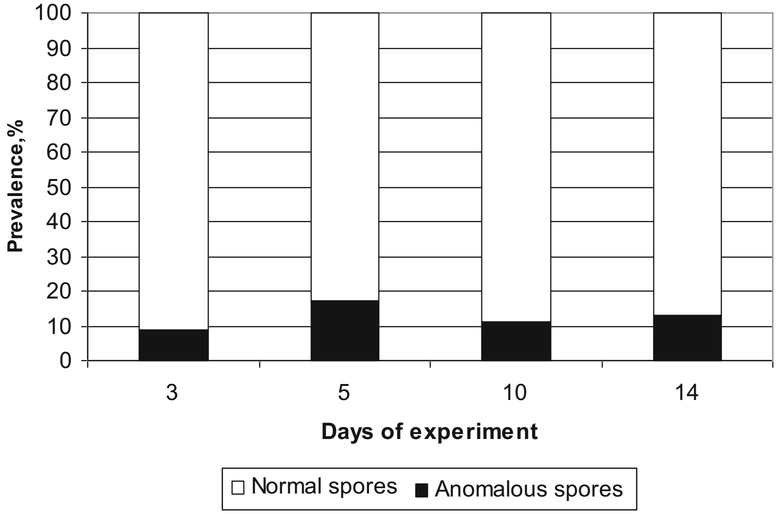

Fig. 29.3 Percent correlation of anomalous and normal spores of *Kudoa nova* in muscles, placed into fresh water and kept under natural weather conditions

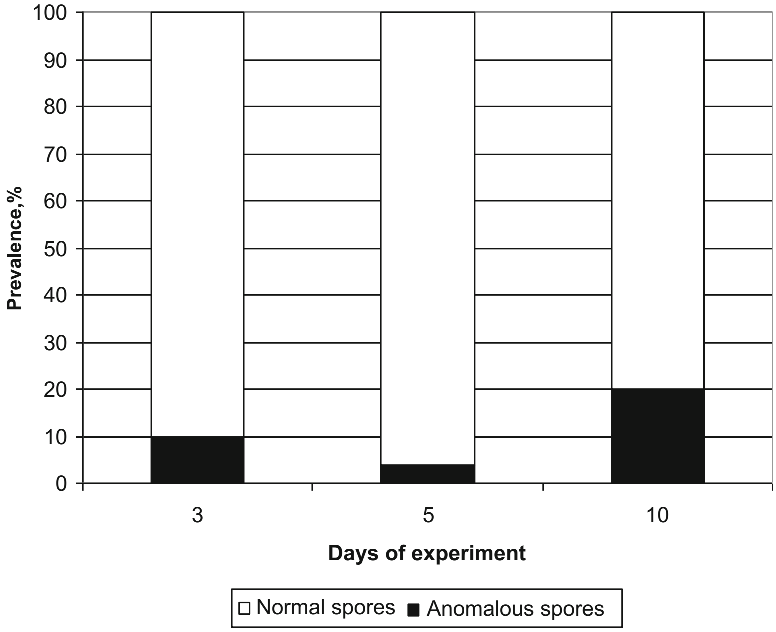

Fig. 29.4 Percent correlation of anomalous and normal spores of *Kudoa nova* in muscles, placed into the sea water and kept under natural weather conditions

29.4 Discussion

There exists extremely small number of experimental investigations on myxosporeans spores survival in the waters of different salinity. The first information appeared in 1901, when E. Linton placed representative of the fresh water genus of *Myxobolus* – *M. lintoni* – into the sea water, in which its spores could without any harm for them exist 10 days (Linton, 1901). The papers of M. Auerbach (Auerbach 1907, 1909) are also known: he conducted an experiment on effect of the fresh water on representative of the same genus *Myxobolus* – eurihaline parasite *M. aeglefini* from cods. It appeared that the given parasite species became a real oceanic species, spores of which perished after more than 12-h being in the fresh water. But spores of parasites *Fundulus heteroclitus* – *Myxidium folium, Myxobolus subthecalis, M. funduli, M. bilineatum* had similar life period in the fresh water and in 1% solution of the cooking salt (Bond 1938). As for the data on survival of the spores of just marine myxosporeans species in water of different salinity, such data are absent completely. In a whole there exists an opinion that marine myxosporeans are studied worse than these fresh water ones, and the main is that they underwent ecological analysis to the less extend (Schulman et al. 1997).

In experiment we conducted about half of the marine myxosporeans *K. nova* species already at the third day felt negative influence of the fresh water, expressed in deformation of spores in cysts isolated from muscles. And this took place despite the fact that spores are very firm and theoretically had to preserve themself longer in the foreign medium. It is well known that *K. nova* bears non-considerable desalination and is much more abundant in the mesohaline shallow Sea of Azov, if compared with the Black Sea. But clean fresh water is a factor effecting negatively composition and condition of spores of the given parasite under its direct contact with foreign medium. When the parasite spores are in the muscle tissue under temperature higher than in refrigerator percentage of anomalous spores in the sea water is higher than it is with cysts isolated from muscles in the sea water in refrigerator and practically is similar with a share of deformed spores in muscles placed into fresh water, kept under natural weather conditions. The biochemical medium of the host organism softens the fresh water negative influence on *K. nova* spores.

It is known that myxosporeans spores changeability having place in nature is often connected with environment unfavorable conditions effect on them (Schulman et al. 1997). It is expressed in changes of spores size and their form and construction. The fact of deformation of *Myxidium giardi* spores from the New Zealand eels from the lake Otomangakau with unfavorable conditions, and absence of polar filaments shooting in the anomalous spores placed into alkaline solution like in our data were described by P. M. Hine (Hine 1978). He connected disturbance of normal life activity in ugly spores with changes in their chemical composition (vanishing of magnesium in valves) and with their functional activity (impossible extrusion). There are most often changes in a number of valves and polar capsules in the many-valves myxosporens spores. Deformation and darkening of spores of *Kudoa* genus representatives under unfavorable water salinity are described for the first time.

29.5 Conclusions

The marine species of *K. nova* myxosporeans reflects negatively its cysts placing into the fresh water, in which spores darken and deform with time, and sometimes destruct themselves. In such spores polar capsules do not shoot out when submerged into alkaline solution, and disturbance of the darkened spores life activity is observed. Location of spores in muscles placed into the fresh water softens negative influence of low salinity and keeps number of anomalous spores at not high level, like in the case of presence of such spores in the sea water. The best results in spores preservation are observed in the sea water, placed in refrigerator.

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Part VII
Ecology

Chapter 30
Population – Structural and Functional Basic Element of Bioceonosis and Species. The Role of Population in the Knowledge of Species Autecology

Nicolae Doniță and Stoica Godeanu

Abstract Every species exists in nature only as one or more populations. They may be investigated in different ways by biologists and by ecologists (in ecology a special branch deals with population ecology – autecology).

To study the ecology of an individual species does not mean to study autecological peculiarities of a single population, but of a multitude of populations within the areal of respective species, searching intrapopulational and interpopulational relationships, their relations to the abiotic environment and the manner of their participation to processes of production, transfer, consumption and decomposition of biomass and necromass, as well as the specificity of energy transfer.

The aim and the role of autecological investigations are highlighted, and the place of this branch among the other fields of ecology. It may be best realized using intensely the mathematical processing of the data.

Keywords Population • Species • Autecology • Areal • Biocoenose • Ecological parameters • Adaptation

30.1 Population, Biocoenosis and Species

Both for biologists and for ecologists the species is represented by a multitude of individuals which have the same biochemical, genetic, morphologic, physiologic, behavioral peculiarities, which live under the same environmental conditions, forming populations in which they live and reproduce. The species must be seen a single whole. However,

N. Doniță
Academy of Agricultural and Forestry Sciences from Romania, “Gheorghe Ionescu-Sisesti”, Bdul. Marasti Nr. 61, 011464 Bucharest, Romania

S. Godeanu (✉)
Academy of Romanian Scientists, 54 Splaiul Independentei, 050094 Bucharest, Romania
e-mail: stoica@bucura.ro

C.W. Finkl, C. Makowski (eds.), *Diversity in Coastal Marine Sciences*, Coastal Research Library 23, DOI 10.1007/978-3-319-57577-3_30

- for biologists, the species is a taxonomic category composed of individuals which are identical from many points of view;
- for ecologists, the species is represented by populations composed of individuals belonging to the same species, characterised by a high fidelity for living in specific biocoenosis, which live under specific environmental conditions and forming together a specific hierarchic unit called an ecosystem.

The best knowledge of population is essential both for biology (through taxonomy), and for ecology (through autecology).

Ecology approaches the living world from a certain biological level upwards, i.e. that level of the living world depends on the component of non-living environment, namely from the population (Bavaru et al. 2007; Botnariuc 1976) (Fig. 30.1)

The species exists in nature only through its populations which live in ecosystems (Bavaru et al. 2007; Bick 1998; Dediu 2007). These populations contribute actually to building the ecosystem structure and functioning; at the same time, they are structural components of the species and fulfil different functions which ensure its existence, perpetuation and evolution. And it must be noticed that this process occurs in fact through the interrelations within the ecosystems, which are informationally controlled by genetic features peculiar to the species, which take place both in populations and in metapopulations (recombination, mutation, selection and gene migration, natural selection of living beings). These relations determine the improvement of the species, through new ecological adaptations, but, also, through the generation of subspecific mutations, which leads to the emergence of new species.

The species is a genetic entity which occurs and performs evolution through the relations of its populations within ecosystems, having, hence, a pronounced ecological causality. This fact is, so far, poorly considered in the manifold definitions of the species.

This is the reason why although the populational level exists both in biology and in ecology, it is seen and approached in different manners.

Population has been defined since the past century as « a group of organisms of one and the same species which populate a biocoenosis » (Du Rietz 1930, cit. Donita and Ivan 1977). This short, but comprehensive definition, emphasizes a very special reality of the living world – the occurrence of a connecting entity between species and biocoenosis: the population of organisms, as a common feature of the two great supraindividual units of the living world.

An accurate recognition of the populations of different species which compose a biocoenosis allows a good progress of ecological investigations.

Winthin one biocoenosis, each species is represented by one distinct population, which has its own ecological niche (Brewer 1994; Chapman and Reiss 1992; Dediu 2007).

Intense ecological investigations from the last half of the 20th century proved the existence of populations and showed their role in structure and functioning of the biocoenosis and their influence upon the habitat – the abiotic environment in which

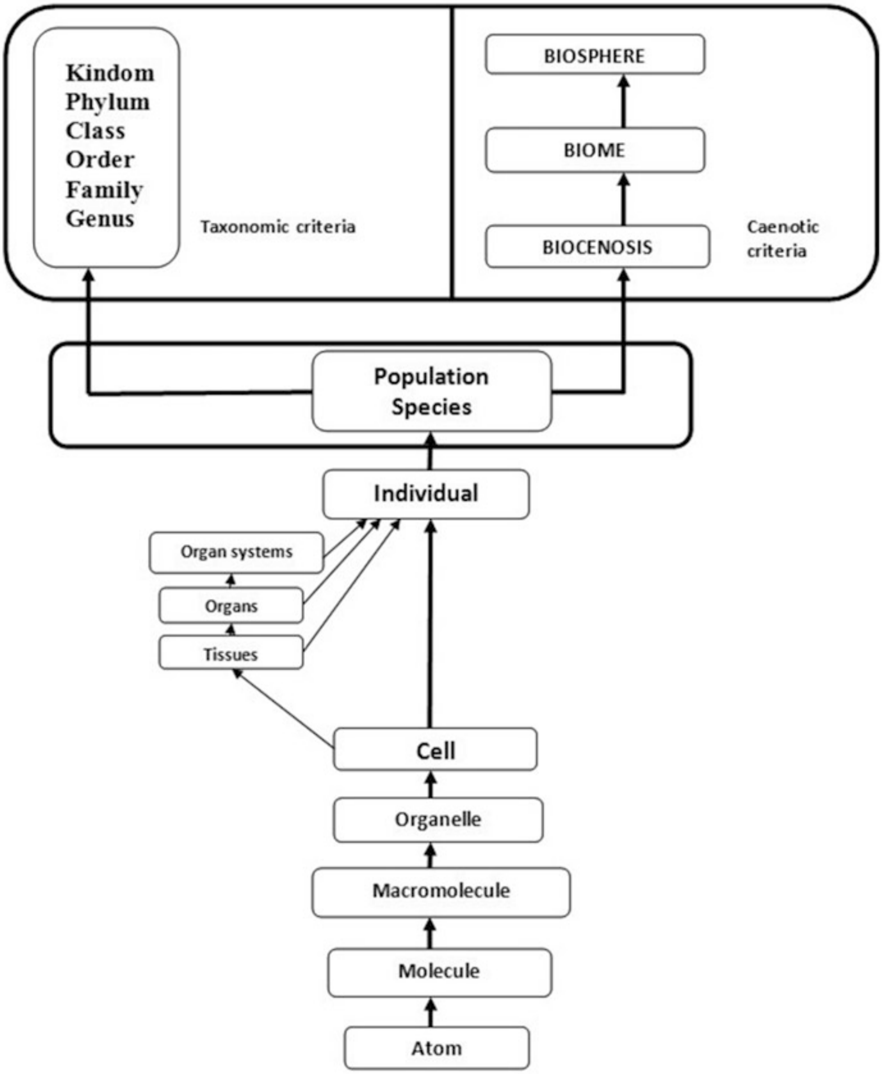

Fig. 30.1 Hyerarchical relations in biology (Bavaru et al. 2007, modified)

the biocoenosis lives, i.e. the ecosystemic role of populations (Bick 1998; Begon et al. 1986; Brewer 1994; Chapman and Reiss 1992).

It was ascertained that the biocoenosis is not a simple, random mass of different organisms, associated by chance, but an integrated system of populations belonging to different species, which present adaptations allowing them to live together, using an appropriate environment, and making up with it an ecosystem.

It was pointed out that populations themselves have a certain organisation and through their intra- and interspecific relationships interact with non-living environment, develop and maintain ecosystemic processes – biomass production, consumption and decay of necromass; this way the populations influence in their turn the abiotic environment.

In all these studies the ecologic aspect of populations was taken into consideration, which were denominated as «ecological populations».

We think that too little attention was paid to the role of populations – as ecological entities – within the structure and processes of the species.

The population of a species appears only in certain biocoenosis – namely in that where it may develop and reproduce within the characteristic ecological niche of that species. These characteristics determine the size of the population and the its role in the processes running within that biocoenosis. Depending on these biotic and abiotic relations, a population may appear (or not) in a certain biocoenosis.

Within the framework of a biocoenosis there are some species whose populations play a prevailing role within its entire activity and, also, occur populations with a secondary, even minor role. From the ecological point of view, in a biocoenosis the population of a species is a feature that may be characterized through the frequency of its occurrence, through the constance of its appearance (as accidental, accesory or constant presence), through the fidelity to respective biocoenosis (being a characteristic, preferential, casual or ubiquiste species), through density (high or low); it may belong to a specific trophic level, or may represent a true knot within the trophic network of the respective biocoenosis are ensured.

As a consequence, the species is not a simple multitude of similar organisms randomly occurring in a geographic space called areal, but forms units composed of populations which exist only in certain types of ecosystems within that areal. These types represent in fact the definite areal of the species, which was described as «ecological areal» (Donita and Ivan 1977; Godeanu 1998).

Populations of a species occurring in a precise type of ecosystem are similar, because they develop under similar biotic and abiotic conditions and may be classified in types of populations. There are certain species whose populations occur in a single type of ecosystem – as the characteristic species for a certain ecosystem. There are also some species with a simple populational structure, unipopulational, characterized by a reduced ecological amplitude. Most are the species with a more complex populational structure, which apprear in several, even in more types of ecosystems. They are multipopulational species, with a large ecological amplitude, sometimes even very large – as the invasive species, the dominant species etc.

The ecological population is an example of how, through a simple element, simultaneously, the building up and the functioning of the species and the biocoenosis are ensured.

In biological research it is well known that every species occupies a certain territory, which is called an areal. Within this areal, the occurrence of the species may be continuous or discontinuous. In the case of the species with a large areal, there may appear some more or less distinct subspecies (hence, speciation occurs through disjunctive evolution).

From the point of view of ecological research, the features are a little more shaded. Because a species is represented by different populations, which belong to a certain type of biocenosis (which, in their turn are integrated in similar or different ecosystems). As a result, the areal of a species is determined by the number and the dispersal of these ecosystems. Because of the variety of the elements of the abiotic environment within the areal of respective species, even in the case of a defined ecosystem type (for instance, deciduous forests, marine stony costal areas, or swamp ecosystems) the structure of the biocenosis is not the same, because the ecological niches of the populations belonging to different species will not be the same. Moreover, between these populations occur – more or less frequently – exchanges of individuals which – joining a new population, bring their own genetic inheritance and the peculiarities of the ecological niche from which they came. As a consequence, their entering into another population represents for this an enrichment from the genetic and ecologic points of view. These newly arrived individuals determine an increase of diversity and stability of the entered population, reducing, also, endogamy processes, otherwise inherent.

If a species is eurioic, hence it has a high capacity to adapt to broad variations of biotic and abiotic factors, it is really an eurioic species; it is able to be a part of the biocoenoses from a large range of ecosystems. Therefore it has an increased capacity to survive. That seems to be a good thing. But ... in the case it enters a weakened ecosystem, characterized by a reduced ecological stability, i.e. a more brittle ecosystem, the respective species occupies the ecological niche of another, more feeble species, which is thus eliminated; the newly entered species thus becomes an invading species. This situation is more obvious in the case when several ecosystems suffer perturbations (usually due to human bad interventions – pollution, chemical treatments, hydrotechnical developments – as man-made reservoirs, overexploitation etc). So, invasive species may seriously disturb their ecological balance.

Within the population of a species, the individuals have to adapt continuously to the oscillations of environmental specific features. This way, the resulting adaptations may be gradually included into the genetic inheritance of the respective population.

Some species may have a single population; these are unipopulational species, and they are deeply endangered by extinction. Other species have numerous populations, which live either in a single type of ecosystems, or in many ecosystems. They are multipopulational species.

Population is a proof how the living nature, through very simple elements, but through complex actions, generates complicated functions which ensure the existence, development and perpetuation of life on our planet.

Within the areal of a species two identical populations do not exist. The more distant the populations, the more different their ecological niches. This situation stimulates segregation of the species in subspecies which, gradually, by successive adaptations will lead to apparition of new species. Even before speciation, individuals, from very distant populations will interbreed with difficulty with individuals of local population, or death rate of the descendants will be much higher.

30.2 Role of Population in Assessment of the Autecology of Species

Ecology is defined as the science of the interrrelations of organisms with their biotic environment (i.e. with organisms from the same species, but also with organisms from other species) and abiotic environment (with the features of the habitat, which is used but, also, influenced by living) (Bavaru et al. 2007; Bick 1998; Brewer et al. 1994; Godeanu 2013).

It is determined by the influence of abiotic environmental factors (i.e. the fluctuation of abiotic features) and that of biotic environment (i.e. of intraspecific and interspecific interrrelations within the biocoenosis), hence, by the characteristics of the ecosystems where they are living.

Ecology was developed initially by botanists and zoologists, as species ecology. There were considered especially the relations of species to abiotic factors: climatic (light, heat, water) and edaphic (moisture, trophicity, acidity), either on land (relief, rocky substrate), or in waters (depth, pressure, salinity).

There are a lot of such classifications of plant or animal species (light sensitive/ombrophilous, thermophilic/cryophilic, acidophilic/baziphilic, oxyphilic/oxy-fuge etc). There were also investigated more carefully concurential connections related to natural selection (protocooperation, mutuality, predation, parasitism, commensalism, amensalism, neutrality etc) (Begon et al. 1986; Brewer et al. 1994; Chapman and Reiss 1992; Odum 1971; Whittaker 1975).

The investigations carried out proved that these relations determine the occurrence of different adaptations: morpho-anatomic, biochemical, physiologic, behavioral or genetic.

The adaptations are those modifications of the organisms which allow the species to exist, to reproduce and to evolve in a certain environment or in several, different, environments.

The adaptations have a qualitative character. For instance, plants developed a lot of adaptations vs. water regime – the structure of root system, protective covers of the stems, of leaves, seeds, osmotic pressure, phenology); animals living in water habitats adapted to water flowing velocity, to attachment to substrate or to rapid burying in sediments in littoral zones of vawe breaking, to salinity (for instance anadromous or catadromous migrations), to water pressure etc.

In essence, every individual species has a number of specific adaptations, which are present within all its populations and are transmitted by heredity. This is the qualitative side of species autecology.

When the study of the communities of living organisms related to their abiotic environment developed, in ecology appeared a new course, by investigation of biocoenotic relations and of biocoenosis' relations to abiotic environment.

In order to distinguish between these two branches of ecology, the following terms were introduced: autecology – for species ecology and synecology – for biocoenosis ecology. And the study of populations, in this new branch of ecology, demonstrates that autecology itself, how it was conceived and applied till now, has to be reconsidered. And this can be done only if the populational structure of species is taken into consideration.

Apparently, autecology deals with the study of the relations of a species to its life environment. One of us (N.Doniţă) states that autecology is the totality of the adaptations to the biotic and abiotic way of life, during the course of evolution, adaptations which are assigned by heredity.

Ecological populations of a species, through the relations within the ecosystems where they occur, acquire certain quantitative characteristics, not hereditary, which depend on the environment of each type of ecosystem. These characteristics, which may be expressed as several ecological values, are classified as:

- A. Structural parameters: types of biocoenosis to which they belong, size of population (number or effective), density, specific adaptations to environmental features, frequency, level of aggregation, rate of apparition/disappearance, rate of increasing/decreasing of population size, genetic structure;
- B. Functional parameters: age structure, sex ratio, birth/death rate, growth rhythm, ingesta/excreta, basic metabolism, bioaccumulation, dynamics of biomass augmentation, specific chemical compounds, energy budget, gross production, net production, necromass production, spreading in territory, specific adaptations to oscillations of environmental features;
- C. Behavioral parameters: way of life, biorhythm, intraspecific relations (feeding, reproduction, social relations, self-defending relations) and interspecific relations (trophic, cohabitation, competition, symbiosis, tolerance, self-defending, sheltering etc).

These population parameters point to the quantitative side of species autecology.

Adaptation to the peculiarities of an ecosystem – the first organization level in ecology – was achieved gradually and evolved continuously, it corresponding to evolution stage of respective ecosystem (juvenile, maturity or senescence). From our point of view, the population of a species is in a continuous adaptation to the oscillations of all environmental factors. And these adaptations must be, always, adequate to reality. In a contrary situation the population suffers, mortality increases, and the population becomes vulnerable in competition with the other species of that biocoenosis. This process of adequate adaptation determines – at the population level – permanent, quite imperceptible changes, even change of genetic characters which, this way, may become hereditary.

All the species show adaptations to each environmental factor (considered separately), but also to certain sets of factors (climate, water chemistry – for aquatic organisms, soil chemistry, periodical or accidental variations of weather features, pollution etc) (Odum 1971; Brewer et al. 1994; Chapman and Reiss 1992).

Adaptations may have different amplitudes. In certain cases, such modifications of the entire population are quite subtle; in other cases, there are deaths of part of individuals, and behavioral or physiological changes occur. If a species is euryoic, it will tolerate easier the changes; if it is stenoic, sacrifices will be more important. Moreover, the populations of euryoic species can live in a lot of types of ecosystems, while the stenoic ones – only in one type of ecosystems. More adequate are these adaptations, higher population survival rate, and these populations will have a better place in the structure and functioning of that biocoenosis.

Ecological adaptations, as features of stability, appear in functioning of population and individuals, both qualitatively and quantitatively, but only at the level of each population of the respective species. They are better evidenced through assessment of populational indexes of the species from each type of ecosystems. This fact is important, because they are not considered as individuals, seen separately, but are analysed as multitudes, more or less homogenous of individuals taken as samples from the same population.

Adaptations to the biotic and abiotic start at biochemical, physiological or behavioral levels and appear at the population level in a statistical way. They became distinctive at one time (Attention! not at the level of the entire species, but within each population which is an element of a biocoenosis from a certain type of ecosystem).

Adaptations have a certain amplitude and always they are adequate. If an inadequate modification appears, it is eliminated by natural selection and results in the death of that new individuals. It is a hard selection, based on the rejection out of population of the individuals who do not have the respective adaptation. Through these adequate adaptations may be ensured the survival of respective population.

It is possible that during adaptation process the number of individuals of the respective population will diminish. If the adaptations are done quickly, the number of individuals will increase, the ecological niche of that population will become steady and as a result, the respective population will play a more important role in that biocoenosis.

The following adaptations are emphasized:

– Climatic adaptations – to main climate types (equatorial, tropical, subtropical, temperate, boreal, arctic), to all periodic oscillations – diurnal, seasonal, annual and multiannual;
– Edaphic adaptations – referring to soil or water salinity, to the presence of some chemical compounds, limiting to primary producers, to the presence of some toxic substances, pesticides, pollutants etc.;
– Coenotic adaptations – to the associations of organisms with which they interact within that biocoenosis (for instance adaptations to the relations with the organisms belonging to the same trophic level, relations prey/predator, symbiotic relations, relations with decomposers, equilibria between all the intrabiocoenotic components, to the response versus the population of some invasive species etc).

Briefly, multiple adaptations of the populations belonging to each species have to result in the formation of some broad ecological niches, fluctuating, perfectly adequate for survival within the respective biocoenosis, but also, to the oscillations of biotope features. And this, according to the Commoner's law "all are connected to all" (Comoner 1972).

In their turn, ecosystems occupy parts from the areal of respective type of ecosystems. In this large area, the climate is not homogenous; relief may be various; there are also important hydrologic differences etc. This means that, within the large areal of an unique type of ecosystem, the living organisms of the biocoenosis will differ, both qualitatively, and quantitatively. Moreover, they will react differently to abiotic features.

Hence, in comparison with the types of adaptation presented before, which referred to an ecosystem occupying a certain place within the general areal of respective ecosystem, now we can see that there are important differences from north to south, from east to west, differences determined by relief, by exposure to solar light, differences due climatic, edaphic, chemical and coenotic factors.

In case of eurioic species, hence of that living in different areals and in more types of ecosystems, appear more complications.

Coming back to autecology, we must agree that the research cannot be performed “in general”, but concretely, at the population level. Hence, if each ecosystem is, in fact, unique, then every population of every species (which represents its biocoenose), is different from the population of seemingly similar ecosystems (for instance a population from different coral reefs, that from different eutrophic lakes, from oligotrophic bogs, from oak forests or from alpine shrubs etc). It results that each ecosystem, though it has the same name, has its own biotope and biocoenose, which are similar, but not identical with others. Biotope differences will determine biocoenoses composed by populations of different species, characterized by different structures and functionalities.

So it means that to study the autecology of a species cannot be done by investigating the « species » in general, not even at the level of a single population, but processing representative samples from a lot of populations from the same type of ecosystem, located in various sites. Autecological research must be done very carefully, very minutely, based on compiling data obtained from a lot of populations occurring in various ecosystems. You can realize now how difficult is to study the autecology of an eurioic species which can live in a lot of types of ecosystems (not only a single type). And all the obtained data must be, continuously, processed mathematically!

Hence, autecology must achieve much more than has been achieved so far.

30.3 Conclusions

Two categories of conclusions can be drawn:

30.3.1 Referring to the Representation of the Species Through the Component Populations

Species has a twofold conditioning – ecological and genetic.

Species are represented by populations. They occur in nature only through these populations, which, themselves, are integrated in biocoenoses, in ecosystems respectively.

Population is the structural and functional element of the two great supraindividual life units – species and biocoenosis.

Through intra- and interpopulational relations, as well as through their relations with the abiotic environment, populations participate in production, consumption and decomposition of biomass and necromass. But, at the same time, through these relationships, controlled by genetic information system, the existence, perpetuation, stability and evolution of the species are ensured.

30.3.2 Referring to the Target and the Role of Autecological Researches

- Autecological research is the result of studies upon populations belonging to different biocoenosis from different ecosystems;
- Autecological research concerns some populations from different ecosystems of the same type, but located – geographically and climatically – in different locations at planetary level, within the areal of respective species and of the ecosystem type;
- Autecological research will highlight the structural and functional differences between the investigated populations, the presence of metapopulations (if they exist), the ecological differences between the subspecies of each eurioic species etc.;
- Autecological research will be able to explain the passage of the individuals of a certain species from one population to another, the manner of migrations from one population to another, the role of invasions, the decline of certain populations within an ecosystem and their development in a similar ecosystem;
- Autecological research will result in a more complex, a more genuine understanding of the ecological niche of each species;
- Autecological research becomes the study of species adaptations and adequateness to a certain life environment;
- Autecological research must emphasize the adaptations of a population for improving its ecological niches;
- Autecological research has to become imperative within the studies concerning the evolutionism. Only it could explain the way(s) of present evolution of species;
- It is necessary the extension of the series of analytical ecological indexes, then creation of some synthetic indexes, able to a better processing of indices proceeded from a lot of populations of respective species;

- Finally, transition from pure autecological research to computer modelling of analysed processes, in order to do prognoses concerning the behaviour of analysed species, its future.

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Chapter 31
The Marginal Biological Indicators – An Efficient Tool for Ecological Monitoring of the Marine Environment

Yuvenaly P. Zaitsev

Abstract As a result of matter and energy accumulation in the marine contour (marginal) biotopes, communities of plants and animals (contourobionts) adapted to specific conditions of these edges of the sea are developed. Because of numerical superiority of early ontogenetic stages of aquatic organisms, contour biotopes and communities are responsible for the reproduction of many organisms, including commercially important species. Due to natural physical and chemical processes, in the same biotopes accumulate different substances, harmful for living organisms. In consequence of this, the main critical zones of the sea are forming just here and first victims are among contourobionts, figuratively named "Environmental sentinels". They need to be monitored in the first place.

Keywords Contour biotopes and communities • Contourobionts • Environmental sentinels • Ecological monitoring

31.1 Introduction

Among many topics of marine life sciences a growing interest recently acquired two research lines: the investigation of biological diversity and the assessment of the environmental state of marine ecosystems. They are interrelated, because the biodiversity is an integral indicator of the status of an ecosystem, and the latter reflects the changes, occurred in the biological diversity.

The outstanding scientist V.I. Vernadsky (1968), first President of the Academy of Sciences of Ukraine, set forth the concept of concentration of "living matter" (the totality of living organisms) at the external boundaries of the sea, namely, water surface (according to Vernadsky, the upper 50–100 m of the pelagic zone, populated by chlorophyll containing phytoplankton), sea bottom (practically the entire

Y.P. Zaitsev (✉)
Department of Biological Science, Institute of Marine Biology – National Academy of Sciences of Ukraine, 37 Pushkinska Street, 65011 Odessa, Ukraine
e-mail: yuv.zaitsev@gmail.com

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shelf zone) and, particularly, the coastline where the former two boundaries meet (Ayzatullin et al. 1979). The upper water microlayer, named neustal (Zaitsev 1974), is inhabited by neustonts – a large variety of organisms, adapted to its conditions. The monitoring of marine neuston is an efficient method of assessment of the ecological status of the marine water surface. The author's proposal to implement this method in ocean ecological monitoring was supported by the UN GESAMP Commission (1995).

31.2 Discovery of the Marine Neuston

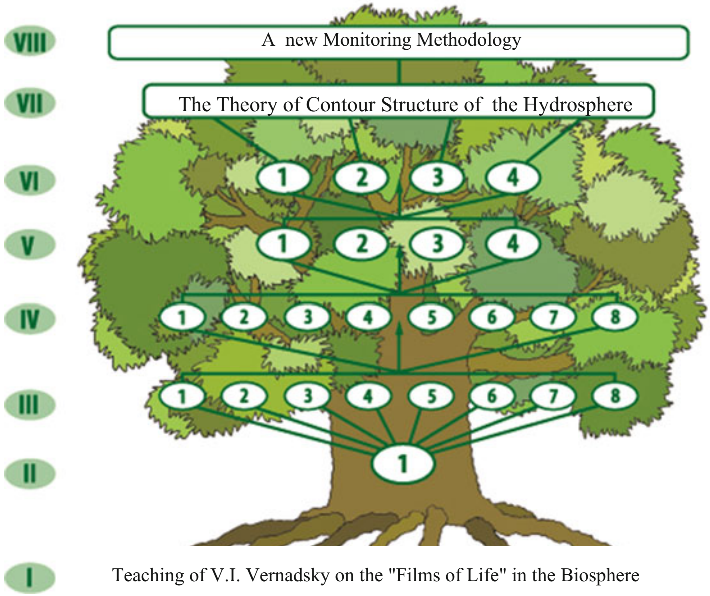
As a result of permanent matter and energy inflow on the sea surface, a specific community of organisms and an unknown before ecomorph (life form) was evolutionary developed (Zaitsev 1960, 1971; Aleyev 1986). It was discovered with nets of original construction (Zaitsev 1964) and named marine neuston – a global scale community composed by many species of bacteria, unicellular algae, fungi, invertebrate, fish eggs, larvae and fry. All of them are well adapted to specific environmental conditions of the surface pelagic biotope – the microlyer of 0–5 cm, named "neustal" (Zaitsev 1971, 1974; Konstantinov 1986; Romanenco 2001; Dediu 2010).

The inhabitants of neustal biotope, or neustonts, have an intensive protective coloration against UV radiation, against predators from the water and from air, appropriate behavioural reactions (Zaitsev 1971, 1974, 2015). Thanks to the predominance of early ontogenetic stages, the marine neuston is thea key community responsible for the reproduction of many organisms, including commercially important species of fish and invertebrate.

Comprehensive study of marine neuston, of its structure, composition, conditions of existence, functioning has created a new "Tree of Knowledge" from previously unknown facts and phenomena that determine the life of all the pelagic and benthic zones of the sea (Fig. 31.1).

31.3 Other Contour Biotopes in the Marine Environment

Similar physical, chemical, and biological processes in other contour biotopes of seas and oceans occurs, confirming the Vernadsky's fundamental idea of "Life films" and identifying within them, a kind of "ultrafilms". As regard of this, the concept of contour biotopes inhabited by organisms-contourobionts was proposed (Zaitsev 1986, 2008, 2015). According to this concept, there are distinguished following contour biotopes: the aerocontour, or neustal (the upper 5 cm of the sea surface bordering with the atmosphere), psammocontour (sea-sandy beach and sea bottom, in the area of the water line), lithocontour (sea-rocky shore and bottom), pelocontour (sea-muddy shore and bottom), biocontour (the surface of living organisms), and the potamocontour (sea-river water masses interface). All of



VIII. Development of monitoring methodology "Environmental sentinels" for the marine environment.
VII. Elaboration of the theory of contour structure of the hydrosphere.
VI. The study of other ultrastructures (contour habitats and their communities) in the Vernadsky's biospheric films.
1. Psammocontour, 2. Litocontour, 3. Pelocontour, 4. Potamocontour, 5. Biocontour.
V. The biospheric significance of marine neuston, as an ultrastructure (aerocontur) of the Vernadsky's euphotic film.
1. Neuston, as a "nursery" of early stages of development of marine organisms.
2. Neustal as a feeding ground of aquatic and terrestrial consumers,
3. Neuston, as an ecological target in seas and oceans.
4. Neustal, as an important "hot spot" in the marine environment.
IV. The study of environmental conditions in the marine neuston biotope (neustal).
1. Penetration in the sea water column of visible rays of solar spectrum,
2. Presence in the neustal of infrared and ultraviolet rays,
3. The biologically active properties of the sea foam,
4. Air bubbles arrival in the neustal,
5. Chemical ecology of the neustal,
6. Radioecology of the neustal,
7. Double press of predators in the neustal,
8. Neustont's reaction to environmental factors.
9. Bioindicators among neustonts.
III. The study of marine neuston components and their distribution
1. Bacterioneuston, 2. Phytoneuston, 3. Miconeuston, 4. Zooneuston,
5. Ichthyoneuston, 6. Planktoneuston, 7. Benthoneuston, 8. Neuston of temperate, high latitude, tropical areas of the world ocean and large continental water bodies.
II. The discovery of marine neuston on the surface of the Black Sea.
I. Teaching of V.I. Vernadsky on the "Films of Life" in the Biosphere.

Fig. 31.1 The discovery of marine neuston and study of its phenomenon. Creation of a dendrogram "Tree of Knowledge" these biotopes are inhabited by a large variety of organisms, well adapted to respective living condition and are composed by different species with predominance of early ontogenetic stages of invertebrate and fish.

In the same habitats accumulate many substances that are harmful for living organisms, especially for early ontogenetic stages – eggs and larvae (Zaitsev 2008, 2012a, b; Zaitsev and Polikarpov 1964, 2002; Patin 1977). As a result of this, here are forming the main hotspots and critical ecological zones in seas and oceans.

Contourobionts are the first organisms in the marine environment, contacting with life-threatening factors and reacting to them by population size reduction up to their complete disappearance in some areas, and in other ways, and signaling of this to those whom it concerns. They got a figurative name of "Environmental sentinels" and recommended as priority species for environmental monitoring facilities (Zaitsev 2012a, b, 2015; Alexandrov and Zaitsev 2016).

In our practice of the Black Sea ecological monitoring, this methodological approach proved to be much more effective, than the traditional one. Facts, confirming the contour structure of seas and oceans, on the one hand specify previous author's ideas on life distribution in the marine environment and in continental waters (Zaitsev 1986). On the other hand, they point necessity of a new approach to assessment of the aquatic ecosystems' state. Traditionally such assessment of seas and oceans is carried out on the basis of survey of the whole water column, by mean of allocation of hydrographic profiles and sampling at all depths of the water thickness and bottom, although this is the most stable and inalterable marine environment.

Along with the water column (pelagial) and the bottom (benthal), the contour, or marginal biotopes are forming a very specific category of habitats in the marine environment. Up to this day, the best studied among them is the aerocontour, inhabited by neustonic organisms (Zaitsev 1971, 2012a, b).

Environmental processes in contour biotopes are developing according to the other scenario, then in the water column. Modification of the habitat conditions here leads to sharp decrease (or increase) of diversity and numbers of populations of organisms, which all their life or at least early ontogenesis stages occur mainly or exclusively in contour biotopes. Many of such species living in contour biotopes are especially sensitive indicators of the marine ecosystem state. They were figuratively called "Environmental sentinels" (Zaitsev 2015).

The idea of the Environmental sentinels appeared at the author during the study of changes in the ecosystem of the Black Sea. This inland sea is an excellent pilot area for researches of the reaction of marine environment to different kinds of man-made impacts. It is in the Black Sea, earlier than in other seas of Europe, have been observed and investigated strong effects of eutrophication, anoxic events, profound changes in species diversity, disappearance of populations of some native species and the emergence of new populations of exotic origin species, change of the trophic structure of communities, etc. (Zaitsev 2008).

31.4 Environmental Sentinels Monitoring in the Black Sea

On the north-western coast of the Black Sea, in the 1979–1980 the population of typical "environmental sentinel" – the brown alga *Cystoseira* (two species) was practically disappeared along the 300 km of the Ukrainian coast (Eremenko 1969, 2006), or drastically reduced in number along the Romanian coast (Bologa 1990). At the same time, besides the extinction of *Cystoseira*, which was a dominating algal population in the lithocontour to the late 1970s, have been disappeared its epiphytic algae *Stilophora, Dilophus* and other, and *Cystoseira*'s, biocoenosis on the whole, composed by dozens of species of invertebrate and fish in the northern part of the Black Sea. The same was the fate of populations of polychaetes *Janua pagenstecheri, Pomatoceros triqueter* and *Ophelia bicornis*, bivalve *Donacilla cornea* and the oyster *Ostrea edulis*, inhabiting the psmmocontour and lithocontour (Zaitsev 2015). At present, only along the Crimean coast two species of *Cystoseira* remained (Milchakova 2003). Species of *Phyllophora* and *Sargassum* also are quite sensitive to eutrophication. The latter occur on the southern (Anatolian) coast of the Black Sea (Zaitsev 2006).

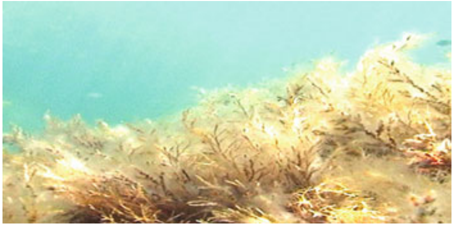
In the north-western shelf zone drastically (tens or hundreds of times) decreased the number of copepods Pontellidae, larvae of Decapoda, larvae and fry of grey mullets (*Mugil, Liza),* sole (*Solea),* garfish (*Belone),* dragonet (*Callionymus*) and other fishes, inhabiting the aerocontour. It became slowly recover only since 2000s, when the man-made impact on the Black Sea became somewhat less. However *Cystoseira* along the main part of the North-Western coast is still absent.

Some representatives of the Black Sea environmental sentinels are shown in Fig. 31.1.

Bivalve *Donacilla cornea*

Polychaete (bristle-worm) Ophelia bicornis

Brown alga *Cystoseira* sp. (a healthy specimen)

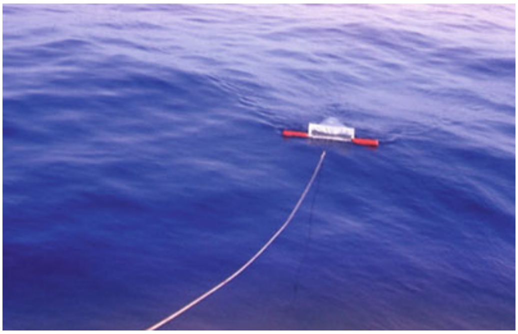


Brown alga *Cystoseira* sp. (unhealthy specimen, covered by filamentous algae)

Polychaete *Janua pagenstecheri*

Polychaete *Spirobranchus tiqueter*

Left: a fry of grey mullets (*Mugil cephalus, Liza saliens*), with air sac on the dorsal side (Zaitsev 1963). *Right*: A flock of grey mullets, hatched from neustonic eggs in the open sea, and without leawing the neustal, migrating to the costs in search of feeding grounds in shallow water bays, lagoons, limans and estuaries. The species diversity and the number of grey mullet fry, coming to the shores, is a good biological indicator of ecological state of the sea surface during the corresponding spawning season



A Neuston net of original construction (Zaitsev 1964)

Unlike the traditional methodology, the monitoring of Environmental sentinels does not require large research vessels, sophisticated equipment, costly cruises, and it allows to involve in this very exciting and practically important work young people under the guidance of experienced biologists. In this way, all the edge of the sea, inaccessible for research vessels, but ecologically extremely important area, could be monitored. The significance of the environmental education of youth and training of environmental ethics rules in this case, can not be overestimated.

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Part VIII
History of Oceanography

Chapter 32
Development of International Cooperation in Oceanography: Incentives from Science, Services, Economy and Security

Gunnar Kullenberg

Abstract The ocean acts as the great integrator of the Planet through transport, redistribution and even recycling of heat, freshwater, chemicals, organisms and other organic material, and much if not most material and waste resulting from human activities. The role of the ocean is acknowledged in the United Nations Convention on the Law of the Sea, UNCLOS. This constitutes "a comprehensive regime dealing with all matters relating to the law of the sea. . .bearing in mind that the problems of ocean space are closely related and need be considered as a whole". Marine research is addressed in a separate part of the Law of the Sea, part xiii. This includes stipulations on international cooperation, which should stimulate the ocean science community, just as the fact of a separate chapter in a major international law ought to raise the status of oceanography in Governments.

However, UNCLOS entered into force at the end of 1994 and international cooperation in ocean research and observations has been in progressive development for about 150 years. Its success is well demonstrated through global programmes addressing many issues of great importance for environment, development, economy, services and security. The results together with related technological developments concern transport and maritime safety, fisheries, mariculture and food security, climate and global change, infrastructure and coastal protection, warning systems for tsunamis and other hazards from the ocean, forecasting of climate-related phenomena like El Nino and the Indian Ocean Monsoon, marine pollution and related effects, availability and economy of non-living marine resources. Some highlights of this international cooperation and the associated institutional developments are presented.

The main aim of the paper is to elucidate incentives and their implications for the development of the cooperation. These are related to scientific necessity in view of the ocean dynamics as well as to the dependence of human development and society on the ocean, coastal areas, the marine environment as a whole and its resources. Apart from the scientific need these incentives concern the issues referred to, together with sustainable development, including of the ocean economy. By

G. Kullenberg (✉)
IOC, Global Forum on Oceans, Coasts and Islands, Stromstad Academy, Stromstad, Sweden
e-mail: gkullenberg@gmail.com

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addressing these and other problems in a fairly comprehensive way oceanography and ocean observations are providing many services and opportunities to society. However, oceanography is still fragmented and not acknowledged in society or Governments in the same way as hydrology and meteorology, and achieving sustained ocean observations are facing problems. Some ideas on reasons for this situation and the relatively weak visibility and status of oceanography in Governments and social perception in general are discussed.

Keywords Ocean • Marine research-resources-environment • International cooperation • Security • Climate and global change • Sustainable development • Incentives • Governance

Acronyms

DOALOS	Division of Ocean Affairs and Law of the Sea, of the UN
IAPO	International Association of Physical Oceanography (now IAPSO)
ICES	International Council for the Exploration of the Sea
ICSU	International Council of Scientific Unions (now ICS)
IOC	Intergovernmental Oceanographic Commission
IDOE	International Decade of Ocean Exploration
IOI	International Ocean Institute
IUBS	International Union on Biological Sciences
IUGG	International Union on Geology and Geophysics
SCOR	Scientific Committee on Oceanographic Oceanic Research
UNCED	UN Conference on Environment and Development

32.1 Introduction: The Role of the Ocean

Covering 71% of the Earth, the ocean is a vital source of nourishment, supporting directly the livelihood of about 500 million people, especially in the poorest nations, and indirectly the global population. Food from the ocean is vital to human health and brain development. Recent economic assessments assign to the Gross Marine Product an annual value of about 2.5 trillion USD, of the order 3–5% of global GDP, not including much of the coastal areas. Mann Borgese (1998) arrived at a higher value of about 7–8 trillion including services as transport, food, energy, deep sea cabling, tourism, recreation. Marine and coastal resources and industries represent over 5% of global GDP. For many nations the ocean-related economic activities such as tourism and artisanal fisheries are major contributors to the national economy and development, supporting up to 30% of the national economy. Over 90% of the world trade is carried by the sea, currently at a value of about 13 trillion USD, having increased from about 7 trillion in early 1990s. Ocean economies are among the most rapidly growing in the world, providing benefits to many sectors of great economic value, including fisheries, energy, tourism and transport, as well as to climate change regulation, carbon sequestration, habitat, biodiversity and influence on human health and well-being. Additionally, the ocean biological system offers exciting opportunities for the development of new drugs to treat many human ailments, such as asthma, tuberculosis and cancer. Marine biotechnology is a rapidly rising industry. Financial benefits from worldwide sales of marine biotechnology-related products are estimated to represent at least a multi-billion dollar market. Economic losses can be very substantial due to coastal erosion, degradation of coastal seas, removal of discarded material and marine litter or debris, disturbances or failure of aquaculture and fisheries, contaminated marine food and swimming areas by both dissolved substances and particulate, suspended matter such as microplastics. In addition large losses of human life and infrastructure are common due to natural hazards from the ocean. The situation gives many incentives and opportunities for science, technology and cooperation.

The deep ocean is still the last frontier of the planet, and the ocean and its seas are still most shared by nations, exploited and least well known. It appears that the resources in the ocean, on and in the seabed, represent a very large treasure for humankind; this possibly being the case, why are they far from completely mapped and the inventory very incomplete? The ocean bathymetry and tectonic conditions are poorly known and incompletely mapped at the same time that the processes there appear to have considerable influences on the conditions on the planet. This situation is mirrored in the Resolution of the General Assembly "Transforming our World: the 2030 Agenda for Sustainable Development, Goal no 14: "Conserve and sustainably use the oceans, seas and marine resources for sustainable development."

The interdependence, the global interconnectedness in context of achieving sustainable development has been well recognized in relation to the world ocean. Many countries have sea coasts and make use of the sea and the waters of the ocean. The contents mix and interact without regard for human interference. The ocean has played a leading role for development of international cooperation, trade and exchange. This has been manifested in our time through the United Nations Convention on the Law of the Sea of 1982 which entered into force in November 1994, providing the rule of law for the ocean. The same sentiments were demonstrated in the presentations of several ocean science, observation, data and information exchange and training programmes of the IOC and partners in the book "Troubled Waters: ocean science and governance", prepared for the fiftieth anniversary of the IOC (Holland and Pugh 2010). Its overall message is "that governments need to work together with greater urgency, to address the many natural and man-made issues concerning the ocean; they need understand better the role that ocean science can play and they need to develop much stronger ocean governance mechanisms to profit from the knowledge obtained." This harmonizes well with the message and aim of the 2030 Agenda.

32.2 Overview of Present Issues and Science Challenges Concerning the Ocean

The major issues concerning the marine environment include: pollution, waste and contamination; overfishing; warming; and acidification. There is also great concern, including among the public, for changes of the ocean currents, from swimming to basin-wide scales, sea-ice melting, sea-level rise, coastal flooding, extreme weather events and changes in their frequency, environmental impacts of aquaculture, effects of marine invasive species, losses of biodiversity and coastal erosion. Public perceptions also show strong connections to marine and coastal environments affected by aesthetics, identity, practical considerations of access, livelihoods, assessment of impacts on marine wildlife, and clean energy production. International evaluations of human impacts on the marine environment do not assess the public awareness and perceptions, concerns and priorities (Gelcich et al. 2014). Public attitudes and understanding is a key to successful implementation of changes, and public perceptions need be taken into account in specifying national programmes, management decisions and interventions.

The scientific community has identified the leading 20 marine research questions as follows (From Rudd 2014):

Cumulative stressors;	Climate change mitigation and manipulation;	Ecosystem structure to service linkages;
Ocean productivity;	Global biodiversity and ecological function;	Thermohaline circulation;
Ocean acidification;	Benthopelagic coupling;	Coral reef management strategies;
Monitoring cumulative effects;	Science communication;	Cross-disciplinary ocean science and management;
Oceanographic data;	Contaminants;	Energy development
Biodiversity contributions to ecosystem function;	Top predator decline;	
Greenhouse gas flux;	Climate change-induced species dispersal;	

This is based on a broad survey of scientists covering 94 countries. Five of the top 10 research priorities were shared by respondents globally. Seven of the top 10 priority questions were shared by physical and ecological scientists: cumulative stressors (1); ocean productivity (2); ocean acidification (3); monitoring cumulative effects (4); oceanographic data (5); greenhouse gas flux (7); and climate change mitigation and manipulation (8); the global ranking in parenthesis. However, only the cumulative stressors question was among the top 10 priorities for social scientists. Many of the high priority questions for social scientists were low in ranking order for natural scientists. Many social scientists top-ranked science communication (1), risk assessment for governance (2), and ocean literacy messages (4), all of which point at the interest in the purpose of environmental management and normative aspects of our relationship with the environment and of interpreting, integrating and advocating science by engaging in the policy process. There were also differences in the rankings between regions. Furthermore, the rankings do not reflect the research priorities of society as a whole or of government policy makers.

Reports from the World Bank and the European Commission, according to Rudd (2014), point to an increasingly held view of the ocean as the driver of economic and social well-being as well as the importance of safety and security, all influenced by the ocean conditions; the realization requires the health of the ocean to be restored and maintained (Rudd 2014). The European Environment Agency (2014, cited by Rudd) states: *"Our seas are rapidly changing while our dependence on them is growing. We do not fully understand the complex interactions of natural and human-driven changes. But we do know that we are not yet on the path to achieving healthy, clean and productive seas"*. Rudd (2014) concludes that his results "provide insights as to how research scanning results can be synthesized and used to target ocean research on questions which, if answered, would be central to achieving ocean sustainability". They also provide stimulation for interdisciplinary and trans-disciplinary research and cooperation.

The results by Rudd were supported by a Nordic Study (W. Boonstra, Marine Policy; cited by Catherine Jex 2016). According to that study marine scientists identified overfishing as a top concern, followed by elevated temperature, contamination and waste, and ocean acidification. Differences depended upon the scientific background. Natural scientists stress the symptoms of global change driven by human impacts, whereas social scientists tend to focus on human causes of the threats. The review by Williamson et al. (2016) highlights the main science issues raised by the G7 Science Ministers namely plastic pollution, deep-sea mining and its ecosystem impacts, ocean acidification, de-oxygenation, ocean warming, biodiversity loss and marine ecosystem degradation, as the areas on which to focus scientific efforts to find proper and economically valid solutions.

The silent services of the ocean in the context of global and climate change include (Stocker 2015): the ocean uptake of over 90% of the excess energy in the climate system, confirmed by observed warming on a worldwide scale to depths over 2000 m; the ocean as a receiver and global distributer of the excess water from melting land glaciers and what melts of the ice sheets of Greenland and Antarctica, this and the warming driving the sea-level rise; the ocean absorption of up to 30% of the carbon dioxide emitted by society and about 28% of the cumulative anthropogenic carbon dioxide emissions from 1750 to 2011 now stored in the ocean, roughly equivalent to the amount taken up by the land biosphere. The price for the ocean uptake is ocean acidification, which has reached great depths. The implications of this include gradual calcium carbonate under-saturation, the critical threshold of which can be predicted, probably with the smallest uncertainty of all projections of future change related to the climate issue. Model simulations suggest this threshold will first be crossed in the Arctic. The specific Sustainable Development Goal target 14.3 calls for minimizing and addressing impacts of ocean acidification, including through enhanced scientific cooperation at all levels.

The Scientific Advisory Board of the United Nations (UNESCO 2016) stressed eight grand challenges which were categorized as serious problems of the entire world community. Number one of these concerns "improving ocean science and governance for the development of sustainable ocean knowledge-based economies", and number five concerns "averting human disasters through prediction of extreme environmental events." The Board recommends that to "address these grand challenges the United Nations should press for greater collaboration among international science networks, including professional societies and academies, and indigenous and local knowledge holders." The First Global Integrated Marine Assessment (World Ocean Assessment 1 2016) concludes that "many parts of the ocean have been seriously degraded", and that "the general threat to the ocean comes from a failure to deal quickly with the manifold problems described in the assessment", as well as independently by the scientific community. The reason for the failure is, following the assessment, related to, even due to, lack of integration of scientific results into management. The problems must be addressed in order to avoid a major risk that they combined drive a destructive cycle of degradation of the ocean life-support system through which it can no longer provide many of the benefits our society currently derive from it. This would seriously limit our means to reach the visionary goal of Sustainable Development. The multiple, cumulative stressors constitute a priority research area. The First World Ocean Assessment (UN 2016) confirmed this in concluding that we are running out of time to effectively protect the world ocean from multiple interactive stressors. This in itself provides ample justification for a consolidated global effort. The problems and priorities are known and documented. Hence now we need to orient ourselves towards providing science-based solutions. It should be noted that the evaluation of the seriousness of the problems largely depends upon science. Finding solutions will also depend upon science and technology, involving several science disciplines and engineering. However, most of the problems are due to our actions and uses of the whole environment. This implies that the society as a whole must be involved in addressing the solutions. This includes besides all the scientific disciplines also policy- and decision-makers and the public, a truly holistic approach. The scientific community has an additional large responsibility in delivering the science results in a timely and understandable fashion, with communication to all these user sectors.

32.3 The Development of Organized International Cooperation in Ocean Research

Early international cooperation related to ocean science concerned marine meteorology, weather observations and information on ocean surface layer currents from ships observations and drifting. Such regular observations were organized into international cooperation in the 1850s. They primarily provided services to shipping and fisheries, the transport and food producing sectors of our society.

Subsequently it was realised that organized international cooperation could be very beneficial for obtaining scientifically based information with respect to the role of the ocean conditions for fish production, including as regards physical and biological conditions, providing advice on the fisheries yield. This organized international cooperation came gradually to feed into fisheries management. This resulted in the establishment in 1902 of the International Council for the Exploration of the Sea, following a series of intergovernmental consultations. Likewise the Commission for Scientific Exploration of the Mediterranean and the Indonesian Fisheries Council were created as formal organizations. However, even if international cooperation in ocean research focusing on physical and chemical oceanography was organized in some regions during the initial decades of the 1900, it was not until well after World War II that such organized international cooperation gradually matured over a period of 2–3 decades. The global expeditions of Swedish and Danish origin with Albatross 1947–1948 and Galathea 1950–1952, respectively, brought use of new technologies into focus leading to major new scientific results, in some cases even breakthroughs, in geophysics and sedimentology, in ocean physics, chemistry and biology. These considerable efforts by small countries also involved international cooperation on individual scientific basis, and stimulated new thinking.

Subsequently in the 1950s several consultations were hold involving leading scientists and organizations as ICSU, IAPO, IUBS and IUGG, on how best to organize constructive and persistent international cooperation in ocean science. The coupling between physical, chemical and biological processes and conditions in the ocean together with the ocean dynamics required interaction between scientific disciplines as well as international cooperation. Furthermore the ocean could not be studied fruitfully without taking into account the ocean-atmosphere interactions, as well as the coupling between the ocean and the other compartments of the environment. At the same time the very limited capacities to do advanced ocean research were serious obstacles. Only very few leading institutions had the capacity to drive extended deep ocean research. The limitations were noted both as regards human resources and infrastructure. How attract well qualified scientists to this new field and how attract sufficient funding? The early efforts had been based on private donations. The social factors as well as the dynamics and size of the ocean made internationally organized cooperation necessary, but also not easily achieved. The scientific fisheries services were organized at the regional level. For the ocean research generally, however, the global or planetarian basis was regarded as more appropriate. ICSU and UNESCO took up the challenge.

Following consultations between leading scientists, ICSU established a Special Committee on Deep-Sea Research which met in 1955. The Committee argued that the main problem was to "apply recent great developments in all basic sciences to the study of the ocean to bring about a level of understanding of the earth and of living organisms." (Wolff 2010). It concluded that more knowledge of the ocean biology should stimulate revisiting studies of terrestrial organisms and help elucidate further the evolution and distribution of plants and animals. The Committee stressed that problems related to the origin of continents and ocean basins, forces in the interior driving formations of mountains, volcanism and earthquakes, and the processes changing the atmosphere and hydrosphere cannot be solved without extensive exploration of the ocean. The cooperation between scientists from many different disciplines was considered to be even more necessary in the future. In light of all this the Committee recommended the establishment by ICSU of a Special Committee for Oceanic Research (Wolff 2010). The activities of the proposed committee should take note of actions of intergovernmental bodies as UNESCO, ICES and others. The non-governmental character of the proposed committee could constructively supplement the work of these other bodies. The recommendation resulted in the creation by ICSU of SCOR in 1957.

The Special Committee on Oceanic Research was given the initial task to continue the oceanographic programmes initiated during the International Geophysical Year 1957–1958 for a 5 year period (Wolff 2010). The method of organizing the specific scientific work through dedicated working groups was adopted. This brought scientists together, which had been an essential aim, to formulate and specify programmes to address the problem areas and agree on distribution of implementation. Much new technologies had been developed for different applications, and they could be applied in ocean research. The aim was to make this a reality. This should stimulate well qualified scientists to do ocean research. The incentives were the opportunities to do science in a new realm using new ideas and technologies. The working groups generated contacts between scientists, stimulating cooperation and preparation of joint proposals, pooling of limited resources, human and equipment, including between different disciplines.

In parallel to this development UNESCO continued exploring the interest and possibility of creating an intergovernmental mechanism dedicated to ocean science, observations and related education and training. It soon became clear that there was a strong need for involving the governments in the global efforts concerning the strenghtening of ocean science, observations and capacity development.

The need for cooperation involving also the governments in such global efforts became clear. The intergovernmental need in relation to ocean research was evaluated already soon after the War through UNESCO by a committee of oceanographers and biologists meeting in spring of 1947 at the Royal Society. They expressed strong support for creation of an organized platform for such cooperation. The meeting was followed up by another one in 1950. However, it took a decade until the intergovernmental UNESCO Conference in Copenhagen in July 1960 reached agreement on the establishment of the Intergovernmental Oceanographic Commission. The scientific community had expressed its support and the Conference was needed to confirm the commitment and involvement of the governments. UNESCO had accordingly prepared a draft agreement which was accepted with minor amendments. The support of the major powers at the time UK, USA and Soviet Union was secured with participation of the leaders Drs Deacon, Revelle, and Zenkevitch. The leader of the 'Galathea' expedition Dr. Anton Bruun referred to the acceptance from the governments as "the largest milestone in the history of ocean research". The ocean research had so far been mainly supported by private efforts. The research community had problems to obtain support from and get the attention of governments. It was necessary to bring the governments to participate in an organization they had accepted. UNESCO was ready to provide the required financial resources. From the UNESCO perspective the main interest was the need for education and training of human resources to do ocean research and be able to use the results. The lack of human resources had been identified as one primary reason for the limited development of ocean research. The need was management and proper utilization of ocean resources and in particular the marine living resources, although large amounts of non-living resources had also been found on and in the sea floor, documented through several evaluations and publications in the 1960s.

The new body was called upon to cooperate with other relevant bodies, in particular SCOR, but also regional organizations like ICES. It should coordinate projects already planned by UNESCO in cooperation with SCOR, which was an advisory body to the IOC from the start. In particular the Indian Ocean investigation was to become a flagship undertaking through the International Indian Ocean Expedition project.

In parallel to the process of establishing the IOC, efforts were underway to lay the foundation for an international law for the ocean, the uses of its resources and other services. This was triggered by the increasing "terraneization" of ocean space through offshore extension of the national sovereignty and jurisdiction. In the beginning the IOC acted within the legal framework of the four Geneva Conventions on the Law of the Sea of 1958. These covered the continental shelf, the high seas, the territorial sea, fishing and conservation of the living marine resources of the high seas, with little attention to marine science or observations. This was not an integrated approach, and from this perspective the First and Second Law of the Sea Conferences in 1958 and 1960 were not successful. Another decade was to pass before the newly independent developing island state Malta brought up the matter in such a convincing way that the UN General Assembly took action. The development and negotiations for the Third UN Law of the Sea Conference was strongly pushed by the young developing states. The successful completion, signing in 1982 (UN 1983) and entering into force end of 1994, was very much due to the united, cooperative efforts of these developing and coming countries. These were not much involved in the creation of the IOC, but came gradually to understand its importance in the 1970s and 1980s. The negotiations for the Law of the Sea, in which the IOC participated, played a large role in this process and so did UNESCO. The scientific community and UNESCO saw the coincidence of the need and the opportunity of the combined interest of scientific enquiry, development and economy, and acknowledged the role of international cooperation. The Law of the Sea which entered into force in 1994 provides the legal framework within which the IOC acts.

Another important non-governmental mechanism for cooperation and dialogue, research, education and training was also created a decade later based on the idea of a constitution for the ocean, leading to the UN Convention on the Law of the Sea, UNCLOS (UN 1983). The birth of this mechanism was the convening of a series of workshops and a major international conference in 1970 in Malta, the home of

Arvid Pardo, who in 1967 had stimulated the UNGA to take action on the subject of a constitution for the ocean as a whole. The Malta conference generated several significant publications dealing with the marine environment and marine sciences, disarmament in the marine sector and the legal and institutional structure of the ocean regime. The group of people organizing the conference and publications needed an organization so that they could continue to provide inputs to the negotiations for the ocean constitution. The organization came into being through support from private donors and a grant from UNDP. The organization under the name International Ocean Institute was formally established in 1972 at the University of Malta (The IOI Story 2001). The process demonstrated the ability of the ocean sciences community to cooperate across disciplines and provide constructive contributions to legal and economic areas. The efforts continued including also education, training and communication with the public and various communities highly dependent upon the marine environment. Major contributions of the IOI included the peace in the ocean (Pacem in Maribus) regular conferences covering all elements of ocean science and governance, with emphasis on a holistic approach in research and training, treating the ocean as a whole in harmony with the Law of the Sea.

A significant lesson from these developments over two decades is the very important role of individuals, accepted scientific leaders able to communicate across disciplines and interests, having as a basic principle of thinking through the problems before taking action and reaching agreement while at the same time being reasonably pragmatic in view of the significance of the main goals. The international cooperation during the cold war was stimulated by the desire to keep exchanges and data flow in place, address various security interests, and maintain dialogue. Many were the interests as elucidated in the study of oceanographers and the cold war (Hamblin 2005), not always motivated by serving the common good.

32.4 Can the Ocean Science Community Deliver the Solutions

Since the creation of these organizations the ocean sciences and marine technology and related capacities have developed so that an overall goal of finding solutions to the challenges of the ocean can be achieved through concerted, cooperative and well coordinated support and action. The ocean dynamics require that ocean research is international and cooperative. A significant manifestation of all this is the generation and successful completion of the International Decade of Ocean Exploration 1971–1980 (IOC-UNESCO 1975).

Systematic oceanographic research was initiated only in the second half of the nineteenth century. The global research cruise of *HMS Challenger* starting 1873 provides a landmark for development and support of ocean research. Almost 100 years later the International Decade of Ocean Exploration was conceived by the US National Council of Marine Resources and Engineering, chaired by the US Vice President, in 1966. The Council argued the case for such a collaborative global effort on the basis of *"food for the world population, maritime threats to world order, waterfront deterioration in coastal cities, increased pollution of the shoreline, expanding requirements for sea-bed oil, gas and minerals, and expanding ocean shipping."* The idea of an ocean decade was announced in March 1968 by the President of the United States as "an historic and unprecedented adventure", (National Academy of Sciences 1969) with the underlying position stated by the same President in 1966 that *"Under no circumstances must we ever allow the prospects of rich harvest and mineral wealth to create a new form of colonial competition among the maritime nations. We must be careful to avoid a race to grab and hold the lands under the high seas. We must ensure that the deep seas and the ocean bottom are, and remains the legacy of all human beings"*. This constituted a foundation and position for the Law of the Sea, as well as for sustainable development: all elements of sustainable development are included in the Law of the Sea, which also includes the idea of peace and security. The concept of the Common Heritage of Mankind was first discussed by the General Assembly in 1967 following an introduction on ocean development by the Ambassador of Malta, Arvid Pardo, in context of the opportunity of preservation of the sea-bed and ocean floor exclusively for peaceful purposes. In 1970, the General Assembly adopted a Declaration of Principles, on basis of negotiations in the Committee on the Peaceful Uses of the Sea-bed and ocean Floor beyond the limits of National Jurisdiction. The Declaration stated that *"The Sea-bed and ocean floor, and the subsoil thereof, beyond the limits of national jurisdiction......as well as the resources of the area, are the Common Heritage of Mankind"*, and shall not be subject to appropriation by any means by States or persons, and *"the area shall be open to use exclusively for peaceful purposes by all States..., without discrimination."* These clauses reflect the declaration of the President of the United States leading to the International Decade of Ocean Exploration. The Marine Council sought international support for the Decade. Following consultations, the IOC in June 1968 recommended support for the IDOE. In December the same year the UN General Assembly endorsed "*the concept of an IDOE to be undertaken within the framework of a long-term programme of research and exploration designed to assist in a better understanding of the marine environment through science."* The Decade, initiated a century after the *Challenger* expedition, marked a major turning point in ocean exploration and changed the science of oceanography (Report by NSF on IDOE, in "The discovery of Hydrothermal Vents", 25 Anniversary, WHOI 2002).

The efforts, spirit and opportunities of the International Decade raised considerable support from governments for ocean research and observations, stimulated much interest in the ocean and the marine environment, the marine resources and their use and management. One of the major discoveries was that of the deep sea hydrothermal vents with their exceptional ecosystems. The example demonstrated the limits of our mapping and knowledge about the ocean floor. Although somewhat improved and extended our quantification of processes at the water-sediment interface and the mapping of the ocean floor are not satisfactory and far from complete. The large role of the ocean for the human environment and health was furthermore brought out at the UN Conference on the Human Environment, Stockholm 1972. During the IDOE the negotiations for the law of the sea were initiated and almost completed with signature in 1982. The research during the IDOE also triggered and stimulated support for several large scale global ocean research programmes becoming parts of the World Climate Research Programme and International Geosphere Biosphere Programme, as well as studies of marine pollution including biological effects, interaction between physical, chemical and biological processes. Sustained observations, monitoring and warning systems attracted increasing attention, including for seawater and sea food contamination, and algal blooms. The international reviews of the health of the ocean by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) were initiated, with the first completed in 1982, 10 years after the Stockholm Conference. At the end of the Decade in June 1981 the IOC requested its advisory bodies to make a study of "expected major trends in ocean research up to the year 2000 (UNESCO 1984).

The successful generation and completion of the IDOE demonstrated that the drive for cooperation in ocean sciences became a success, leading to attraction of gifted scientists from several disciplines to do ocean studies, with new technologies for observations and experiments. The vision of the founders of SCOR proved to be realistic. It should be noted that the cooperation was developed and tested during the cold war. The last two decades of the Century saw the development of the Sustainable Development paradigm, the UN Conference on Environment and Development, Rio 1992, resulting in the Rio Declaration, Agenda 21, and conventions on climate change and biological diversity, and several follow-up meetings, including on intergovernmental programmes regarding Small Island Developing States, control of land-based sources of marine pollution and addressing risk reduction.

In the new Millennium the global framework of international agreements has been further developed through the Outcome Document of the Sustainable Development Conference Rio + 20 in 2012; the Small Island Developing States SAMOA Pathway of 2014; the SENDAI Pathway for Risk Reduction of the 3rd UN Risk Reduction Conference 2015; the results of the UNFCCC-COP 21 in Paris 2015, in addition to the new Sustainable Development Goals and the 2030 Agenda.

The implementation of all these international legal instruments and agreements requires large efforts at national level with coordinated and cohesive programmes responding to the specific needs at national level, as well as to the regional and global requirements. In order to achieve this there is a strong need to strengthen the dialogue, interaction, cooperation and coordination between institutions and sectors at national and international level, as well as between scientific disciplines, observations and services. This aspect is particularly important for the ocean. Although some frameworks have been agreed, for instance with respect to sustained ocean observations, data and information exchange, capacity building and development, more needs to be done, including in economic terms. The growing pressure on the planet seems to motivate further coherent, consistent and cooperative efforts towards more complete understanding, knowledge and mapping of conditions and inventories of the ocean, including the sea floor and interactions between the subsoil and the ocean. The pressure and concerns furthermore emphasize the need for scientists and policy makers to work together.

The ocean is a necessary compartment of our common heritage and an important part of many cultures. Coastal States around the world, in particular Small Island Developing States, are striving to protect and valorise their marine resources. The development of science-based and integrated management frameworks as Marine Spatial Planning, Integrated Coastal Area Management, Marine Protected Areas and Large Marine Ecosystems become a prerequisite to ensure sustainable economic activities, and help ensuring long-term protection of ocean ecosystems. The globalization requires safe international communication systems very much depending upon cables on the ocean floor linking the continents together. Dimensions of a blue economy need ensure a fair and sustainable development of marine resources, including development of blue carbon markets, protection and restoration of ocean ecosystems, more use of renewable energy and deep sea resources from the ocean, recycling of pollutants to prevent them reaching the ocean, provision of uncontaminated water for desalination, improving current fisheries and aquaculture management regimes. However, although the linkages and interactions are recognized, and that the ocean should be treated as a whole, the ocean governance and management are still very fragmented.

Climate change impacts on the ocean will have profound implications for all human societies and most of our activities. In view of this insight, social sciences have a large role to play through research and observations, not only of the ocean and its resources, but also of the human development. The research, technologies, sustained observations and dynamic modelling capabilities as well as the capacities to utilize these elements at national, regional and global level have been sufficiently developed to make an effort in form of an ocean decade both feasible and rewarding.

The issues and impacts are interlinked which underlines the necessity of considering not only the maximum global warming but several combined targets, and adopt a holistic approach in evaluating the life-support system and mitigation of changes of the whole system. This reflects the realization in UNCLOS of the need to consider the ocean as a whole. The approach is reflected in the chapters of the Law of the Sea. Besides specifying the delimitations of different zones, the Law includes rules regarding the conservation and management of the living resources of the high seas, concerning protection and preservation of the marine environment, with respect to conduct of marine scientific research, development and transfer of marine technology, including the option of establishing regional marine scientific and technical research centres, and settlements of disputes.

32.5 Institutional Arrangements

Ocean research and observation activities are covering a wide range of interests, sectors, users and uses, disciplines, transfer of technology, skills and technology development, industrial developments and now biotechnology of potentially very large significance. All of these activities are of great socio-economic relevance, and the goal to ensure that benefits are shared in a fair way is one of the foundations of UNCLOS. Observations of the ocean and coastal seas so far largely rest on the scientific communities involving several disciplines and institutions. Nevertheless, a gradual shift in the methods of observing the ocean is underway from exploration to a more sustained nature with the aim to provide ocean services, possibly eventually matching the meteorological weather services.

The statutory role of the IOC is to promote coordination and cooperation in ocean research, services and capacity building. Since 1960 the number of institutions and other organizations having the marine environment or parts thereof in their sphere of interest has increased at least by an order of magnitude, probably two. This is reflected in the number of marine scientists, research and education institutions and significant infrastructure investments for ocean observations. These show the move of ocean sciences from exploration by means of research vessels to permanent establishments of large distributed facilities, as noted in Field et al. (2002).

The diversity of interests including the fast growing development of ocean economy, the fragmented, essentially sector-oriented management despite UNCLOS, and the Sustainable Development Goals of the 2030 Agenda call for a unifying proposal for mobilizing over a time period new government and industrial resources in support of marine science, its applications and links to policy making, sustained observations and services with related capacity development and technology transfer in order to meet the goal of sustainable ocean development. The experiences from the International Decade for Ocean Exploration 1971–1980, and the International Year of the Ocean 1998 show that they stimulated much support for ocean-related activities at local, national and global level, in governments, the public, civil society and scientific communities. The national governments were willing to provide additional resources for research and infrastructure, while local governments supported local awareness creating actions. These experiences are very positive and support the idea of launching another ocean decade to address the issues, priorities and uncertainties, and ensuring delivery of results in a timely fashion to users, in particular Governments and concerned national Agencies.

It can be assumed that, at the global level, the UN system will continue to play a central role in the protection of the world ocean and the management of the marine resources, relying on: UNCLOS as the legal basis; major relevant programmes as the substantive basis for action; structures of the UN system supporting the programmes as the institutional basis for action. Some structural-institutional issues need be addressed and resolved. These include arrangements for reviewing progress and guiding the implementation of the Law of the Sea, chapter 17 of Agenda 21, the relevant parts of the 2030 Agenda and of other associated global agreements, the UN frameworks; how do these arrangements work? What kind of changes and adjustments or improvements need be done to make the existing arrangements more efficient? The call by the Scientific Advisory Board of the UN that the UN "should press for greater collaboration among international scientific networks" seems very pertinent. The same holds for the UN and its various Agencies.

A hierarchically organized reporting and coordinating chain is not the most efficient, as demonstrated by the process organized after UNCED 1992, which involved the steps: from the specialized agencies, to and through the Advisory Committee on Coordination (ACC), the Subcommittee on Oceans and Coastal Areas, the Inter-Agency Committee for Sustainable Development, and the Commission for Sustainable Development to the General Assembly (see e.g. Holland and Pugh 2010) This process requires much agency time for reporting and the output of the intermediate bodies have little influence on the work of the reporting Agencies.

The structure of the UN system makes an efficient coordinated implementation difficult to achieve. In particular there is no accepted focal point or body which could serve as a focus for coordination and action. The efforts to address this issue have so far not been successful. There is a need for an innovative approach or an enforcement mechanism. This should address and deal with the structural inadequacies of the UN system. Streamlining the structures, mandates, programmes and operations of the relevant elements of the UN system ought to be pursued with the aim of strengthening the ability to meet the needs of the present and the implementation of the 2030 Agenda as well as related agreements. Perhaps the idea of ad hoc alliances between organizations addressing specific tasks could be pursued. This cannot be left to the Governments, the agencies need come forward with ideas.

The major players in relation to ocean affairs in the UN system are IOC, WMO, IMO, FAO, IAEA, UNEP and UN through UN-DOALOS, and possibly also the ISA. These also include strong support from UNDP and GEF The bathymetrical charting is under the auspices of the International Hydrographic Organization, in cooperation with IOC. The large importance of the marine environment and the ocean in the tourism industry should likewise be recalled, and possibly dialogue be established with the World Tourism Organization. One aim of consultations between the organizations could be to derive a coherent and well coordinated ocean programme as a result of cooperation and agreements between these major players. This could build on the ocean parts of the 2030 Agenda, but needs also to address social and economic aspects and interactions with the other compartments of the planet, and could be one outcome of an ocean science decade.

The problems at the international level are reflected at the national level. There is often a lack of a coherent, integrated policy on the ocean and marine affairs at the national level. This may need to be adjusted in view of the increasing role of the ocean and marine resources beyond the coastal zone for the socio-economic development, including support to the most vulnerable areas and populations. This concerns food production, transport, tourism, extraction of many resources like oil, gas, minerals and diamonds, various biological material for pharmaceuticals and medical products, salt, freshwater, coastal developments, defense and security, including risk reduction from natural hazards. It ought to be in national interests to develop and ensure an adequate ocean policy: the instruments, the scientific and observation backings are available; models of forecasting ocean conditions which can be applied in management are available. A dedicated effort like an ocean science decade in context of the 2030 Agenda can stimulate the relevant process both nationally and internationally (IOC 2016).

The substantive programmes of the UN system are numerous, having increased very significantly since 1960. Despite considerable efforts of coordination and cooperation they are still fragmented, mostly sectoral, underfunded and without adequate coordination. The number of related programmes outside of the UN system has likewise increased strongly. They constitute a necessary complement to the UN system programmes. In view of the large threats to the ocean we need, for the future we want, it seems that a dedicated effort of cooperation, coherence and consolidation of activities is needed. One priority of this should be to narrow down uncertainties and ensure timely and understandable delivery of results to Governments, national agencies and international bodies responsible for management, as well as to the public and community groups.

32.6 Concluding Outlook: The Decisive Role of Science Cooperation

The important roles of the scientific communities to contribute to solving the issues facing the human society also in context of the ocean are evident. The incentives for the scientists have changed over time. Initially the main drive was exploration, including bathymetry, tides, wave, current and wind conditions for navigation, fisheries and coastal developments. After WW II the need to increase the knowledge about the ocean and its resources, strengthen ocean research and use new technologies stimulated scientists to enter with basic science into the relatively new environment of the deep ocean. This was also driven by the need for food for the growing world population, and increasing use of resources and energy.

Presently ocean and other sciences are stimulated by requirements to address the priority issues of interdisciplinary and trans-disciplinary nature. Furthermore the international cooperation has developed to reach the planetary level and succeeded to create better than before dialogue and exchange between several science disciplines and across sectors, as natural-social-economy-health sciences. The challenges of creating adequate dialogue with policy and decision makers, as well as with communities and the public, and deliver the scientific results for use in livelihoods and management, put pressure on and provide incentives for science leaders and practitioners. The socio-economic developments give incentives to gifted scientists to address ocean literacy in context of the ocean as a driver of economic and social well-being, provider of livelihoods and seek to elucidate interactions between natural and human-driven changes. This includes the needed interaction between natural sciences aiming to understand global change due to human impacts and social sciences aiming to clarify the human causes. Incentives are also evident in the need for ocean science to address issues related to development of sustainable ocean knowledge-based economies. Science leaders need to stimulate more cooperation at the global level between science networks and academies and drive for more integration of scientific results into management. A great responsibility of the cooperation concerns finding solutions to the identified problems, reduce uncertainties and deliver the results. However, an equally great responsibility rests with funders of science to facilitate and streamline processes of funding, ensuring a balance of support in terms of disciplines so as to avoid negative competition, as well as finding adequate means for enhancing dialogue between the scientific community and other sectors of society. The ocean science community has shown that it can deliver solutions to problems of large social concern, from local to global scales. An example includes the success in risk-reduction from natural hazards resulting from the ocean, as cyclones, storm waves and tsunamis. The impacts and public reactions of the tsunami in December 2004 triggered governments to call for and support development of tsunami warning systems in several other basins, something which had been proposed by the IOC repeatedly. The advances in dynamic coupled models make much improved forecasts on conditions possible, as well as improved analyses of consequences of management interventions. This shows important results of scientific cooperation. These results also provide further incentives for continued and strengthened cooperation internationally and between sciences. This includes technology transfer and infrastructure. Success in this direction, however, also depends upon active participation, dedication, trust with open sharing of knowledge, ideas and experiences by leading scientists such as professor Bologa and those involved in the formation of SCOR, IOC and IOI.

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Chapter 33
Romanian Hydrography – Over 100 Years of History

Romeo Boşneagu

Abstract The evolution of the Romanian hydrography, with an over 100 years of history, closely followed the Romanian Navy history. Since the Union of the Romanian Principalities until now, Romanian Navy has developed from a small river flotilla to the today Romanian Naval Forces, which includes the Romanian Maritime Hydrographic Directorate (M.H.D.). Today M.H.D. is the Romanian national authority in the field of maritime hydrography, with its operating own national law. This paper presents the centenary history of Romanian hydrography in parallel with the Romanian national history, as well as the Romanian Navy history.

33.1 Introduction

The Black Sea has the aspect of a deep basin, oriented from west to east, that is extending on approximately 6° latitude and 5° longitude, between the parallels: 40° 55′N, and 46° 37′N and the meridian lines: 27° 27′E, and 41° 47′E. It is an intercontinental sea, being in connection with the Mediterranean Sea through the Bosphorus narrow, respectively with Azov Sea through the Kerci narrow (see Fig. 33.1).

The maritime communications represent a basis component of the economic infrastructure of the Black Sea riverside countries. The development of the maritime routes in this area was determined by the geographical factor and the political-economical factor, as well.

The strong development of the world economy, of the Western European and of the Mediterranean Zone had been a proper impulse for the economic development of the states from the Black Sea Basin, too.

Since the Ancient times, they were made researches in the Black Sea, it was crossed and taken into possession by the seafaring peoples, who built cities-ports on its shores that standeth until today, the geographical factor having the main role in choosing the favourable places for them.

R. Boşneagu (✉)
"Mircea cel Batran" Naval Academy, Constanta, Romania
e-mail: romeo_bosneagu@yahoo.com

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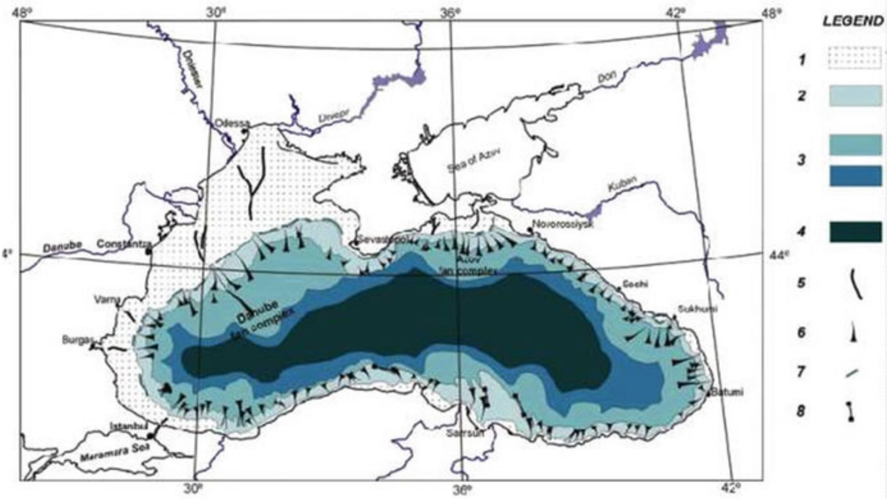

Fig. 33.1 The geomorphological division of the Black Sea into zones (After Panin and Ion-1997) Legend: (*1*) the continental shelf; (*2*) the continental slope; (*3*) Piedmont; (*4*) abyssal plain; (*5*) paleo-channels from the continental shelf, filled with holocenic and present sediments; (*6*) the main submarine valleys-canyons; (*7*) paleo-terraces; (*8*) fracture areas

So, the first documentary attestations of the populations that have settled in the adjacent areas of the Black Sea and Danube showed their economic, cultural and military preoccupations related to the sea and the river vicinity. Nowadays, the fishing, the seaborne or the seamanship are the specific occupations for the populations in these areas.

Since the early antiquity, The Black Sea basin came to the attention of the seafarers nations. The name of the aquatic basin that today we call Black Sea has undergone several metamorphoses in the historical past. It is supposed that the populations settled around the sea, especially the Getae and Scythians, having more aptitudes as shepherds and ploughmen than navigators, saw in the immensity of its waters just a frightening and incomprehensible ghost, the reason being why they called it *Ahsaena,* meaning “gloomy” or “black”(V. Trufaş 1969).

Entering in the Black Sea waters, the Greeks took over from the natives the word *Ahsaena*, they understood its gloomy sense and changed it into *Axeinos*, which in Greek it means “*unfriendly*”, “*inhospitable*” (I. Lepşi, 1939).

The fruitful trading connections with the local populations have made the Greeks to settle down on the coast of the *Unfriendly Sea* (Pontos Axeinos) and to found many cities that constitute centres of civilization. In this situation, the name of Pontos Axeinos seemed pointless and even vexatious to them, therefore they changed it in Pontos Euxeinos (*Hospitality Sea*). This name lasted 12 centuries, until the great migrations of the late antiquity have destroyed the civilized centres. Once with these, it is lost the old name, too and thus it was assumed the old denomination, i.e. of Pontos – which had definitely imposed – the Black Sea (Bârdeanu and Nicolaescu 1979).

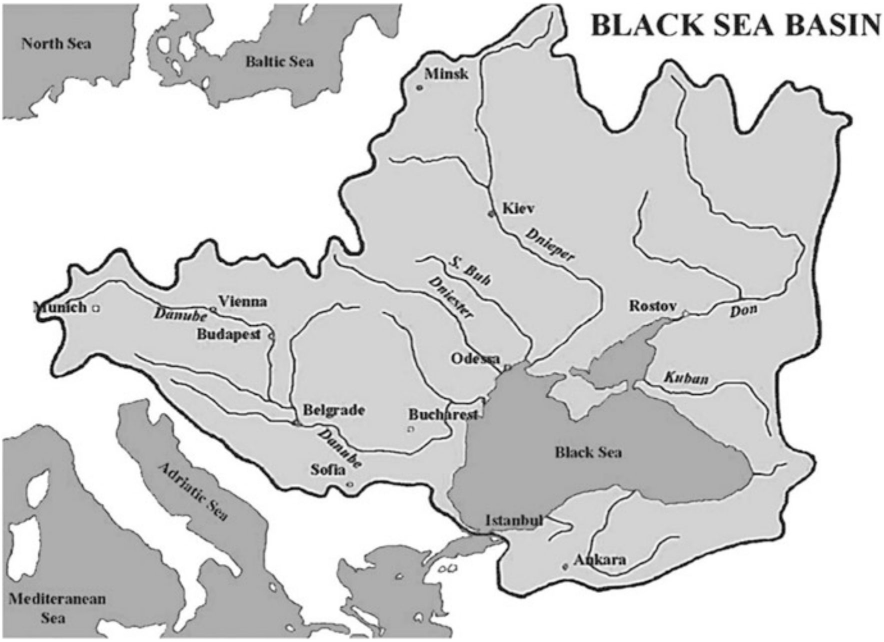

Fig. 33.2 Black Sea hydrographical basin (After Nicolaev and Bologa, GEO-ECO-MARINA 11/2015 Review)

Romania, as Black Sea riparian country, has a sea coast of 245 km length. Also, Romania has 1075 km of river, representing 38% from the total length of Danube, out of which 236 km are inland waters, the both riversides being on the Romanian territory. As area, in Romania, the Danube basin occupies 221,670 km^2, that represents 28% of the total hydrographical basin (see Fig. 33.2).

The navigation ensuring and the hydrometeorological information systems for the maritime routes in the Black Sea are some complex and laborious activities, without those it can no longer conceive today for a safe and fast sea transport. In the Black Sea, there are few hundreds of light and unlit means for navigation ensuring, that are under the responsibility of the specialized agencies of the riparian countries. Also, the Black Sea basin is an integral part of the various global navigation and hydrometeorological information systems.

After obtaining and recognition of its national independence and now, as European maritime state – member of the European Union and the North Atlantic Treaty Organization – Romania claimed the recognized role in the geopolitical space of the Black Sea by the measure of its status, benefiting as well from the natural advantage of its own waters and the wide opening to the Mediterranean and Atlantic world horizon through the western basin of the Black Sea.

33.2 Romanian Navy – Romanian Maritime Hydrography History

The developing of the Romanian Navy began to stand out once with the Union of Romanian Principalities in 1859, event that led to the unification of the fleets of the two Romanian states, on the 22nd of October, 1860, named *Fleet Body*, under the command of Colonel Nicolae Steriadi, representing the structure that constituted the nucleus of the future leadership of the Romanian Navy.

During the Romania Independence War (1877–1878), the *Romanian Flotilla* led naval actions, installation of riverine mine dams, enemy ships attack and artillery fire support.

Until 1882, the Romanian ships used for the river navigation the Russian maps, and for the maritime navigation the English ones. Once with the Romanian military ships presence increasing on Danube as well as the foundation of the *Navy Children School,* the need of the Romanian charts and nautical documents had increased. Mihail Draghicescu, Chief of the General Staff of the Romanian Flotilla ordered to be made hydrographical measurements on Danube, i.e. during the instruction marches on the river as well as the students practice performing on board of the Romanian vessels, in order to accurately acknowledge the fairway and the navigation obstacles (Ciorbea 1996a, b).

Thus, during the years 1882–1883, Mihail Draghicescu together with the crews from *Fulgerul (the Lightning)* and *Lebada* (the *Swan*) vessels, have achieved an extensive hydrographical data, that later were used for drawing up the first Romanian Danube chart. In 1895, this map was reproduced at 1:28,000 scale and it was continuously updated by the military crews while they were fulfilling the missions on Danube. The map had been used in very good conditions until 1904 (Bologa 1998).

Between 1885 and 1886, from *Grivita* gunboat board, there were executed the first hydrographical survey on the Romanian Black Sea littoral, respectively in Sulina – Gura Portitei (Portita Mouth) area.

In 1887 was made the first Romanian chart of Romanian littoral waters, without hydrographic details (see Fig. 33.3).

The first Romanian hydrographical research structure was the *Special Section for the Hydrographical Works from Danube and Black Sea*, founded in 1897 and led by Lieutenant Commander Alexandru Catuneanu (see Fig. 33.4), hydrographer specialist having specialized studies in France and participant in two hydrographical campaigns in Far East and Caledonia. On 30th of June, 1897, several officers had been detached to this hydrographical unit and under his command they began the hydrographical survey of the Romanian coasts. The hydrographical surveys had been performed up to 10 km from the coastline, respectively on survey lines spaced at 2500 m one from each other (Draghicescu 1943).

Beginning with 1893, a group of hydrographical and hydrological researchers, led by Grigore Antipa (see Fig. 33.5), has conducted several works campaigns aboard of the cruiser Elisabeta, Navy Ship Mircea and gunboat Grivita. For 9 months, during Antipa's expedition around the Black Sea aboard of a military

Fig. 33.3 First Romanian littoral waters chart without hydrographic details – 1887 (Source: With the permission of Romanian Maritime Hydrographic Directorate)

ship, they were prevailing made biological and hydrological observations as well, researches evidenced in the work "Black Sea – Oceanography and General Bionomic and Biology" (1941).

In 1900, after a laborious activity performed for 4 years, based on the hydrographical and hydrological measurements, executed by Navy Brigg *Mircea* and boat *Rahova*, it was drawn up the first Romanian chart, known as *Catuneanu Chart*. In the same year it was printed in Paris and it was awarded by the gold medal

Fig. 33.4 Photo: Commander Alexandru Catuneanu (Source: http://romaniaforum.info/board3-marina-romana-romanian-navy/board140-marina-militara-romana-pina-la-1945-romanian-royal-navy-before-1945/1603-1900-harta-catuneanu-prima-harta-romaneasca-de-navigatie-a-litoralului-vest-al-mn-costa-romaniei-portret-al-comandorului-alexandru-catuneanu/)

Fig. 33.5 Photo: Grigore Antipa (Source: http://www.antipa.ro/press-room)

at the Universal Exhibition held in the French capital. It was updated and reprinted in 1929 (see Fig. 33.6) and it was used in the Romanian Navy until 1952.

In 1900, during the Romanian-Bulgarian border demarcation, the Romanian officers had performed a hydrographical survey mission in the Danube basin, i.e. near Silistra – Gura Vaii (Valley's Mouth) area, after that being drawn up a Danube map at a scale of 1:50,000, (see Fig. 33.7), respectively another map of Ostroavele area at 1:20,000 scale.

In 1904, in Galati, it was established a *River Hydrographic and Piloting Service* of the Romanian Navy, within it had operated a river piloting practice school.

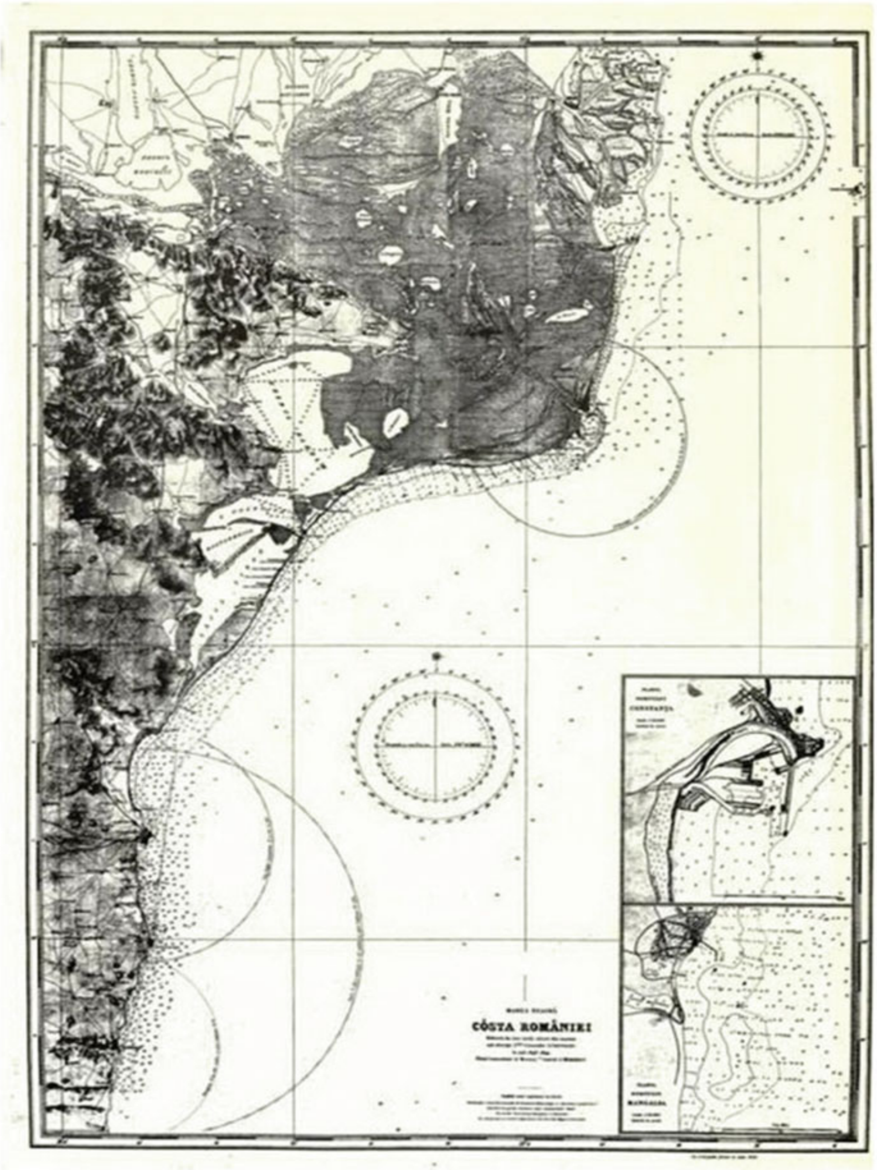

Fig. 33.6 Catuneanu Chart, 1929 edition (Source: With the permission of Romanian Maritime Hydrographic Directorate)

Until the First World War, the combative potential of Romania increased significantly, the Romanian Navy (this new name dating from 1898) had benefited from three programs including the endowment with ships and navigation means. Generally, the management involvement of the Navy Staff was direct and in

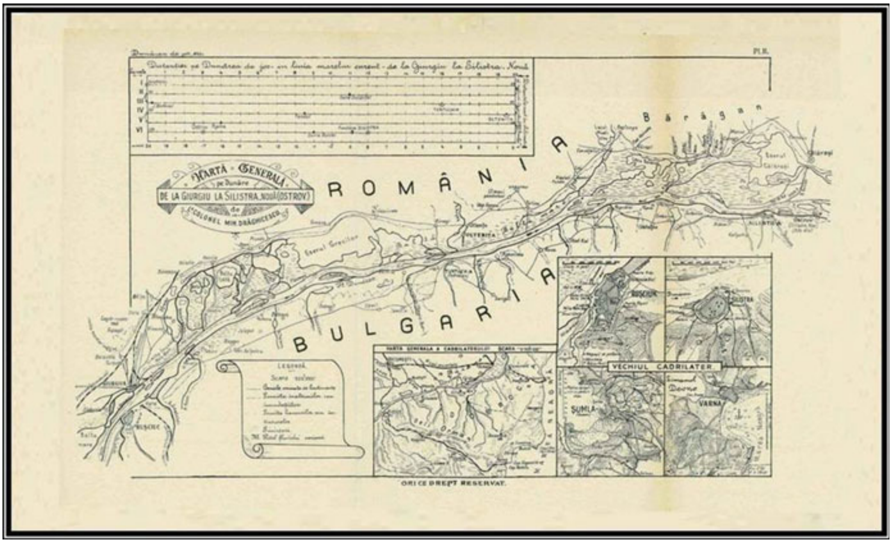

Fig. 33.7 First Romanian Danube Chart (Source: With the permission of Romanian Maritime Hydrographic Directorate)

particular we must remind the role of Rear- Admiral Emanoil Koslinski in the implementation of the third program of endowment with warships. In 1907, in Galati, within this program, they had been launched four monitors and eight river gunboats, that represented the first Danube Squadron.

In this period, among the great Romanian scientists with international recognition, who had contributed to the development of the marine sciences, we must first remind of: Emil Racovita, Grigore Antipa and Ioan Borcea. The professor Ioan Borcea, the pioneer of the Romanian oceanography, had founded in 1926 the *Zoo-marine Scientific Research Unit* in Agigea, subsequently completed in 1937 with a Chemical laboratory.

A reference scientific personality in the field is Constantin Brătescu, which was distinguished oneself by its geographical researches (1922, 1928, 1933) in Dobrogea, Delta and even marine area. Among other scientists, we remind Gheorghe Nastase (with his works in the marine morphohydrography field-1935), R. Ciocârdel (respectively, his works about the seawaters movement −1938), P. Bujor (1900), E.C. Teodorescu (1907) and M. Celan (beginning with 1930), with his works about the benthic algaology.

During the interwar period, they had been performed researches in the hydrography and marine hydrology fields by the Marine Hydrographic Service of the Navy – Ports and Waterways General Directorate. In 1933 it was installed the first registering tide gauge (maregraf) at Constanta.

After the Second World War, the marine researches had been resumed, particularly, in the field of the marine biology, but beginning with 1959, they have been also performed hydrographical and hydrological surveys in the Romanian territorial

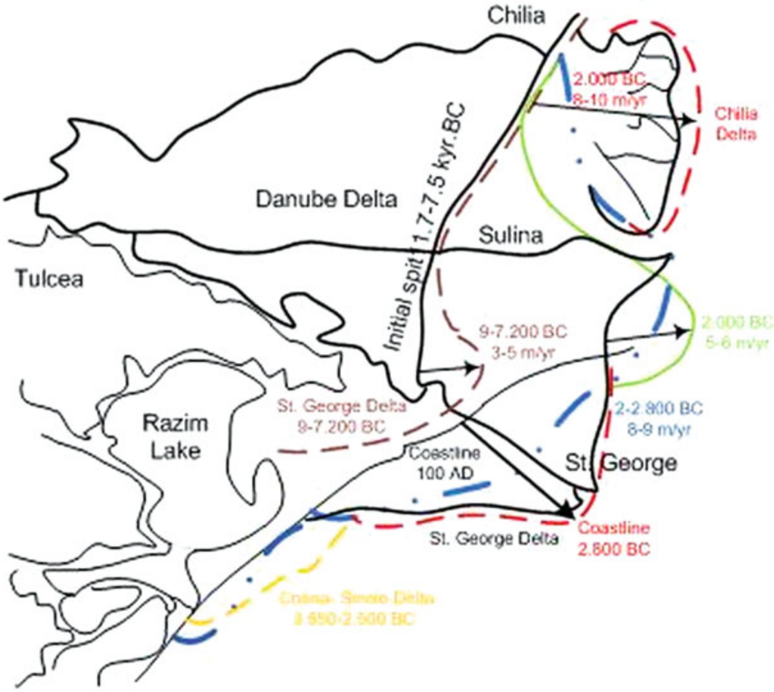

Fig. 33.8 Paleogeographical evolution of Danube Delta (After Panin-1997)

waters and the continental shelf (1961–1969), sporadically continued until 1978 and resumed after 1990 within the national and international researches campaigns.

Among many Romanian scientists, who had devoted their lives to the sea study, we must remind of: M. Băcescu, A. E. Pora, A.C. Banu, H. Skolka, C. Bondar, Gh. Gomoiu, A.S. Bologa, N. Panin (see Fig. 33.8 – researches on the paleogeographical evolution of Danube Delta) and many others; it is remarkable the co-ordination work of the marine research activities, led by A.S. (1989–1999), Gh. Serpoianu – 1990 and for decades, the teaching and the scientific work of dr. O. Selariu in this field.

In the years of the First World War, the Romanian Navy was part of the general war effort, the Romanian Navy Staff had organized many naval actions, particularly on the Danube river. The Vice-Admiral Constantin Balescu, commander of the Romanian Navy, remarked himself during the military operations carried under his command in the summer and autumn of 1917, when the Navy batteries and the monitors artillery bombarded with much effectiveness the positions of the enemy naval forces, the Romanian Naval Forces recording notable successes. Also, they had been realized river hydrographical surveys as support for these military actions.

The achievement in 1918 of the Romanian national unitary state, as result of the union of all Romanian historical provinces, had allowed the development of the Romanian Military Fleet during the interwar period. Following the efforts of the

Navy leaders, its endowment became much diversified by new types of ships, such as: the destroyers „M" type – „Mărăşeşti" and „Mărăşti", the destroyers „R" type – „Regele Ferdinand" (King Ferdinand) and „Regina Maria" (Queen Maria), the first Romanian submarine, the „Dolphin", the second Tall Ship Mircea. In 1939, in Galati, it had also been launched on water the first Romanian military ship – named „Admiral Murgescu". Thus, the Romanian Navy has become a modern and balanced force, able to deal with the threats in the Black Sea. In 1936, with the occasion of the Romanian Navy Day celebration, the Vice Admiral Ion Balanescu, commander of the Romanian Navy, stated that the Romanian Navy represents a factor of great importance in the national defence system, having the mission to protect the waterways as well as the Romanian Merchant Marine and, especially, the Romanian maritime and river coasts defense (Filip 2011).

On 23rd of February, 1926, it was founded the *Maritime Hydrographical Service* (M.H.S.) through the Ministerial Decision No. 126/1898, based upon the provisions of the Law of the Romanian Navy Organization, and the Art. – Romanian Navy Operation Rules, issued in 1912. Its headquarters was established in the building of the Naval School from Constantza (now being the Museum of the Romanian Navy), under the leadership of Alexandru Stoianovici, in the following organization: the Hydrography Office, dealing with the maps, instruments, their storage and distribution; the Astronomy Office, dealing with the equipment for time signalization; the Geophysics Office, dealing with the oceanography, physical oceanography and meteorology instruments.

Following some shipwrecks occurred on the Romanian coast, respectively during the winter of 1927–1928, it was studied the question related to the improving of the navigation security, process to which M.H.S. had attended in the next period.

In January 1928, the *Maritime Hydrographical Service* had participated to the rescue action of the ships trapped by ice on the Danube, as a result of the particularly harsh winter.

Between 1926 and 1940, the *Maritime Hydrographical Service* had performed numerous specific actions, out of which the most important were: the performing of the hydrographical surveys at the mouths of Danube, the prospectings performance in order to extend the port of Constantza, the publication of the navigation charts at the scale 1:50,000 for the Romanian littoral area, as well.

In 1930 The Romanian Hydrographic Service organized pilotage services in Constanta and Sulina, and hydrographic survey in Mangalia and Sfintu Gheorghe areas, and also, studied the solutions for placement of a new seaport, which in addition to solving the need for a greater commercial shipping, and to ensure a good place for a naval base. It was taken back to study the river channel Cernavoda – Constantza, and the possibility of exit to sea by the St. George Danube arm.

In the interwar period, the gunboat *Stihi,* transformed as a hydrographic ship (Fig. 33.9) participated in several hydrographic campaigns, thus resulting complex data for Romanian ports charts, as well as the places of anchorage along Romanian coast (Bologa and Papadopol 1997a).

In October 1940 a delegation of the M.H.S. participated in the work of border delimitation between Romania and Soviet Union at the Chilia Danube arm.

Fig. 33.9 Old hydrographic Romanian Navy ship *Stihi* (Source: https://vapoareromanesti.wordpress.com/2015/04/01/eugen-stihi/)

During the Second World War, the Romania Royal Navy has led many naval actions in the Black Sea, revealing being the action of 26 June 1941, when, in front of Constantza, the artillery of Romanian destroyers „Mărăşti" and „Regina Maria", and of the coastal batteries have rejected the incursion of Soviet ships, „Moskva" – the Flotilla Ship Commander – were submerged (Fig. 33.10) and the destroyer „Harkov" damaged. Another very important action was the evacuation of Romanian and German troops from the Crimean Peninsula in the largest naval operation organized and carried out in the Black Sea, codenamed „60,000 Operation". In this period M.H.S. provided hydrographic and hydrometeorological informations for the combat actions of the Romanian Navy: installation of lighthouses and navigation signals, offsetting compaselor magnetic ships, installation of navigation equipment on ships were not fitted with such devices, hydro-topographic survey for different points on the coast, and for delineation and marking of wrecks (Ciorbea 1996a, b).

33.2.1 Romanian Navy Hydrographers Heroes

In August 1942 was executed hydrographic survey for setting a new naval base on Chilia at the Potapov river mouth, using the tug Smârdan from Danube Division. On August 26, 1942, while the hydrographic survey, the tug blew a magnetic mine launched by Soviet aviation and sank almost immediately. In this tragedy the whole crew lost their lives. After 68 years from this event at the Sulina Lighthouse, on the

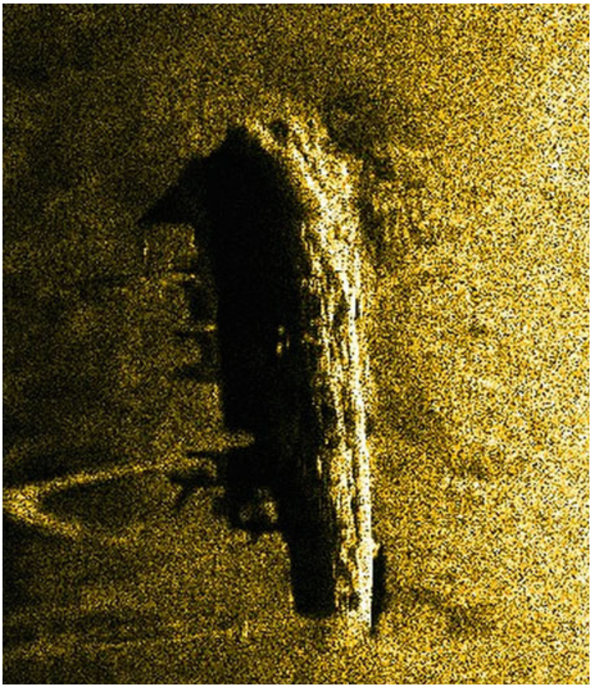

Fig. 33.10 Distroyer Moskva wreck – WWII (Source: With the permission of Romanian Maritime Hydrographic Directorate)

monument built in their memory was placed a plaque with the names of the eight hydrographers heroes.

In 1946 Lieutenant Commander Constantin Copaciu, alongside other specialist officers, was part of the Soviet-Romanian Joint Commission to establish border on the Prut, on Chilia Danube arm and Black Sea between Romania and U.R.S.S. He argued vehemently Romanian territorial rights, according to international maritime law. Due to differences in the interpretation of international treaties, he refused to sign the Soviets boundary proposals for the Soviet-Romanian border, for which he was charged with high treason and sentenced to hard labor for life and military degradation. In 1964 he was released from prison, and in May 1965 was retired from the Army, which recognizes him a quality captain commander, but also on the "Antifascist War Veteran". In 1966 he leaves Romania and settled, with his wife, in Monaco, where he is employed at the International Hydrographic Bureau in Monte Carlo. He became a member of the European Society of Geography and of the Marine Research Society in London. He regained, since 1965 the right member of the International Commission of the Danube in Vienna and was received in American Geophysics Union of Washington and in the International Association of Geodesy in Copenhagen. He made scientific expeditions in the North and the South Seas, in the Mediterranean Sea, also in the Indian, Pacific, Atlantic and Artic Ocean. The research results he published, between 1977 and 1981, in a specialized magazine in Monaco. Is memorable the meeting between dr. Alexandru Bologa and Captain Navy (R) Constantin Copaciu in Monte Carlo, in 1986 (Bologa 1998).

After World War II, in the first post-war years Romania had lost the maritime fleet, and in a large measure the river fleet, due to the take-over of Romanian vessels by the fleet of the Soviet Union, ships being returned later, partly as a result of the agreement between the Governments of Romania and U.R.S.S. Between 1946 and 1947, Romanian Navy, as well as the whole of the Romanian army, was reorganized to accommodate the conditions for peace, but also because of political and military pressures to which they were subjected by the authorities in Bucharest by the Soviets. With all these difficulties, produced from the brutal mixture of Soviets the Romanian Navy has been supported as a elite weapon in the Romanian Army and to participate in guaranteeing the national sovereignty and territorial integrity.

Between 1945 and 1955 the Romanian Maritime Hydrographic Service participated in the redevelopment project for river and Romanian coastal navigation routes, and has edited over 20 new navigation charts, at different scales, to the west part of the Black Sea.

In the period 1948–1954 it have been performed in topographical and hydrographic survey for ensuring the Romanian Navy safety actions in the Black Sea, and for the construction of the Mangalia Naval Base.

After 1952 were fixed the limits of the seven marine maps at scale 1:50,000, using original hydrographic data and for the coastal side the most recent data of the maps published by the Romanian Topographic Direction. For that date the seven maps, with numbers from 50 to 56, were passed in secret category being used only by the Navy. Then followed three sheets of the map at the scale 1:100,000, with the numbers from 100 to 102, as well secret. At the end of the activity has been carried out an album with ten sheet map, this being the first catalogue of maps published by the Romanian Hydrographic Maritime Service.

33.3 Romanian Maritime Hydrographic Directorate – Modern History

On 11 November 1955, by the decision no. 2444 of the Council of Ministers of P.R. of Romania, the Hydrogafic Maritime Service was reorganized in Maritime Hydrographic Directorate (M.H.D.). The Romanian Maritime Hydrographic Directorate has the attributions: management and keeping up to date the hydrographic, cartographic, geodetic and shipping data, according to national regulations, resolutions and I.M.O (International Maritime Organization), I.H.O. (International Hydrographic Organization), I.A.L.A/A.I.S.M (International Association of Lighthouse Authorities), and N.A.T.O. standards.

The first charts made by the Romanian Maritime Hydrographic Directorate were: the Plan of the Maritime Base Mangalia – scale 1:5000 and the Plan of the Constantza Port- scale 1:10,000 (see Fig. 33.11).

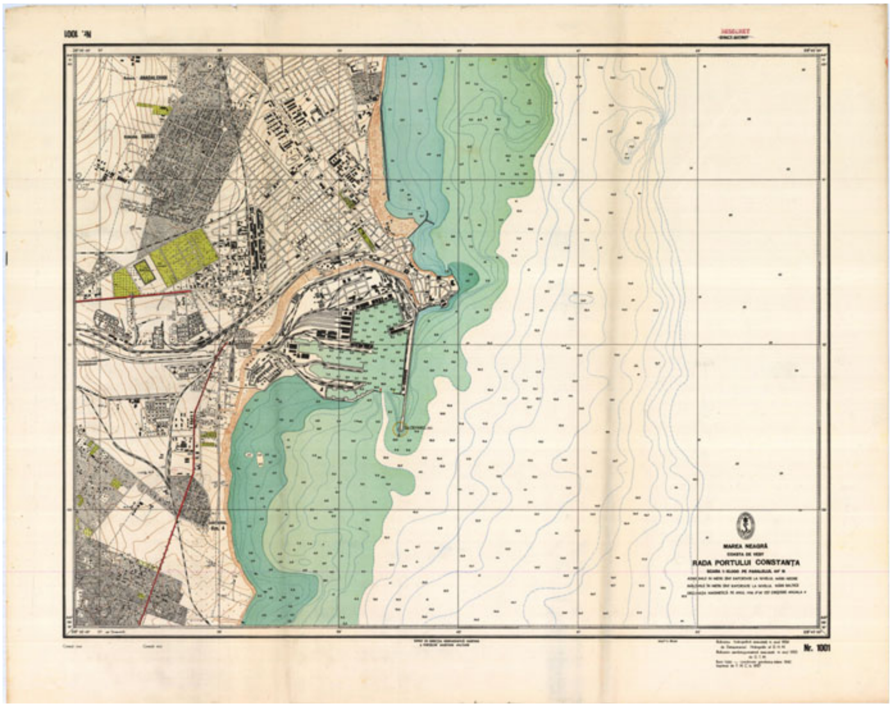

Fig. 33.11 Plan of the Constanta Port –1956 (Source: With the permission of Romanian Maritime Hydrographic Directorate)

At the end of august 1959 the first conference post-war had taken place with subjects regarding hydrography, where were adopted important documents: Instruction for the maritime survey, the Atlas for conventional marks for the maritime charts and the Maritime Signaling System.

Simultaneously with the reentering in function of monitors, The danube Flottila was reconstructed, named from 1959 The Fluvial Brigade. In 1962 was founded The Maritime Division, the successor of Sea Divion's traditions, which was the great Romanian Navy unit disbanded at the end of World War II.

Between 1965 and 1989, the Romanian Navy Staff had prepared, sustained and coordinated the development of the Navy, in accordance with the intern and extern Romanian policy, as well as with The National defence doctrine in that period. A series of maritime military ships built in the Romanian shipyards at the end of the 1970s and the beginning of the 1980s.

The period 1959–1964 is characterized by a productive hydrographic activity, which allowed the hydrographic and hydrological analysis, from Vama Veche to Baia Musara to be completed. At the hydrographic and hydrological survey contributed as on top of specialists of Maritime Hydrographic Directorate, staff from State Committee of Waters and Oceanography Laboratory of the Romanian Academy. The detailed study of the areas in wich the hydrographic case presented permanent modification (Mangalia, Midia, Gura Portiţei, Sf. Gheorghe, Sulina) and of the seacoast lakes was continued with the purpose of assuring some activities organised by the Navy and some ministrys. The hydrographic piece of work were extended to the boundary of the continental plateau, and hydrological piece of work extended from west basin of the Black Sea, in the international liability boundaries of our country. The analysis consisted of: the determination of planimetric base of canvass in the zone Chituc – Gura Portitei; the hydrographic survey of the coastal strip on a breadth of 100–150 m from the water surface, in the Constanta – Gura Portitei area, at the scale 1:10,000; the hydrographic survey in the Tuzla – Eforie Sud area, between 5 and 12 m, at the scale 1:10,000; the hydrographic survey in the Eforie Sud-Gura Portitei area, from the sea surface to the isobath of 12 m, at the scale 1:10,000; the hydrographic survey in the Midia – Gura Portitei area, from the isobath of 8 m until the boundary of the range of the radio navigation stations, at the scale 1:50,000; hydrographic survey in the Neptun – Comorova area, from the depth of 5 m to the coast; hydrographic survey in the Midia – Gura Portitei area; the production of the Romanian Black Sea charts, first edition, at different scales. The Romanian Military Topographic Directorate helped The Maritime Hydrographic Directorate with the photographing and reducing to scale in Mercator projection of the principal cartographic materials for obtaining the originals of the maritime charts. Those were drawn with the topographic pen by the cartographers from the Maritime Hydrographic Directorate.

From 1966 The Maritime Hydrographic Directorate became the Romanian government representative, as a State Member of IALA/AISM.

In this period the Maritime Hydrographic Directorate executed actions of great diversity for the benefit of Romanian military and civilian ships, to ensure the safety of navigation in the area of responsibility of Romania, of which the most important were: hydrographic and oceanographic campaigns between 1957–1970 and 1973–1982; editing The Romanian Black Sea Pilot, and Notices for mariners; installation of the speed base from Tuzla (1957); installing the unlit signals at Chituc and Zaton (1958); electrifying the lighthouses Tuzla (1957) and Midia (1958), construction and commissioning of Constanta's lighthouse (1960); construction and commissioning a new lighthouse from Sfantu Gheorghe (1968) (Moroianu 2012).

Last but not least we offer a briefly reviews of the hydrographic survey campaigns, with the summary indication of the action areas in which oceanographic systematic survey were carried out, on hydrological standardized profile, seasonally repeated four times, each year or multidiural fixed stations, researches in which Romanian hydrographers directly participated actively and permanently, as follows (Selariu 2011):

(a) 1959–1960, stage in which, through considerable effort has been made a valuable joint action of hydrology and marine hydrography in territorial waters, with hydrological research and off the continental shelf, on two profiles of approximately 100 nautical miles each (East Gura Portiţei and East Mangalia);
(b) 1961–1969, the stage in witch has implemented cooperation joint plan system of the former Soviet countries, Bulgaria and Romania, plan which provide

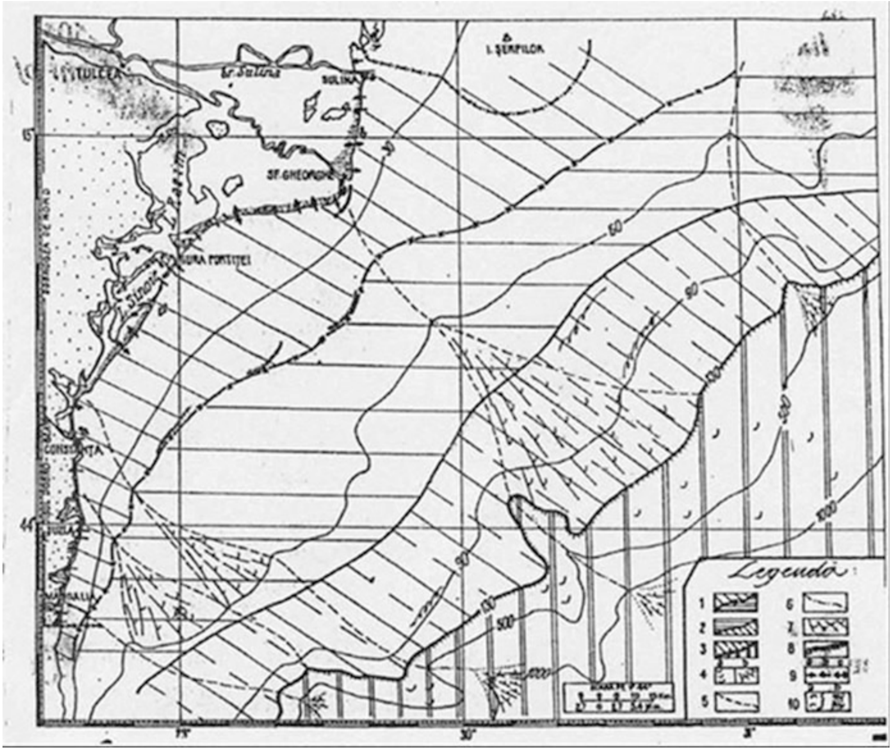

Fig. 33.12 A geomorphological sketch of the NW Black Sea continental shelf (Source: The Black Sea Continental Shelf. Studies and Research on Marine Hydrography and Hydrology in the second Half of the twentieth Century, Romanian Journal of Geography, vol. 55, 2, 2011, p. 126)

complex maritime research, with a program exclusively hydrologic in case of studying the whole shelf of western and northwestern Black Sea (Romania got five sections: Sulina, east oriented, measuring 90 miles, and two shorter profiles measuring 30 miles each: Gura Portiţei oriented east-south-east and Constanta, east oriented);

(c) 1970–1977, a better stage coverage of the entire Romanian continental shelf stations (program remains as previously established, as well as the seasonal pace of the campaigns) and, in addition, there are provided fixed multidiurnal stations.

Between 1971 and 1973 took place the second hydrographic campaign in the seaside area Vama Veche – Capul Midia. A summary of findings on the geomorphology of the continental shelf in the northwest of the Black Sea is presented in Fig. 33.12.

After processing the hydrographic and oceanographic data, the sketches have been drawn in ink and were taken to cartographic documents fund in the matter making of new navigational charts. It has been made a number of changes in the process of obtaining the originals of editing the marine charts, such as the content and shape. For the first time the marine charts and Romanian nautical documents are prepared in accordance with the recommendations of the International Hydrographic Bureau. So were written and edited the new cartographic products: The Romanian Black Sea Pilot; The Notices to mariners; a set of navigational maps; the first Atlas of conventional signs; The Instructions on the content of navigational charts; The Instructions on how to apply the conventional signs on charts; The Instructions on the form and content of the notices to mariners. It establishes The Registry for keeping records on changes that need to be mapped, are made the Standard charts, The Unique system of numbering the charts depending on the sea regions and scale, The Scheme of the Romanian shore and the north – east Black Sea basin charts.

In 1984 it has been editing and multiplying the first four hyperbolic charts to a scale of 1:10,000.

In 1985 the International Hydrographic Organization attribute to Hydrographic Maritime Department the publication of the first international map whit the number INT 3820, From Cape (Nos) Kaliakra to Danube Delta, printed in the next year (Fig. 33.13).

Outside nautical charts, in 1986, it is completed: The navigation map of the Danube-Black Sea Canal (see Fig. 33.14) and the first Plan of Constantza Harbour, and Constanza Sud-Agigea Plan, at scale 1:10,000, and in 1989, it is drawn up a map of navigation for channel Poarta Alba – Midia, Navodari.

The Romanian Revolution from December 1989, witch return to political pluralism and democracy, that put the Navy in a position to act in real combat conditions. The Navy Staff was restructured in a modern way, in the new European geopolitical context, changing the Staff of the Romanian Naval Forces. Following the tradition of sea-river defense were set up the Maritime Fleet and The Danube Flottila.

After 1990, The Maritime Hydrographic Directorate was reorganized, it moved to its current headquarters and realized, among other things: editing of 37 national navigational charts (Fig. 33.15) with scales ranging from 1: 750,000 to 5000; editing "Cartea farurilor, semnalelor de ceata si radiofarurilor din Marea Neagra si Marmara" and "Nautical Tables" DH – 90.

In 2002 The M.H.D. finished the first Romanian navigation electronic map (E.N. C.) in accordance with the standards I.H.O. S-57, edition 3.1 (see Fig. 33.16).

In 2004 it was approved the Law no. 395 on Maritime Hydrographic Activity in Romania, law that establishes and regulates the activity of the Maritime Hydrographic Directorate granting this institution the status of national authority in the field of hydrography.

In the same year was realized for the first time, the implementation of the "CARIS" program, which includes the whole navigation situation, topographic and hydrographic on types and classes of objects standard OHI S-57, and were made and edited the first charts in raster format: Chart 1.150.01, *From Nos Kaliakra to Capul Midia*; Chart 1.500.01, *The northwest part of the Black Sea*; Chart 1.500.07, *From Sulina to Zouguldak*; chart 1.250.01, *From Nos Kaliakra to Braţul*

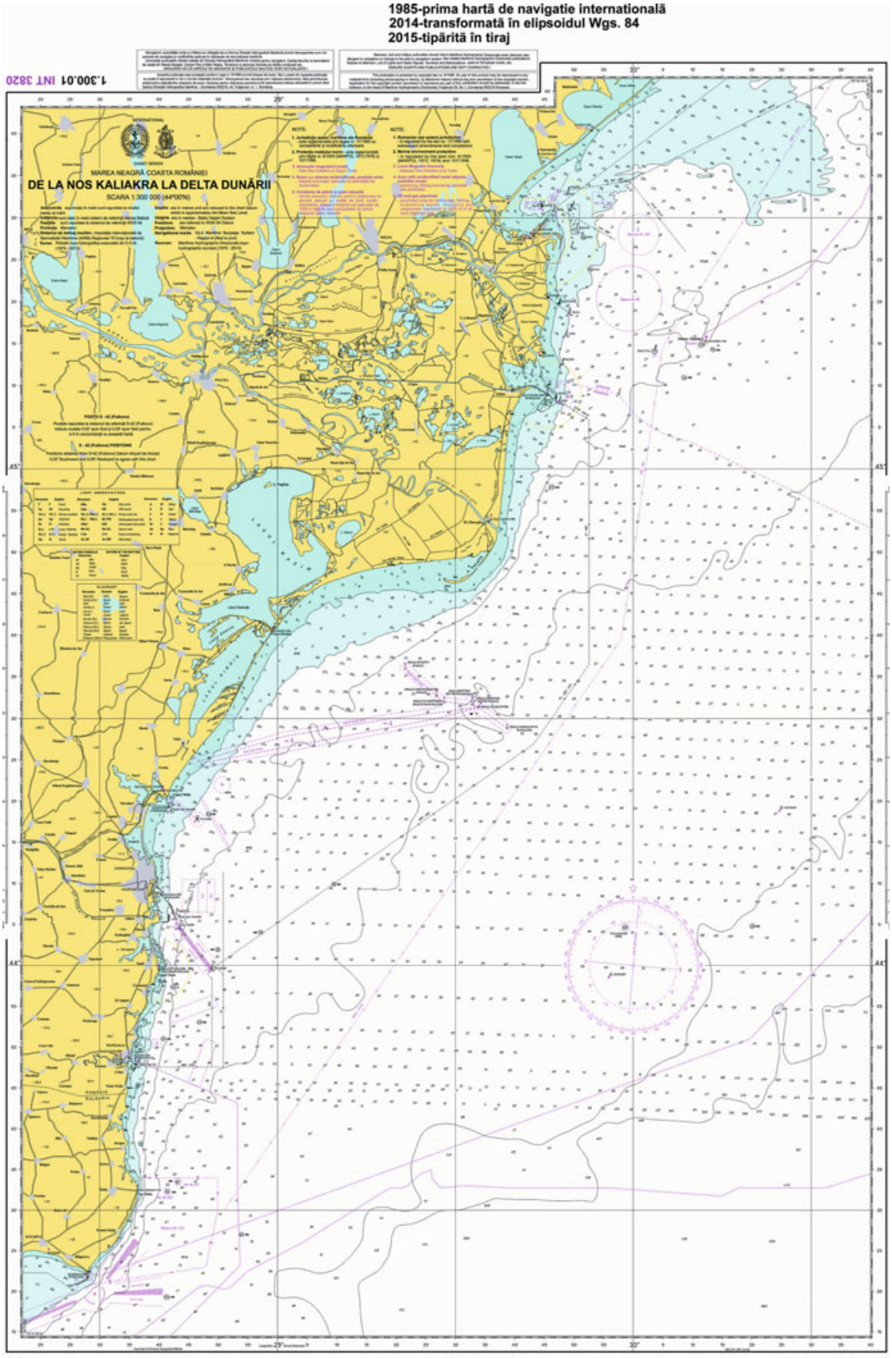

Fig. 33.13 Chart INT 3820 scale 1.300.000 – last edition (Source: With the permission of Romanian Maritime Hydrographic Directorate)

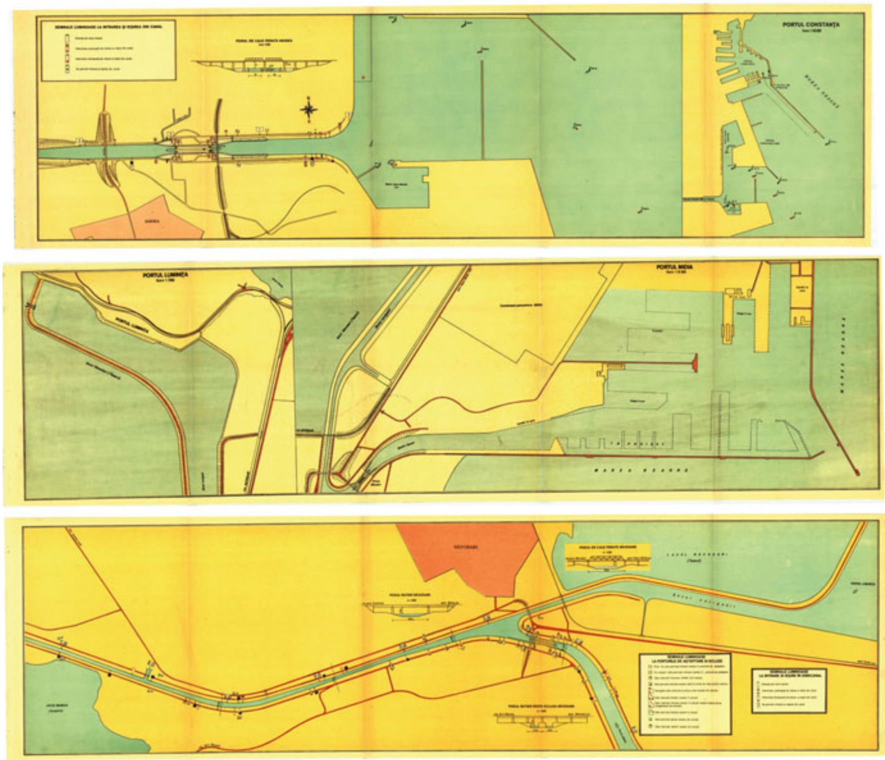

Fig. 33.14 Danube-Black Sea Canal Map – 1886 (Source: With the permission of Romanian Maritime Hydrographic Directorate)

Chilia; Chart 1.050.01, *From Vama Veche to Capul Tuzla*; Chart 1.050.02, *From Capul Tuzla to Capul Midia*; Chart 1.050.03 *From Midia to Grindul Chituc*; Chart 1.050.04, *From Grindul Chituc to Zaton*; Chart 1.050.05, *From Zaton to Sfântu Gheorghe*; Chart 1.050.06, *From Gura Sfântu Gheorghe to Gura Musura*, and the first electronic navigation charts: 1.025.02 *Portul Constantza*, and 1.050.01, 1.050.02, 1.050.02, 1.050.03, 1.050.04, 1.050.05, 1.050.06, 1.300.01, 1.750.01 ENC's) (Popa 2016).

In the 2007–2009 period it was developed The Romanian Naval Forces Integrated Meteorological System, integrated in The Romanian National Meteorological System, contains modern automatic weather stations that transmit real-time standard weather parameters in the adjacent littoral area, located at the Romanian Lighthouses.

In January 2007, The Maritime Hydrographic Directorate became the representative of the Romanian Government, as a member of the International Hydrographic Organization (see Fig. 33.17).

Also, M.H.D. became also member in the "Mediterranean and the Black Sea Hydrographic Commission" (MBSHC), and in the "Black and Azov Seas Working

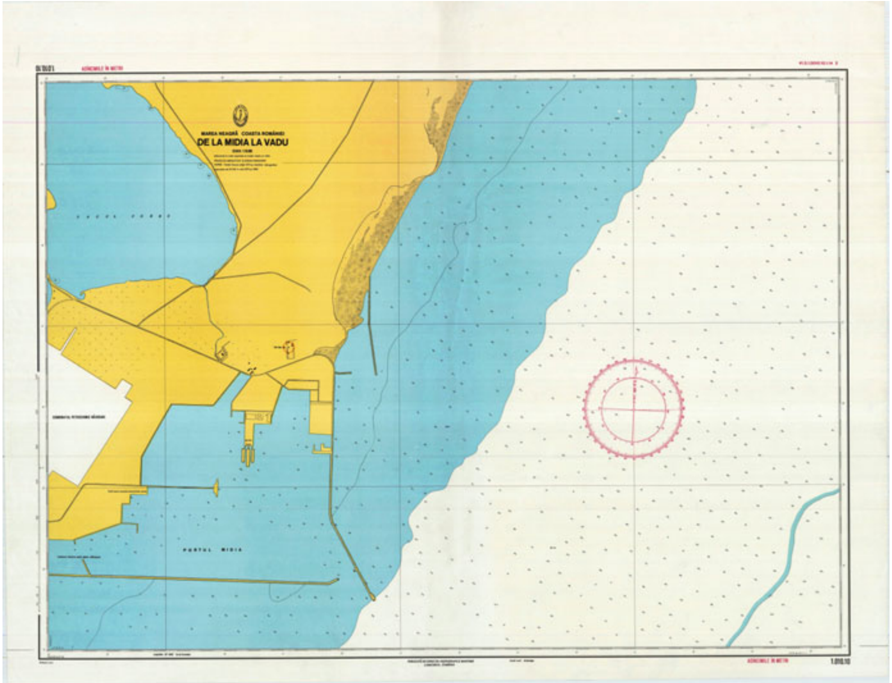

Fig. 33.15 Chart 1010.10, De la Midia la Vadu (Source: With the permission of Romanian Maritime Hydrographic Directorate)

Group" (BASWG), when they laid the foundations of the international cooperation in the field of hydrography. In 2009 The Romanian Maritime Hydrographic Directorate organized at Constantza the 9th Meeting of the BASWG Working Group. The 9th Meeting of the Black and Azov Seas Working Group (BASWG) took place in Constanta, under the Chairmanship of Rear Admiral Mustafa Iptes, the Director of the Turkish Hydrographic Office. Representatives from the HOs of Romania, Ukraine, Turkey and Bulgaria participated. The NAVAREA III Coordinator for the Mediterranean and Black Seas, Commander Aguilar from Spain, participated as an Observer. Vice Admiral Alexandros Maratos, representing the International Hydrographic Bureau, also participated as an Observer (see Fig. 33.18).

Between 2004 and 2016 the Romanian hydrographic ships and boats have conducted annual hydrographic survey wich were concretized in developing a new international chart INT 3905 (1.030.02): *Romania's Black Sea coast; Port of Constanta*, scale 1:30,000 (see Fig. 33.19).

In 2012 The Romanian Hydrographic Maritime Directorate became the 27th member of the International Centre for Electronic Navigational Charts (IC-ENC), center located beside the United Kingdom Hydrographic Office, which collects, validates and distributes to the international maritime community interested in electronic navigational charts of the Member states. In April 2013 it has been

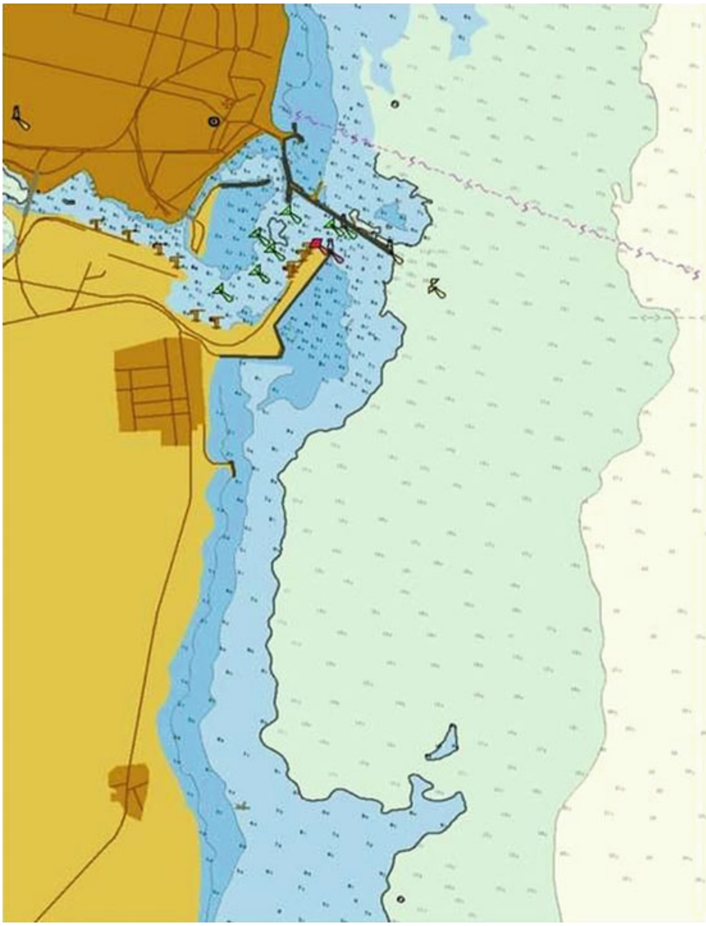

Fig. 33.16 First Romanian E.N.C. – 2002 (Source: With the permission of Romanian Maritime Hydrographic Directorate)

validated and distributed internationally the first Romanian E.N.C: Chart no. RO405002 (E.N.C equivalent to Chart 1.050.02, From Capul Tuzla to Capul Midia) (Fig. 33.20).

In 2014, five new charts were drawn, transforming the projection system of charts from S-42 in WGS-84 as it follows: Chart 1.300.01 (INT 3820), *From Cape Kaliakra to Danube Delta*, scale 1: 300,000; chart 1.250.01, *From Nos Kaliakra to Chilia*, scale 1: 250,000; chart. 1.030.02 (INT3905), *The Black Sea – port of Constanta*, 1:30,000 scale; chart 1.005.12 1.005.11 Mangalia port. Also. in this year were developed two new nautical publications: *Cartea farurilor și semnalelor de ceață din Marea Neagră și Marea Marmara* (4th edition), and *Regulile sistemului de balizaj maritim* (2th edition).

Fig. 33.17 Romanian delegation (Captain Romeo Bosneagu and Commander Octavian Buzatu) handed over the Romanian flag to the I.H.O. representatives (A. Maratos, K.E. Barbor and H.M. Gorziglia) – Monaco, 2007 (Source: Author's photo)

Fig. 33.18 The 9th meeting of the BASWG working group – Constantza, Romania – 2009 (Source: With the permission of Romanian Maritime Hydrographic Directorate)

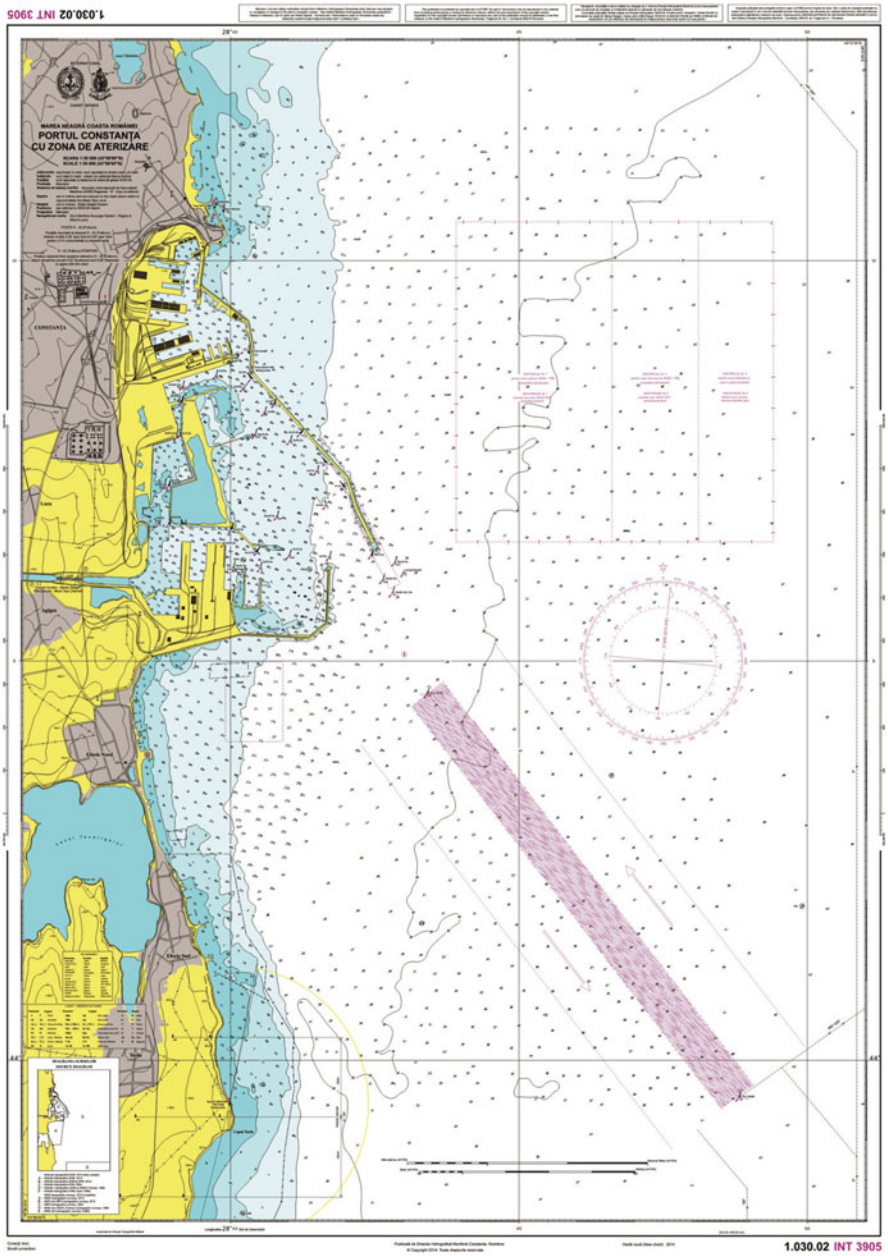

Fig. 33.19 Romanian chart INT 3905 (1.030.02), scale 1:30,000 (Source: With the permission of Romanian Maritime Hydrographic Directorate)

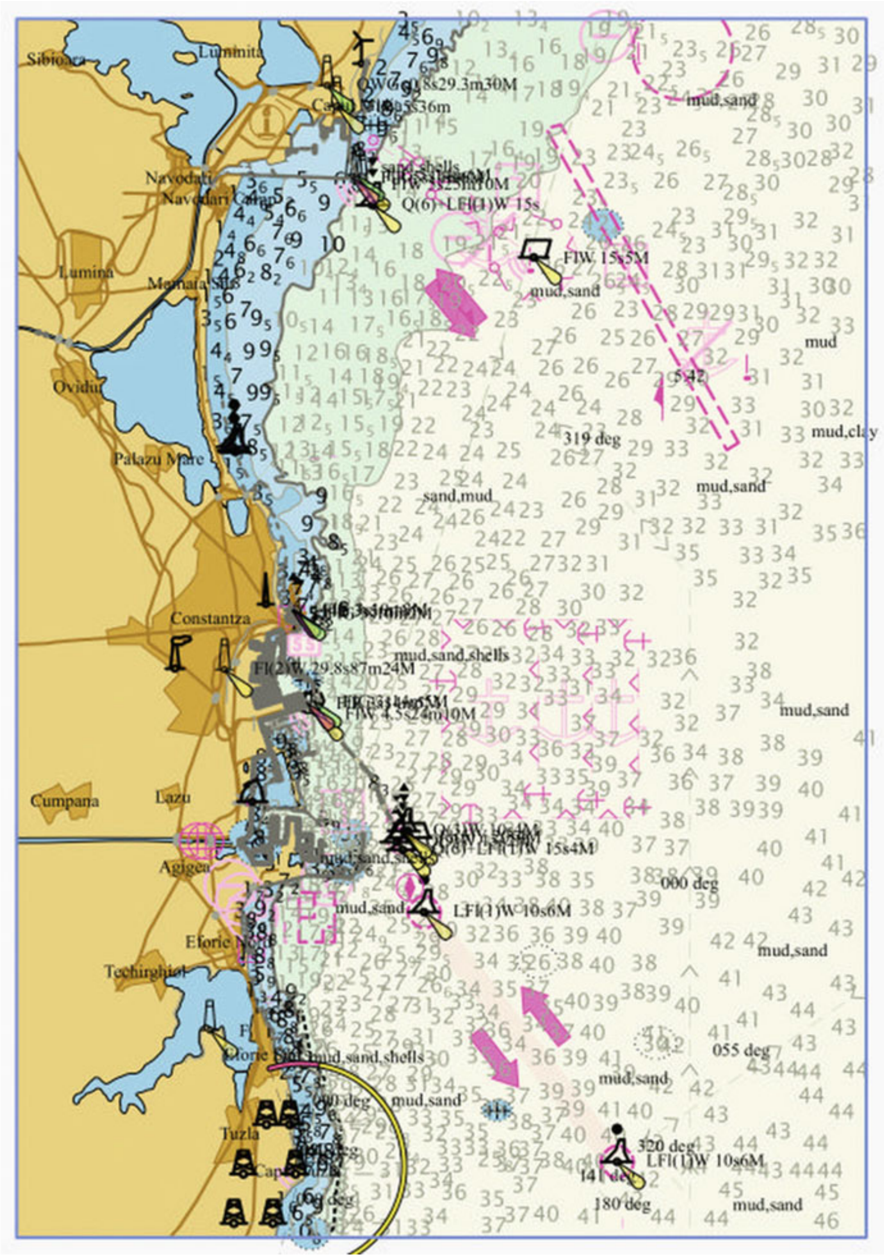

Fig. 33.20 Romanian E.N.C RO405002, *De la Capul Tuzla la Capul Midia* (Source: With the permission of Romanian Maritime Hydrographic Directorate)

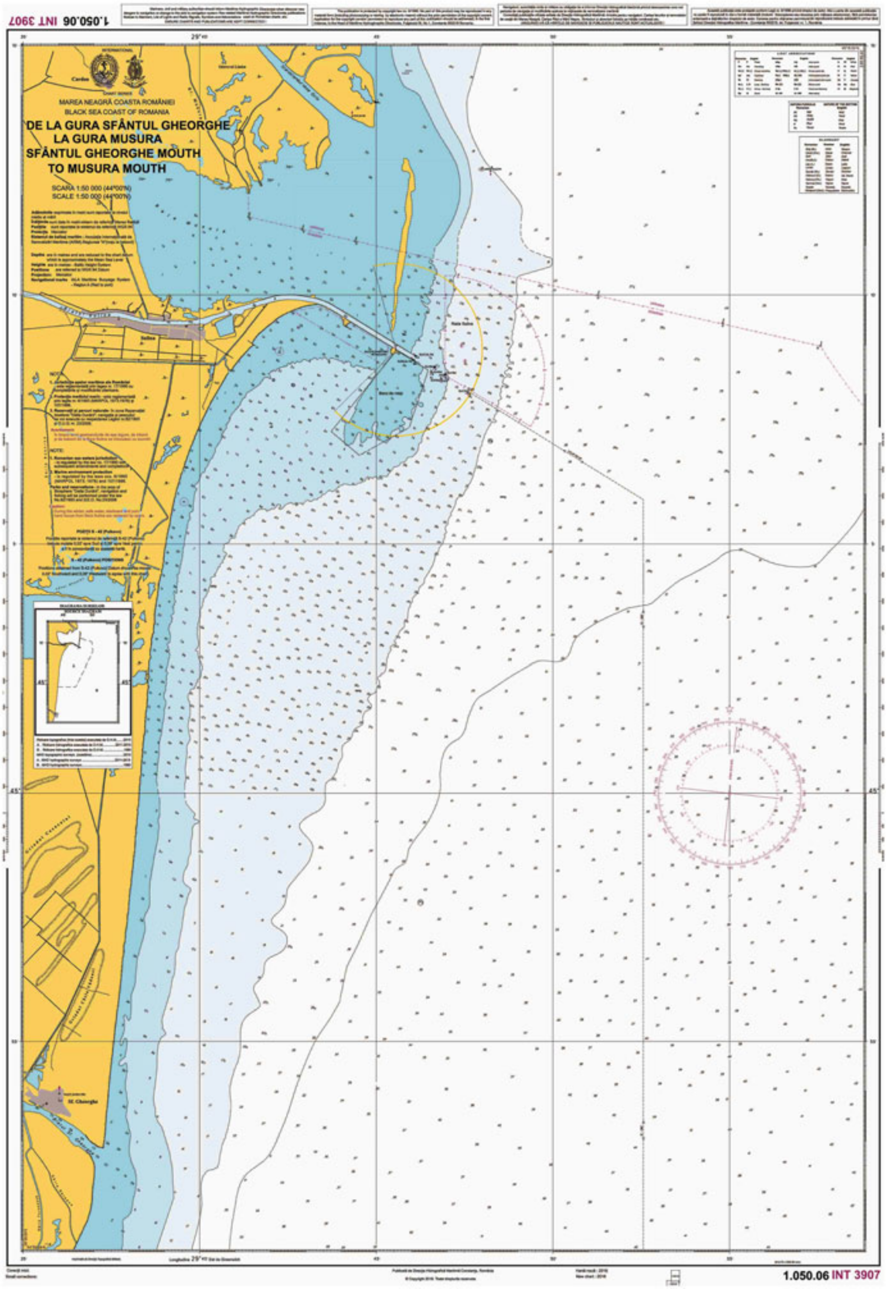

Fig. 33.21 Romanian chart INT 3907, 1.050.06, *De la Gura Sfântu Gheorghe la Gura Musura,* scale 1:50,000 (Source: With the permission of Romanian Maritime Hydrographic Directorate)

In 2015 M.H.D. obtained two new serial numbers for international charts, and were drawn two new national maritime navigation maps, so: chart 1.050.06 (INT 3907) *From Sfântu Gheorghe Mouth to Musura Mouth*, scale 1:50,000, and chart 1.030.09 (INT 3908) *Sulina port*, scale 1:30,000, charts made in 2016 (see Figs. 33.21 and 33.22).

Also, until 2016 were validated the followings E.N.C.s (Popa 2016) (see Fig. 33.23):

RO405001	–	Marea Neagră Coasta României
		De la Vama Veche la Capul Tuzla
RO405002	–	Marea Neagră Coasta României
		De la Capul Tuzla la Capul Midia
RO405003	–	Marea Neagră Coasta României
		De la Midia la Grindul Chituc
RO405004	–	Marea Neagră Coasta României
		De la Grindul Chituc la Zaton
RO405005	–	Marea Neagră Coasta României
		De la Zaton la Sf. Gheorghe
RO405006	–	Marea Neagră Coasta României
		De la Gura Sf. Gheorghe la Gura Musura
RO501021	–	Marea Neagră Coasta României Portul Constanţa
RO501022	–	Marea Neagră Coasta României Portul Constanţa

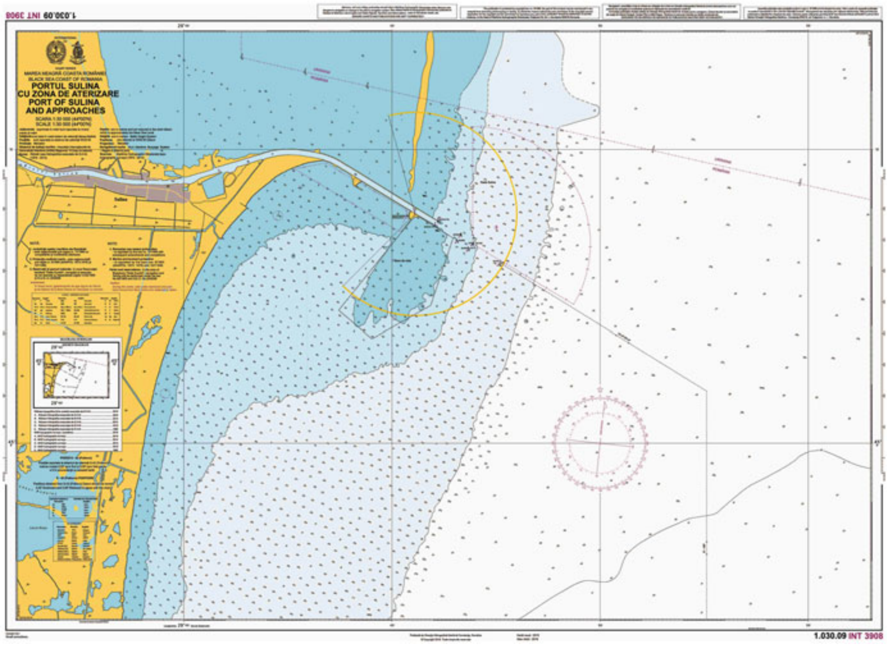

Fig. 33.22 Romanian chart INT 3908, 1.050.06 Portul Sulina and approaches, scale 1:30,000 (Source: With the permission of Romanian Maritime Hydrographic Directorate)

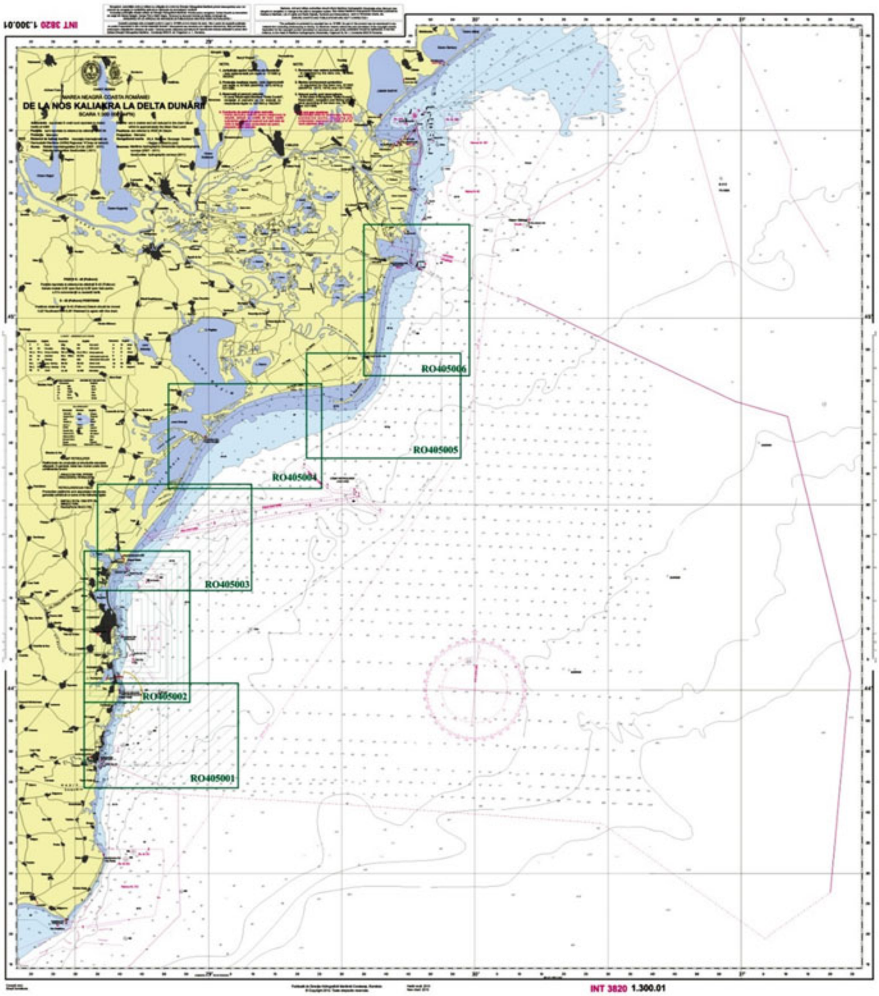

Fig. 33.23 Romanian E.N.C.s scheme (Source: With the permission of Romanian Maritime Hydrographic Directorate)

At this date they expect getting two new numbers for international chart: chart. 1.010.11 *Mangalia Port*, scale 1:10,000, and chart 1.010.31 *Midia Port*, scale 1:10,000. To be printed in the following year along with the entire series of 1:50,000 scale charts.

Are in progress electronic navigational charts no. RO503009, *Sulina Port*, RO501031, *Midia Port*, RO405006, *Black Sea from Gura St. Gheorghe to Gura Musura*, RO2350BS *Black Sea-Romania area of responsibility*.

Since 1971 and until now, The Hydrographic Maritime Directorate – institution with unique profile in the country, the main expert of Romania in matters concerning marine geography and maritime delimitation – participates with specialists in the Interministerial National Commission of negotiations on the delimitation of the Exclusive Economic Zone and the continental shelf of the Black Sea. So Romanian cartographer officers were part of the delegation regarding "Maritime Delimitation in the Black Sea" at the International Court of Justice in The Hague, which determined the delimitation of the continental shelf of the Black Sea between Romania and Ukraine, delivered in February 2009 (see Fig. 33.24), and the participation, currently, of some experts in the meetings of the technical Commission for the delimitation of the continental shelf and the Exclusive Economic Zones of Romania and Bulgaria in the Black Sea. Specifically, the Hydrographic Maritime Directorate contribution in solving the case consisted of: making available to the committee the maps necessary to the preparation of the rounds of negotiations; verification in the field, on the Romanian seaside, of the geographical coordinates of the base points involved in boundary; preparation of some graphic schemes with different variants of solutions to support Romanian proposals during the negotiation rounds; performance of topographic calculations on the solutions proposed by the two parties (comparing the costal lengths, the marine areas, etc.); participation in all rounds of negotiations between Romania and Ukraine conducted after 2002 (about 8 rounds); development of some schemes necessary to complete the documents sent by Romanian Ministry of Foreign Affairs to the International Court of Justice; participation (by writing schemes, perform calculations, etc.) supporting the oral phase of the trial in The Hague; Rear Admiral Eugen Laurian, Rear Admiral Aurel Constantin, Commander Buzatu Octavian, Captain (Navy) Catalin Pocnetz, Dorina Ilaşcu et al. were part of the Romanian team (Laurian and Bosneagu 2009).

Since 2008 The Hydrographic Maritime Directorate is accredited as an national institution engaged in scientific research activities, being involved in projects with national and European founding. Example the GLOBE project – *The influence of the global and regional changes of the geo-climate on sustainable development in Dobrogea*, in Romanian National Programme *Partnerships in priority areas*, 2007–2010, as leading institution, along with prestigious Romanian institutions: GEOECOMAR Bucharest, INCDM Grigore Antipa Constantza, University Ovidius Constantza, University of Bucharest, Maritime University Constantza, Naval Forces Scientific Research Center.

Since 2006 until now M.H.D. has entered into an intensive program of modernization resulted in: developing and approving the new status of the Maritime Hydrographic Directorate; the reorganization on special departments (hydrography, oceanography, marine cartography, meteorology and safety of navigation); staff training abroad with the support of I.H.O; equipping with modern specialized vessels (hydrographic ship Alexandru Catuneanu) (see Fig. 33.25), hydrographic boats (Figs. 33.26 and 33.27), coastal topogeodezical mobile laboratories and modern equipment for oceanography and hydrography, cartography, maritime meteorology; modernizing of aids to navigation on the Romanian Black Sea coast; performing several hydrographic and topographic survey campaigns in the

Fig. 33.24 Final maritime delimitation line in Black Sea – I.C.J. Hague, 2009 (Source: With the permission of Romanian Maritime Hydrographic Directorate)

Romanian Black Sea areas (see Figs. 33.28 and 33.29); development of new classic and electronic charts; signing protocols of cooperation in hydrography/oceanography and cartographic domains with Hydrographic offices from Greece, USA, United Kingdom, Netherlands and Italy. At national level, M.H.D. collaborates with different partners in hydrography, meteorology, and marine exploitation field; at international level M.H.D. has ongoing relationships with I.H.O, IALA/AISM, and many others national hydrographic institutions (see Fig. 33.30).

Fig. 33.25 Romanian *Alexandru Catuneanu Hydrographic Ship* – 2016 (Source: With the permission of Romanian Maritime Hydrographic Directorate)

Fig. 33.26 Romanian *Alexandru Catuneanu Hydrographic 2*, onboard „*Alexadru Catuneanu*" Hydrographic Ship – 2016 (Source: Author's photo)

33.4 Conclusions

In over 100 years of history, the Romanian Maritime Hydrography evolved enormously, it demonstrated the ability of the Romanian hydrographers and cartographers to accomplish, with limited resources, true works of mapping art, among which we proudly mention *Catuneanu* Chart, a reference international chart in 1900, but also the numerous recent charts respectively from the past, classical and electronic, national and international ones, validated and appreciated for their quality, as well. Today, after a period of more than a century, the comparison

Fig. 33.27 Romanian *Hidrografica 3*–2016 (Source: With the permission of Romanian Maritime Hydrographic Directorate)

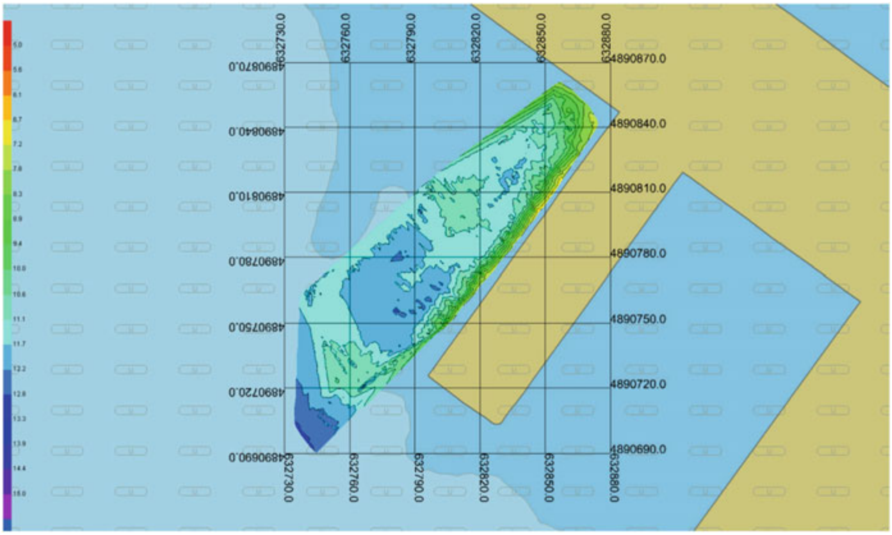

Fig. 33.28 Survey in a Romanian harbour (Source: With the permission of Romanian Maritime Hydrographic Directorate)

between *Catuneanu* Chart and Chart INT 3820/2016 (see Fig. 33.31) show the precision and the accuracy how *Catuneanu* Chart had been drawn, taking into account the limited means of that period and it expresses the admiration of the Romanian hydrographers and cartographers for our predecessors work.

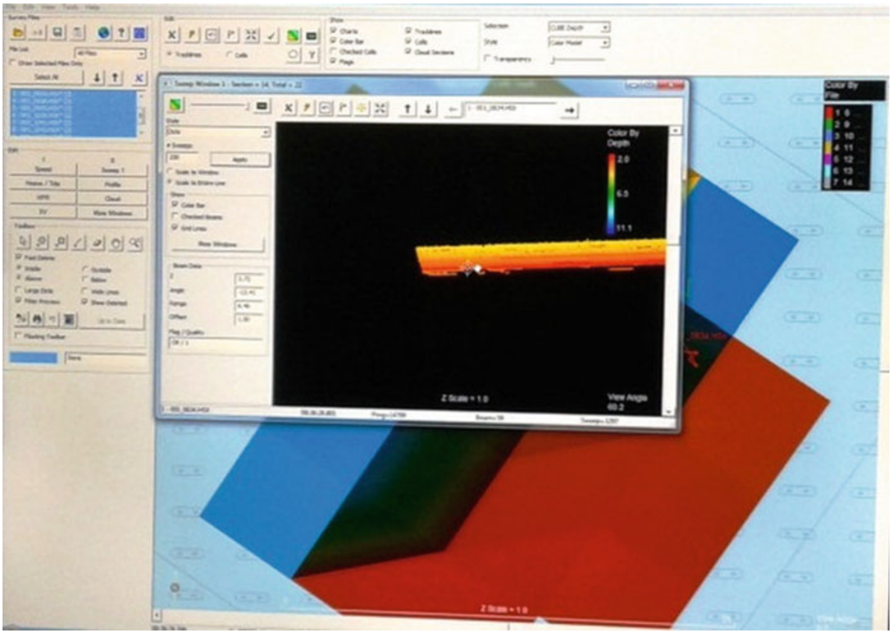

Fig. 33.29 A submerge wreck near the Romanian coast (Source: With the permission of Romanian Maritime Hydrographic Directorate)

Fig. 33.30 Captain (Navy) PhD Romeo Bosneagu, Director of The Romanian Maritime Hydrographic Directorate handing over the M.H.D. flag to the Directors of I.H.O. – Vice Admiral Alexandros Maratos and Captain K.E. Barbor – 2007, Monaco (Source: Author's photo)

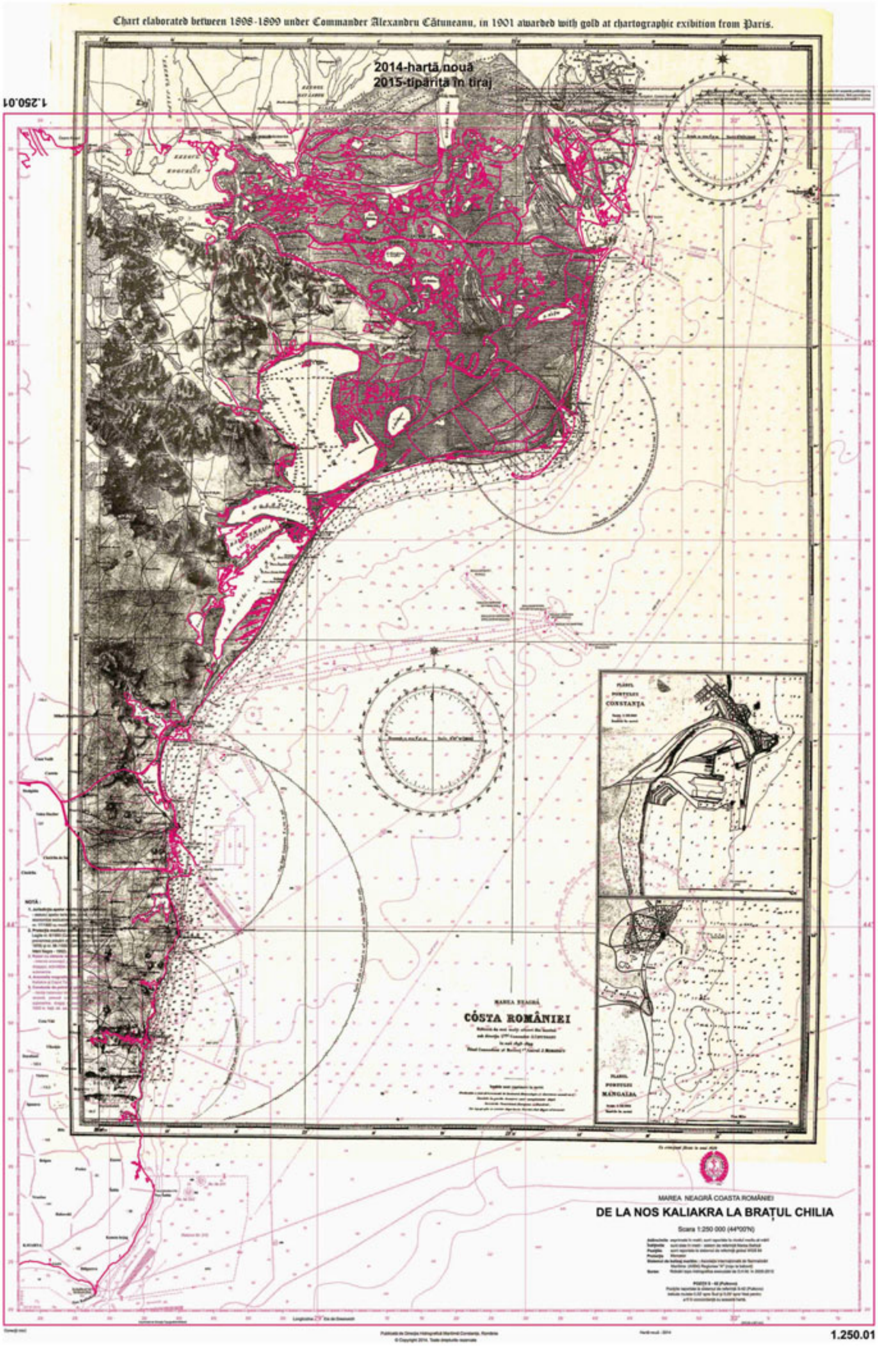

Fig. 33.31 Overlay Chart INT 3820/2016 – Chart *Catuneanu* (1929 edition) (Source: With the permission of Romanian Maritime Hydrographic Directorate)

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Chapter 34
On Romanian Assertiveness in Navigation on the Black Sea (Fourteenth – Late Nineteenth Century)

Valentin Ciorbea and Nicoleta Stanca

Abstract The article presents the beginning of navigation in the Black Sea in the early Antiquity, especially on the west coast. We will highlight the role of Thracian-Getae, the ancient Greeks, Romans, Byzantium and Italians. Since the fourteenth century, Romanians asserted their interests in the Black Sea through the institution of the rulers of the principalities. The leaders in Moldavia and Wallachia included among their titles the control of the maritime coast and of the ports, had ships built and extended navigation and trading in the region. The establishment of the Ottoman Empire diminished the Romanian navigation in the Black Sea after 1848 with the transformation of the Black Sea into "a Turkish lake", but there is proof that it continued on a smaller scale. The change of the navigation regime in the Black Sea after 1829 gave the Romanian principalities new opportunities for sailing and after 1859, Romania created its own naval juridical system. The union of Dobrogea with Romania in 1878 brings an important section of the coast and Constanța port. In this context, the Romanian Maritime Service is created as a state institution with the role to develop Romanian opportunities on seas and oceans.

Keywords The Black Sea • Romania • Navigation • Naval juridical system • Maritime service

The Black Sea witnessed, begging in the early Antiquity, significant stages of navigation, until Romanians asserted their geopolitical interests in the region since the fourteenth century through the institution of the rulers of the country and of ship sailing.

V. Ciorbea (✉)
Academy of Romanian Scientists, Bucharest-Constanţa, Romania

Doctoral School of Humanities – History, Ovidius University of Constanta, Constanta, Romania
e-mail: valentinciorbea@yahoo.com

N. Stanca
Faculty of Letters, Ovidius University of Constanta, Constanta, Romania
e-mail: nicoletastanca1506@gmail.com

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34.1 The Beginnings of Navigation in the Black Sea: The Thracian-Getae, the Greeks, the Romans and the Byzantines

Written historical evidence and discoveries of an underwater research campaign support the statements above. For instance, Herodotus informs us that Thracian-Getae kings allied with the famous city of Troy helping it with ships. In his turn, Diodorus of Sicily, highlights that in the twelveth to eleventh centuries B.C., there was a Thracian thalassocracy. Professor Charles King, from Georgetown University, in his history of the Black Sea, noticed phantasmagoric, bizarre elements of the Thracian tribes on the coasts of the Pontic region (King 2015: 44–45). In the 1960s, as a result of an underwater research campaign by American specialists in the area between Caliacra head and Sozopol, there was evidence that the Thracian-Getae practiced navigation using ships of a few tons. The discovery and complex analysis of 150 stone anchors of about 70–80 kg, of local materials, dated from the 2nd–1st millennium B.C. and by some appreciation from the 3rd millennium B.C., prove the beginnings of navigation in the Pontic region. These elements show that the ancient Greeks, considered for a long time the first mediators of the maritime relations between the Pontic west coast from the mouth of the Danube to the south, between the Thracian-Getae and the Aegean Mediterranean world, were actually preceded by the natives (Ciorbea and Atanasiu 1995: 9).

Very well known historians, such as Gheorghe Brătianu, the author of a monograph dedicated to the Black Sea (Brătianu 2000), and Radu Vulpe claimed that the Phoenicians, brave sailors, also entered the Black Sea. Moreover, the Cariens, holding the thalassocracy of the East-Mediterranean area in the eight century B. C., explore the Pontic coast. Thus, the impact of the Hellenic civilization on the Thracian-Getae population is traced back to the eight century B.C. and it grows in the following centuries in concrete terms through the founding of commercial centres of production, in time turned into real city-ports at the Black Sea, which stimulated the economic and cultural exchanges and developed the level of the Greek influence at the mouth of the Danube and the region between the river and the west coast.

On the banks of Sinoe lake, in an area favorable to sheltering ships, the colonists from Milet founded the city of Histria in 657 B.C. The Doriens from the Pontic Heracleea founded at the end of the sixth century A.D. the city of Callatis and the Milesiens established Tomis in mid-sixth century.

Navigation on the Black Sea was not easy. If to the south they sailed in the sense of the current anti-clockwise, to the north they had to confront the currents at a distance of 3–9 km from the shore, wide of 35–50 km. It was estimated that the sailors of those times practiced the cabotage, skillfully using the coast winds and the anticyclone currents. There are also views according to which, they sailed in open ships to shorten the passage from the Straits to the west coast.

The interest for the Istro-Pontic politics connected by the Bosporus and the Dardanelles to the great ancient powers starts with the conflict between the Persian

Empire of Darius I and the North Pontic Scythians, ending "in the inclusion of the Black Sea in the Achemenid Empire" (Iosipescu et al. 2015: 14). Then followed the Macedonian domination imposed by Alexander the Great's campaign and Mithridates, the 6th emperor (about 120–63 B.C), the king of Pontus imposed the west Pontic cities protection, a period presented in the works of Strabon, Polybius and Eutropius. The great king Burebista, founder of a powerful state north and south of the Danube, became interested in the maritime façade.

The Roman Empire entered the geopolitic Pontic game in 72 B.C, when under Nero (56–68), the Roman domination is extended and a fleet is created and installed at Noviodunum under the name *Classic Flavia Moesia* (Iosipescu et al. 2015: 43). We owe to Rome the establishment of the institution of the *maritime city council* located at Tomis.

The maritime trading is illustrated on the western coast of the Black Sea by the different types of Greek amphora found at Tomis in large quantities, to which we could add the coins issued by Mithridates VI. On these coins, on the emblem of Tomis, there were divinities connected to navigation and trading. In the pantheon of Tomis a special attention was given to the cult of the Dioscuri, considered protectors of navigation and of the city.

The study of coins, pounds and funeral tombs revealed the different types of ships on the west Pontic coast of the Black Sea: *ponto; lapidaria naves; tesseraria; scapha; vegeia; placida; musculus; natis*. On a funeral stone erected in the memory of an important ship-owner from Tomis, we see an *oneraria* ship. In the Roman period in Tomis, there was an important sailors' college, called *naukleros*.

Directly connected to the maritime activity in the port of Tomis beginning in the third century A.D., there was the complex construction called by the archeologists after its discovery "The Roman edifice with mosaic", where 120 intact amphora, 8 anchors and many other materials used for ship repairs and maintenance were found.

The Byzantine emperors, such as Constantine (306–337), Julian (361–363) and Valens (364–378) were preoccupied by the maritime trading on the west coast of the Black Sea. About Valens, the Greek historian Zosimas, in his *Historia Nova*, relates us that the former ordered the building of trading ships to the mouth of the Danube for supplying the army in the war with the Goths.

The western region of the Black Sea witnessed in its further evolution the decay of the Danuabian *limes*, the Byzantines being forced to close the provinces of Scythia, Moesia Secunda, Haeminontus and Thracia, the eastern Balkan Peninsula entering under the domination of the Avars and Slavs. The apparition of the paleo-Bulgarians in the region under the rule of Asparuch led to the creation of the Bulgarian state, acknowledged at Constantinople. Along the Black Sea coast, a new theme was built, Thracia. The maritime waterways controlled by the Byzantines are demonstrated by the discovery at Yassi Ada, a small island in the Aegean Sea, of a ship, whose loading formed of anchors, earthen lamps, pigments and nails, etc. prove its presence in the port of Tomis. The main ships used by the Byzantines were the *dromon, pamfila and acacia*. The Vikings or Varegians, as they were called by the Greeks, show interest in the maritime waterways on the west coast of the Black Sea. Constantine VII Porphyrogenitus (913–959), in his work *De adminstrando imperio,* mentions their travels to Constantinople and Ana Comena, in her work *Alexiada*, refers to them in the twelveth century.

A new stage in the navigation on the Black Sea is opened by the great Tatar invasion in 1240–1242, in whose aftermath Constantinople signs “the Mongolian peace” and is forced to open the Black Sea for international sailing. The Venetians, Genovese, Pisans and other Italian sailors transformed the Black Sea into the “turntable” of the European commerce, to use Gheorghe Brătianu’s phrase. Not without a reason, it was stated that the revolution in sailing and maritime trading in the thirteenth to fourteenth centuries make it known and disputed (Iosipescu et al. 2015: 111). “Mare Maiu”, “Mare Maius” or “Mar Maggiore”, terms included in navigation maps, or “the Big Sea” experienced a spectacular growth of navigation and port activities. The “Motzo map”, after the name of the researcher Bacchisia R. Motzo, who published it in 1974 in Caligari, confirms the expansion of the maritime waterways, the knowledge of the distances between the ports, etc. The Black Sea was connected to the “Silk Road”, an economic way from China to Western Europe (Charles King 2015: 100).

34.2 Romanians at the Black Sea (Fourteenth to Eighteenth Centuries)

It was rightly stated that the maritime trading in mid-fourteenth century was influenced by the Romanian political assertiveness through the union of the territories from the Carpathians up to the Danube and the Black Sea, the space in which they had been formed as a people through the Romanization of the Dacians and the Getae after the conquest of a large part of Dacia by Emperor Trajan (98–117 A.D), to which proto-Romanians added Slav influences (Giurescu 1973: passim).

The mid-fourteenth century marks the moment when the pre-state elements, the kniezates and voivodates, are united and extend their territorial control to the limit of the formation home of the Romanian people, in the south-east to the mouth of the Danube and the Black Sea. Basarab I, the founder of Wallachia, stretched his control over the maritime Danube, the southern region between the Prut and the Nistru, called then Bessarabia (Giurescu and Giurescu 1975: 271–272).

Reaching the Pontic coast finished the historical process of formation of the Romanian medieval states. The Black Sea represented the end of the way and, at the same time, the opening necessary for development. The influence of the Black Sea upon the Romanian rulers at the end of the fourteenth century and the beginning of the fifteenth century was so powerful that they included its control in their titles. We find this in a document from Roman I (1391–1394), the Moldavian ruler, who called himself “the only great ruler of the country from the mountains up to the sea shore” (Toderașcu 1977: 25). As we have mentioned, two famous specialists in the history of Black Sea in the thirteenth to fifteenth centuries, Șerban Papacostea and Virgil

Ciocâltan, opened the possibility of a strong link with the Pontic centres through the territories liberated from under the power of the Golden Hoard (Papacostea and Ciocâltan 2007: 209). The commercial waterways at the Black Sea through the decisive contribution of the Genovese coupled in the western direction the way of Moldavia with the way of Wallachia: Maurocastrum, from the margin of Nistru, Vicina on the Lower Danube, Licostomo, from the mouth of Chilia, became strong commercial centres.

More illustrative is the title of the ruler of Wallachia, Mircea cel Bătrân (1386–1418), "great voivod and only ruler of the entire Wallachia, the areas over the mountains, the Tatar regions and the herteg of Almaș and Făgăraș, prince of Banat, Severin and of both parts of Podunavia up to the Big Sea and unique ruler of the city of Dârstor" (in a document from 1406).

The maritime façade and the mouth of the Danube boasted ports, such as Chilia, Lycostomo, Geanavarda, Constanța, Mangalia and Caliacra. As a result of a campaign of the sultans Mehmed II (1451–1481) and Baized II (1481–1512), the Ottoman Empire takes over the region of Dobrogea, between the Danube and the Black Sea. Moldavia continued to maintain its presence at the Black Sea during the reigns of Alexandru cel Bun (1400–1432), of Petru Aron (three terms in between 1451 and 1457), when sultan Mehmed II grants Moldavian traders the right to sail and protection for their ships since June 9, 1456, and especially of Ștefan cel Mare (1456–1504), who was concerned to change the rapports between Moldavians and Ottomans in his favour. He included in this policy the fleet formed by the so called "Moldavian pânzar (a ship)" (Ciorbea and Atanasiu 1995: 23–24). Besides the use of the ships for the defense of the maritime ports, Ștefan cel Mare was interested in navigation in the area of Mount Athos. An inscription found at Zografu monastery informs us about the *ships tower* built in 1475 upon the order of the ruler (Iorga 1913–1914: 44–47). It is no wonder that the church painting in Moldavia includes ships, the most representative being those of St. Parascheva in Roman, St. Nicholas in Bălinești and The Beheading of St. John at Sucevița (Solcanu 2002: 71–74).

The Ottoman expedition of 1482 resulted in the occupation of Chilia and Cetatea Albă, major ports in Moldavia, an event which affected the maritime evolution of the country in the following centuries. The Black Sea becomes "a Turkish lake", the Turkish ships doing the trading of most products from the ports at the mouth of the Danube and Constanța. As far as the Romanian ships are concerned, they were not entirely absent from the maritime trading, but as specified "they sailed Turkish-flagged and they were forced to serve the interests of the ruling power" (Toderașcu 1977: 30).

At the order of the ruler of Wallachia, Neagoe Basarab (1512–1522), a mooring point was erected at Mount Athos, when two ships were built. There is information on the two ships from the famous travelers Paul of Alep and Evlia Celebi. The former crossed the Siret on a ship. A Polish envoy, Iosif Podoski, counted seven smaller ships on the Prut (Solcanu 2002: 73).

In the context of the 1677–1678 Russian-Turkish conflict over the control of the Black Sea, which brought the Czarist Empire, through the Treaty of Kuciuk

Kainargi (1774), the freedom of navigation on the Danube and the Black Sea, the Romanian Principalities show an increasing interest in water trading. After over 300 year since the Turkish control of the Danube and the Black Sea, Enăchiță Văcărescu, a close councilor of the Wallachian ruler Alexandru Moruzi, created the job of the royal sailors for the transport of Romanian products towards the Ottoman Empire. The ruler was given by Constantinople the right to build various types of ships, a right that we had had but lost in the unfavorable circumstances. As a result of the granting of this right, Alexandru Moruzi issued in November 23, 1793 *The Charter for the Wallachian ships to sail on the Danube*, which actually founded the first Romanian fleet. When the charter was officially due, the Romanian fleet counted 17 ships, according to the number of Wallachian counties (Urechia 1893). The ruler decided that the ships "all of them, the Romanian ones and others were supposed to sail every year especially in the benefit of the state" (Urechia 1893).

34.3 The Development of the Romanian Commercial Maritime Service (Nineteenth Century)

A major stage in the development of navigation on the Black Sea is represented by the Treaty of Adrianople, signed in 1829. The document sets the international juridical basis for a new age in the development of Romanian navigation. The members of the Moldavian Assembly inform on 30 January 1830 count Pavel Kiselev, who ran the Russian military administration of Wallachia and was the president the Wallachian and Moldavian Assemblies, that measure would be taken for building a commercial fleet for the transport of the products of the country (Toderaşcu 1977: 32).

The rulers Alexandru Ghica and Mihail Sturdza make appeals to the High Porte (the headquarters of the sultan of the Ottoman Empire) for the right to possess a commercial fleet to sail on the Danube and the Black Sea. In October 1834 sultan Mehmed II (1808–1839) signed a document approving "for the Wallachian commercial ships a yellow and red flag with stars and a blue bird with a head" (Basarab 1991: 9). For Modavia, the flag had "stars and an ox head, in bright red and purple culours". The beginnings were represented by the ship "Marița", built in the naval shipyard in Giurgiu through the initiative of Alexandru Vilara. The ship, called after the wife of Prince George Bibescu, was a brig. On 7 December 1834, loaded with grain, it left Sulina for Constantinople, the voyage lasting 18 days because of a storm. The number of ships increased. According to data, the Romanian flag could be seen on several ships under names, such as "Dochia", "Wallachia", "Prince George Bibescu", etc.

The French diplomat Felix Calson, secretary of the French Consulate from Bucharest, appreciated that Moldavia and Wallachia had 20 ships. "Gazette Piemontese" of March 20, 1851 mentioned "over 100" Romanian ships (Toderaşcu

1977: 33). The majority of the ships came from the Romanian naval shipyards on the Danube. Only in Galați were built, between 1839 and 1840, 17 ships. Various merchants are granted the right to be ship-owners and send their ships in the Black Sea and other seas (Toderașcu 1970: 69). Among the ship-owners, there was the Moldavian ruler Mihail Sturdza, who is granted, in 1840, the right to use the ship "Moldavia", of a capacity of 235 tons.

Starting in 1845–1846, many Greek ship-owners from the Ionic Islands chose, to sail, out of commercial advantages, under the flags of Moldavia and Wallachia. The trading to and from the Romanian ports was dominated by the ships under foreign flags attracted by the enriching business in the Romanian ports. For instance, out of the 685 ships that entered the port of Brăila in 1839, 254 were Turkish, 195 were Greek, 105 from Sardinia, 38 from Russia and only 16 from Wallachia (Ciorbea, Atanasiu 1995: 38).

In 1857, the first Romanian steamboat starts sailing, namely "Ceocan", which transported wood and salt on the Danube and a part of Siret River (Bârdeanu and Nicolescu 1979: 145).

After the union of the Romanian principalities in 1859, under the rule of Alexandru Ioan Cuza, new elements of modernization and order are introduced in the domain of navigation. The ruler approved of a new model of pavilion, the obligation for ships to get a document issued by the Ministry of Foreign Affairs or the Diplomatic Agency in Constantinople. The most important document adopted was the *Law of Navigation for the Commercial Marine*. It set the requirements for a ship to get the Romanian nationality and the documents which were compulsory for any ship to keep on board (Smaranda 1982: 1–6).

The union between Dobrogea and Romania in 1878 brought free exit to the Black Sea for Romania. The Romanian state will buy the port of Constanța from a British company and build the bridge over the Danube, Fetești-Cernavodă, opened on 14/26 September 1895 by king Charles I. New circumstances for the development of the commercial fleet are thus created.

An absolutely remarkable achievement, at the end of the nineteenth century, more precisely on 1 November 1890, through the efforts of Grigore Manu, the director of the State Transport Administration, is represented by the Romanian River Navigation, a national institution of civil navigation on the Danube. After a 5-year experience, the same Grigore Manu addressed the Parliament the request to grant the creation of national institution of maritime navigation. Supported by the great historian N. Iorga and the reputed economist P.S. Aurelian, Grigore Manu's endeavor was successful. The Ministers Council issued on 28 April 1895 a decision through which Grigore Manu had to organize an institution of maritime navigation in the Ministry of Public Works.

In this respect, Grigore Manu was granted 2.5 million lei, the sum to be used for the organization, buildings and installations, agencies and storehouses for freight and for the purchase of the first ships. From an Austrian society the "Medeea" ship was bought for 150.000 lei, and from "John Carlisle" House from London, the "Meteor" ship was purchased for 800.000 lei. After a period of reparations, the "Medeea" left the port of Brăila for Galați-Sulina-Constanța-Constantinople, in its maiden voyage under a Romanian flag, with 25 passengers on board and 600 tons freight. On 26 August 1895, the "Meteor" went on its first voyage on the same route.

On 14 September 1895, as established by the Parliament, the first Constanța-Constantinople regular maritime line for passengers was officially inaugurated. The date also represents a historical moment for the beginnings of the Romanian Maritime Service. In a document, issued by the Royal House, king Charles I underlined "the functioning of Constanța port, helped by God, the establishment of Romanian State Maritime Service as a big and decisive step in our economic development" ("Marea Noastră" 1937: 96).

On 30 October 1895, the Romanian Maritime Service was directed under the jurisdiction of the General Direction of the Railroads. A new law set three important characteristic for this service: (a) passenger, post and freight transportation between the Danubian ports (from Brăila downwards) and the foreign maritime ports; (b) passenger, post and freight transportation between the Romanian maritime ports and the foreign maritime ones; (c) ordering and supervising the building of foreign ships (Vârnav 1897: 41–42).

Interested in the development of the commercial marine, King Charles I recommended that the government should grant a new sum of money for the building of new ships. Answering this request, Ion C. Brătianu stated: "this bill is part of the complex political and economic plan, conceived after the union of Dobrogea with the country and meant to offer Romania, in the Black Sea and a European context, the place that it deserved" (Moșneagu 2008: 280) and asked the Parliament for ten million lei. New ships were rented to ensure the continuous link Constanța-Constantinople for the travelers that came by train from London, Paris, and Vienna for the near East.

On 1 July 1898, the postal and passenger ship "King Charles I" started sailing, baptized together with the "Princess Maria" ship, ex-"Ignazio Florio", rented by the Maritime Service, in the presence of the royal family.

The Maritime Service extended its activity, establishing the "Freight Service", which had in the beginning five ships: "Dobrogea", "București", "Iași", "Turnu-Severin", "Sulina" and a smaller boat "Viitorul". The "București" cargo inaugurated the maritime line Danube-Rotterdam.

In conclusion, in spite of all the facilities, the Romanian Maritime Service was, in the early twentieth century, still far from satisfying the needs of the Romanian foreign commerce, the statistics showing that the trading was then under foreign influence (Cristodorescu 1905: 138).

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Chapter 35
An Original Document About the History of the Antarctic Expedition « Belgica »

Alexandru Marinescu

Abstract The author presents original documents useful to understand the connections between the members of the staff and the projects of the Belgica Expedition in the Antarctic Region (1897–1899).

In 1998 an article was published in Noesis, the journal of the Romanian Academy for the History of Sciences, dedicated to the correspondence between members of the staff of the expedition "Belgica". At that time I thought that the hundreds of letters and documents scattered among the prestigious European archives of Anvers, Bruxelles, Krakow, Cluj, Bucharest, and probably elsewhere, deserved to be gathered in a formal volume, with foreword, notes, short biographies and all that would make a publication of this type exhaustive. Unfortunately, I could not bring this project to fruition. Instead I only published the correspondence between Adrien de Gerlache, the initiator, organizer and leader of the expedition "Belgica" (1897–1899) and the Romanian Emil Racovitza, the expedition's naturalist. This correspondence, mostly dating from the planning phase of the expedition, was printed by the publishing house "Compania" from Bucharest in the "Journal" volume, and released on the centenary of the Belgian expedition.

Previously I read countless letters addressed to Emil Racovitza, but until the end of 1990 I never encountered a letter written by Racovitza, even though I knew that he replied to his correspondents, annotating on each letter received by him both the receipt date as well as the reply date. The last day of my visit to the Royal Institute of Natural Sciences in Bruxelles, during the final hours of my stay while the luggage was being prepared and I was waiting to depart for the airport, I was delivered in the laboratory a big box with the "Belgica" documents. These papers were forgotten for years, probably ignored by everyone, stored in a corner of the laboratory belonging to the Professor who directed the Museum's section of Oceanography.

Full of emotion, I discovered among the documents from the box more than 40 letters authored by Emil Racovitza written to other members of the expedition. I

A. Marinescu (✉)
Romanian Committee of History of Science and Technology, Bucharest, Romania
e-mail: juandi@yahoo.fr

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was troubled and anxious that I could only read a few of his letters in the limited amount of time that I had left that day. Most certainly I had no time to take notes. However, I received assurances that the letters would be copied and sent to me in Bucharest. Four days later, copies of the letters were sitting on my desk at the Museum of Natural History “Grigore Antipa” in Bucharest.

Unfortunately, the letters from Racovitza have not been published yet. Only a limited number of his letters have been discussed in the book “Emil Racovitza, the naturalist of the Belgica expedition” (All Publishing House, 1998), issued the same year as the volume published by the Romanian Cultural Foundation in French “Racovitza E. – Letters, Antarctic Diary, Conferences”. But this last publication, printed under excellent graphic conditions (Collection Rameau d’Or), included a mysterious cover which concealed completely the real title of the book. In addition, it had a disastrous distribution and a large number of volumes were returned to the editor.

In 1998, the year of the Belgica centenary, I was invited for a few days at the Ast castle in Huise Zingem, property of the son of Adrien de Gerlache, the baron Gaston de Gerlache. He was an Antarctic explorer himself who led the Belgian expedition of 1957 after being a hero of the Royal Air Force during the Second World War.

I was invited to study the extraordinary archives of the de Gerlache family. One day, while we were discussing in his study full of keepsakes, under the eye gaze of a big Royal Penguin (Aptenodytes patagonica) perfectly adapted to its frigid environment, the Baron de Gerlache shared with me his astonishment: indeed, the Belgica expedition had been forgotten by the authors of exploration and discovery books in spite of its significant accomplishments. It was the first expedition to spend winter beyond the South Polar Circle, surviving the extreme Polar night and making complex scientific observations during an entire year. It was also the first expedition with an international team including the Norwegian Roald Amundsen, the future conqueror of the South Pole on the 14th December 1911, and Frederick Cook, the future conqueror of the North Pole on the 21st April 1918. I tried to understand why the records for this particular expedition were so scarce in spite of its remarkable history which succeeded with so many advances in the field of Antarctic research. Beyond the books written by certain members of the expedition staff (Frederick Cook, Adrien de Gerlache, Georges Lecointe) and some conferences in 1900, the publications are very rare. The number of related documents preserved in European archives are largely unknown. I do not know if my arguments convinced Gaston de Gerlache, but I still believe I was right.

That is the reason why I selected out of hundreds of original documents, the minutes of a meeting of the staff of the Belgica expedition, written by Georges Lecointe on the 22nd of September 1898, a day after the discussions held on the 21st September “at two hours in the afternoon, with the purpose of fixing the program of the time schedule to put in place after the release of the ship from the ice”.

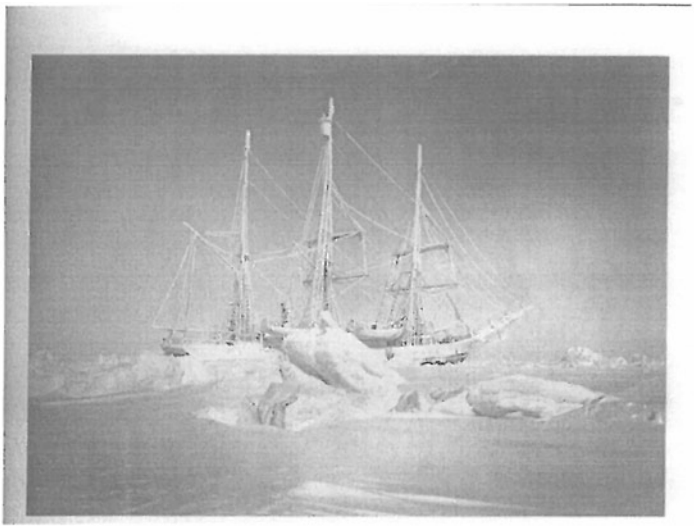

Photo made by Frederick Cook in 1898

It is a document of 16 pages written on the ship 118 years ago. Belgica had been blocked at that time in the ice pack since the 4th of March 1898. The movement between the glaciers was decided by the Captain Adrien de Gerlache, supported by his second in command, Georges Lecointe, but with Roald Amundsen and Emil Racovitza as the most fervent opponents. While Amundsen realized "immediately the outmost danger to which de Gerlache and Lecointe exposed the entire crew", the Romanian naturalist thought that the captain and his second could not "take such an important decision prior to asking each member of the expedition for an approval vote, since it had been decided before leaving Europe not to winter with the ship. . .". Belgica remained captive in the ice pack for 13 months, a terrible time for the 17 members of the crew. Scientific research continued to be made daily. Belgica recovered its freedom on the 14th of March 1899 after the crew dug with extraordinary efforts a channel through the ice.

Toward the end of 1898 in an attempt to maintain as much as possible the morale of the crew Captain de Gerlache gave instructions that the ship be prepared for sailing away. This incident occurred 2 months before the famous meeting of the staff on the 21st of September 1898 that we will review next.

De Gerlache started the meeting by asking if anybody had a proposal to make. As nobody reacted, the Captain communicated his campaign plan for the year 1898–1899. Arctowski and Cook asked some questions, and afterwards de Gerlache engaged Racovitza for his opinion on the feasibility of fishing in the Belgica channel. The naturalist answered with coldness "Yes, Captain, you can fish anywhere. . .".

De Gerlache's plan was courageous: the ship would arrive in the Montevideo harbor from which Lecointe would sail to Belgium to try and raise funds to extend the polar campaign for a third year. The Belgica would wait for the results of Lecointe's efforts for 2 months near Rio de la Plata. If the negotiations were a success, the ship would weigh anchor to sail for the Cape of Good Hope and on the 1st of August 1899 would leave for Melbourne. If the fund raising ended in failure, de Gerlache would start on the return voyage to Europe. Once he would arrive in Montevideo, the Captain would consider the expedition finished and declare that the participation in the third year of the campaign should be on a volunteer basis.

Henryk Arctowski was the one who spoke the most during this meeting. In his opinion the plan proposed by de Gerlache was excellent and he was looking forward to its execution.

He summarized the plan for the 98–99 campaign as follows:

1. Attempt to break free from the ice pack.
2. Work as intensely as possible to further scientific research in the regions of the Antarctic Ocean proposed in the plan and during the crossing between the Isle of States and Rio de la Plata.
3. Once the team would arrive in Montevideo, everyone would consider their duties complete. He understood this third point as a third campaign of the Belgian Antarctic expedition with a clear and well defined purpose and that should be performed on a volunteer basis by those who were invited to continue the work on the ship during this optional year in other conditions than the preceding ones.

Emil Racovitza stated that in accordance with a discussion held with the chief of the expedition he would abstain from voting and from expressing an opinion regarding the plan presented, except for zoological or botanical information the Captain could potentially solicit from him.

The de Gerlache project was adopted with five votes in favor and one abstention. The utility of this third year of campaign through the Sea of Ross and the Magnetic Pole was also submitted to a vote, obtaining the approval of de Gerlache, Lecointe, Cook and Amundsen. Racovitza and Arctowski abstained. Racovitza was asked if he believed his work would be productive on the Isle of States. He answered that "he will not participate to a third year of campaign as a member of the expedition, but he will continue to work for several more months as long as no health issues or family emergencies forced him to return to Europe. He did not wish to abuse the good will of the Argentinean Republic".

The idea of a trip towards the Australian coasts before going south after the end of the Antarctic winter and the pursuit of research existed from the start of the initial planning phase of the expedition. Adrien de Gerlache kept this possibility in mind with the purpose of avoiding the difficulties of winter for his crew since survival during Antarctic winter was unproven for humans at that time. But this hope disappeared the moment they become prisoners of the ice pack. The plan proposed by de Gerlache and Lecointe for the third year of expedition kept the initial flow. Indeed, if the staff meetings were sometimes filled with illusions, the work plan for the year 1898–1899 seemed realistic as long as the ship could escape from its ice prison without too much damage.

At the end of the meeting minutes we find a detailed “Project of itinerary for the summer campaign 1898–1899”, signed by Adrien de Gerlache and Georges Lecointe. The minutes of the staff meeting were signed by Racovitza, Arctowski, Cook and Amundsen.

However as we know, Belgica’s return trip towards Europe followed a different path. De Gerlache chose the most dangerous way back in order to avoid meeting other ships, and the ship sailed through Cockburn channel in the Strait of Magellan. On the 26th of March, the Belgica passed by Black Island, a conglomeration of black rocks. Two days later, on the 28th of March, the ship entered the harbor of Punta Arenas. It was in this harbor that the first news about the expedition’s status were sent to Bruxelles on the 1st of April, arriving in Belgium on the 27th of the same month.

The plan to conduct scientific research in the Tierra del Fuego (Patagonia) was abandoned, since repairing the ship became the top priority.

The scientific members of the crew were authorized to return to Europe. Frederick Cook returned to Patagonia to complete his anthropologic research, and Amundsen returned to Norway. Racovitza, accompanying a sick sailor, also returned to Europe, making stopovers in Montevideo and Buenos Aires.

When the Belgica arrived to Boulogne-sur-Mer, on the 30th of October 1899, all the members of the expedition were on board the ship. They had a triumphal arrival in Anvers in the morning of the 5th of November 1899, putting an end to a heroic trek. That day marked the end chapter of a remarkable journey of discovery and final point of a great scientific victory.

Chapter 36
Venice-of-the-North's Ups and Downs: A Brief History of the Port City of Bruges, Belgium

Roger H. Charlier and Constance C. Charlier

Abstract Venice Italy is famed for its rich history built on trade and centuries of accumulated wealth. But when a major storm in 1134 opened an inlet in the North Sea coast, near what is today Bruges Belgium, it created natural access to a new port. The "waterway" brought such an economic bloom to the Flandrian city that it became known as the Venice-of-the-North eventually competing, and perhaps surpassing, its namesake as the richest city in Europe. What Mother Nature giveth, she can take away, and indeed shifting sands, silting, combined with ships' larger sizes, wars and political conflicts brought Bruges to ruin. From enjoying centuries as one of the largest and wealthiest harbor cities in the Western world, it became an impoverished settlement, until it rose from its ashes through the construction of a strategically connected manmade port, away from the inlet. The new port fell victim to World Wars I and II, but is now a ranking and continuously expanding North Sea harbor. The paper traces the vicissitudes of Bruges.

36.1 What's in a Name?

Since the advent of advertising and the financial gains produced through tourism, many tourist offices and cities have tried to bank on the drawing power of the name "Venice". The nickname "Venice-of-the-North" has been claimed many times over and expanded to "Venice-of-the *fill in the blank*" (Fig. 36.1) (Wade 2009). It has been used as shorthand to describe cities built on waterways, with canal systems, many bridges and active ports. In Europe, Amsterdam (Fig. 36.2) and Stockholm (Fig. 36.3) are among those who like to be called Venice-of-the-North because they

R.H. Charlier (✉)
Vrije Universiteit Brussel (Free University of Brussels), 2 Avenue du Congo [box 23], B-1050 Brussels, Belgium
e-mail: roger.charlier@vub.ac.be

C.C. Charlier
University of Arizona (retired), Axelrod and Associates Consultants, 352 Oliver Road, Santa Barbara, CA 93109, USA
e-mail: conniecharlier@yahoo.com

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Cities called Venice of the North	Cities called Venice of the East
Amsterdam, Netherlands	Dhaka, Bangladesh
Birmingham, United Kingdom	Barisal, Bangladesh
Bruges, Belgium	Bandar Seri Begawan, Brunei
Annecy, France	Fenghuang, China
Geithoorn, Netherlands	Lijiang, China
Hamburg, Germany	Suzhou, Jiangsu Province, China
	Tai'erzhuang, Shandong Province, China
Saint Petersburg, Russia	Tongli, China
Stockholm, Sweden	Wuzhen, China
Wroclaw, Poland	Zhouzhuang, China
Fort Lauderdale, Florida	Nan Madol, Federated States of Micronesia
Venice Beach, California	Alleppy, Kerala, India
Tigre, Argentina	Kerala Backwaters and Alappuzha, India
Copenhagen, Denmark	Srinagar, India
Nantes, France	Udaipur, India
Sète, France	Osaka, Japan
San Antonio, Texas	Malacca, Malaysia
	Manila, Philippines
Other "Venices"	Sitangkai, Tawi-tawi, Philippines
Monasterevin, Ireland – *Venice of Ireland*	Ayutthaya, Thailand
Recife, Brazil – *Venice of Brazil*	Can Tho, Vietnam
Puerto de Mogán, Canary Islands – *Venice of the Canaries*	Hanoi, Vietnam
Basra, Iraq – *Venice of the Middle East*	

Fig. 36.1 Venice-of-the-"*fill in the blank*"

are criss-crossed by canals. St. Petersburg (Fig. 36.4) in Russia has used the name, as has Bangkok claiming the label of Venice-of-Asia and in the United States there are even cities called Venice, in Florida and Venice Beach in California (Fig. 36.5).

Surprisingly, Ghent (Flemish *Gent*, French *Gand*), on the confluence of Leie (French *Lys*) and Scheldt rivers (in Flemish *Schelde*, French *Escaut*, Latin *Scaldis*), like Venice, is built on several islands, but never banked on the name of Venice. Perhaps this is why Ghent is usually eclipsed by Bruges when tourists plan their visits to Belgium.

Fig. 36.2 Amsterdam, The Netherlands (C. Charlier 2008)

Fig. 36.3 Stockholm, Sweden (C. Charlier 2016)

Fig. 36.4 St. Petersberg, Russia (C. Charlier 2016)

Fig. 36.5 Venice Beach, California, USA (C. Charlier 2012)

Fig. 36.6 Bruges, Belgium (C. Charlier 2016)

Bruges (Fig. 36.6), in Belgium, is also cut up by canals, but it earned the nickname Venice-of-the-North long before the rest, during the Middle Ages. It rivaled the original Venice (of the Mediterranean) in political influence, wealth, and power. For centuries Bruges was both the largest city and the largest port of the Western World. Its power was such that England was grateful for the treaties it could sign with it. Bruges was so large it had two auxiliary harbors, both to the north: Damme and Sluis (*L'Ecluse* in French), meaning lock. Because in Flemish and Dutch *brug[gen]*, means bridge[s], popular etymology ascribed the name of the city to the numerous bridges that, like in Venice, are found all over the historical part of the city. Actually the name *Brugge* (*Bruges* in English and French) is derived from the Nordic *bryg*, meaning an unloading or trans-boarding point.

36.2 Venice, Italy: Where It All Began

Venice is a city of small islands, enhanced during the Middle Ages by the dredging of soils to raise the marshy ground above the tides (Fig. 36.7). The resulting canals encouraged the flourishing of a nautical culture which proved central to the economy of the city. Today those canals still provide the means for transport of goods and people within the city. The maze of canals threaded through the city requires the use of hundreds of bridges to permit the flow of foot traffic.

Venice is built on an archipelago of 118 islands formed by 177 canals in a shallow lagoon, connected by 409 bridges. In the old center, the canals serve the function of roads, and almost every form of transport is on water or on foot. In the nineteenth century, a causeway to the mainland brought the Venezia Santa Lucia railway station to Venice, and the Ponte della Libertà road causeway and parking facilities (in Tronchetto island and in piazzale Roma) were built during the twentieth century (Cosgrove et al. 2015).

Originally formed by the interaction of Adriatic tidal currents and the waters of several Alpine rivers (Piave, Sile, Bacchiglione, and Brenta), the lagoon has always been crucial to the survival of Venice. Its mud banks, shallows, and channels are a

Fig. 36.7 Grand Canal of Venice, Italy (C. Charlier 2007)

source of income from marine and bird life and from salt pans. The lagoon has served as protection (the Venetians defeated the Genoese in 1380 through their superior knowledge of the navigable channels) and as a natural sewerage system, with the tides flushing out the city's canals twice daily (Madden 2013).

But the lagoon requires careful husbandry to prevent it from threatening the very existence of Venice. The deepening of channels in the twentieth century, the over-extraction of fresh water from mainland aquifers, the rising of the Adriatic Sea, and the geologic sinking of the Po River basin have all combined to lower the land level, creating a serious flooding problem. On a regular basis, when high tides combine with winds from the south and east, the waters of the lagoon rise and flood the city, creating the acqua alta ("high water") so familiar to Venetians, and elaborate raised platforms are laid out in main squares to allow tourists and others to walk around the city.

Though first settled circa 569, Venice began to establish itself as a trade power after a treaty in 814 between the Franks and the Byzantines established its independence from the Carolingian empire without requiring any special emphasis on its obligation to Constantinople. Thus Venice became part of both worlds, east and west, yet without obligation to either. It is perfectly placed between the Mediterranean and the mountain passes up through the Alps into northern Europe, and poised to prosper from trade. In return for help against Norman marauders, the Byzantine emperor granted Venice an astonishing concession in 1082: free trade throughout the Byzantine empire, without being liable for any dues or customs. Fortune was guaranteed.

Soon extra trade routes opened along the coasts of the Byzantine empire and beyond. In 1096 the First Crusade set off eastwards to recover the holy places of Christendom from the Muslims, resulting in a great increase in trade, travel and pilgrimage to the eastern Mediterranean. Venice, which had the skills to provide the transport and an already established trade concession, was perfectly placed, and reaped the benefits of these developments (Fig. 36.8).

36.3 Bruges, Belgium: In Comes the Competition

The history of Bruges stretches far back to Julius Caesar who was responsible for the construction of the earliest fortifications there in the first century BC. These were erected in an attempt to defend the Roman Empire against the very real threat of pirate attacks. In the ninth century AD, the Count of Flanders, Baldwin I (or Baldwin the Iron Arm), strengthened the Roman walls and built a castle to protect against Viking raids. The town of Bruges eventually grew around this castle.

Bruges has a long history as a port. For centuries the Zwin (the south-westernmost channel of the estuary of the river Scheldt) linked Bruges to the sea. At 17 km (10.5 miles) inland from the North Sea it is not in a naturally perfect setting for a sea port but the area is made up of ever shifting sands. Beginning in the eleventh century, fierce coastal storms opened and closed access to the sea. A 1040

Fig. 36.8 Gondola in Venice, Italy (C. Charlier 2007)

English text calls Bruges an important maritime trading centre. English wool, furs, amber, flax, and honey were the major imports adding wine and cloth to its trade over time. But by the end of the century access from the sea is closed by silting and Bruges' success is hindered by Mother Nature.

Not giving up, in 1134 canals are built after a storm flood shifted the silt thereby opening an inlet from the Zwin to Damme, very near to Bruges and allowing the re-opening of the maritime trading route. Damme (only 7.5 km or 4.7 mi away) became an outer port for Bruges and later Sluis took on the role when the route to Damme became impractical. From there small barges would move goods along the Langeroi. Damme, in the twelfth century, was a small fishing settlement on the Zwin, but accessible to reasonably sized draught ships. Then in 1180 Philip of Alsace (1165–1191), the Count of Flanders, granted it city status. That conveyed to Damme warehousing rights on Bordeaux wines and herring, a privilege that carried profitable income. Goods would be transferred to flat-bottom boats to complete their journey to Bruges. Philip II, (called Philip Augustus 1180–1223) King of France and the suzerain nemesis of Flanders, put Damme to the torch in 1218 out of anger over defeat in what is considered the first British naval victory, but by 1225–1241 the people had reconstructed a church, and "hallen" (covered market). Damme's fate remained linked to Bruges'.

Like most Flemish towns of the Middle Ages, textiles fueled the prosperity and importance of Bruges. And by the end of the thirteenth century, the history and prosperity of Bruges was buoyed by the wool trade. As an emerging market powerhouse, the Bruges Bourse made its appearance in 1309 and is thought by many to have been the world's earliest stock exchange (Coispeau 2016). From 1200 to 1400 Bruges threatened to eclipse Venice as a trade mecca. Bruges became the most important trading center of Europe with its stock exchange, large consulates, and flourishing art community. The first book printed in English the Recuyell of the

Historyes of Troye came from Bruges in 1473 and was printed for Margaret, Duchess of Burgundy and sister of English Kings Edward IV and Richard III (Various 1907–1921; Blake 1976, 2004).

Bruges' wealth started to diminish in the fifteenth century, when the larger harbor of Antwerp began to dominate and take up the trade of Bruges and Damme. Mother Nature never sleeps and she continued to create challenges for the port. In 1520 the Zwin's silting closed off sea access and set off real economic decline. Damme was virtually destroyed by the Gueux (Gueuzen), insurgents battling Philip II, King of Spain and sovereign of the Netherlands (the XVII Provinces, imperial lands of the Habsburg) during the period spanning 1578 through 1584. But Bruges was not giving up yet. A 1622 canal to Oostende gave Bruges a new outlet to the sea. They continued to import from other Hanseatic League trading cities and guilds quite actively from the thirteenth to the seventeenth centuries. Silting problems continued and struggling to hold on to its trade, yet another canal is built further away. Begun in 1751 and finished in 1753 the Coupure Canal opened access for sea going vessels from Ghent into the city centre (Boussauw 2014; Charlier 2005; De le Courte 1891).

Damme lived a short revival when Napoleon I (1769–1821) who ruled over the occupied Belgian (Southern Netherlands) provinces, initiated the digging of a canal that would have linked Bruges with the Scheldt river and thereby given Bruges and Damme a new access to the sea. The waterway went as far as Hoeke. When the Congress of Vienna (1814–1815) selected William I (1772–1841) of Orange-Nassau (King of The Netherlands, 1813–1840) to succeed Napoleon I to the reunited XVII Provinces, he ordered the pursuit of the digging which proceeded to Sluis (to the French L'Ecluse). That is where the "canal that goes nowhere" stopped because the Belgians revolted in 1830 and demanded independence. Sluis and the lower part of the Scheldt River became Dutch territory, the Sluis Canal – the canal that goes nowhere) was put to rest forever and Scaldisian Ghent got the direct link to the Scheldt delta by way of a Ghent-Terneuzen canal, in part through Dutch territory (Lambert 1985).

By 1847 Bruges had declined to the poorest city in Belgium and its hungry citizens were moved to riot. By the 1890s Bruges had became known in the world through the writings of Georges Rodenbach (Rodenbach 1892) as Bruges la morte or "the dead city".

36.4 Coastal Lands Versus Ebb and Flow

Bruges is not the first town to find itself at the mercy of Mother Nature's whims. A glance at old maps shows the considerable difference of position of the shoreline in the Humber Estuary of England during Roman Times and the contemporary littoral (Bruun et al. 1978). It is part of the FloodProBE research project supported by the European Commission addressing "Technologies for Improved Safety of the Built Environment in Relation to Flood Events". As a pilot site (in company with

Prague, Rotterdam Airport, Dordrecht, Trondheim, Orleans, and Gloucestershire) the project is working to improve methods for assessing the vulnerability to flooding of the urban environment (Van and Van Ree 2011). Historically at least 20 towns on that Humber coast have been lost to the sea in less than a millennium.

Across the channel France, Belgium, The Netherlands, Germany, Denmark have to cope with erosion that menaces huge economic interests on their coasts. Ter Streep, Harendycke and Scarphout were once shore villages of the Flandrian coast and the Verdronken Land van Saaftingen (Drowned Land of Saaftingen) was a rich pasture area of the Scheldt Delta. Accretion has transformed thriving ports into near land-locked cities and has sometimes provided puzzles to geologists and riddles to toponymists. Why is Montreuil-sur-Mer (France) not on the sea and why is Belle Isle (France) a town at considerable distance from the nearest water body? How did it happen that oyster shell “reefs” formed inland in the southwest of France?

The European Union commissioned a study on the shifting coastlines that showed more than disquieting trends. In its desire to protect and promote sustainable development of coastal zones, in March 2013 the European Commission adopted a draft proposal on Coastal Erosion and Protection in Europe. Its directive aims at establishing a framework for maritime spatial planning and integrated coastal management. According to their website (European Commission 2013), “The proposed instrument will require Member States to establish coastal management strategies that build further on the principles and elements set out in the Council Recommendation on Integrated Coastal Zone Management of 2002 and the Protocol to the Barcelona Convention on Integrated Coastal zone Management, ratified by the EU in 2010.” Coherent application with maritime spatial planning will improve the sea-land interface planning and management, including the effects of infrastructure works to protect coastlines against erosion or flooding on activities in coastal waters such as aquaculture or protection of marine ecosystems (Pranzini and Williams 2013).

Tidal inlets have a geological or hydrological origin (Fig. 36.9) (Aubrey and Giese 1993; Hayes and Duncan 2013). Two examples of tidal inlets that once gave access to thriving ports are Brouage in France and Bruges in Belgium. Brouage was the departure point of the explorer de Champlain who sailed to “New France” in 1603, and Bruges was once the wealthiest port city of Northern Europe. The first one is today a historic site and developed into an artists’ center, the other, also a tourism mecca, has however risen from its ashes and re-sited its port on the North Sea. Both are amidst contemporary polderland, neither has a fishing fleet left and the tourism trade has supplanted, or equaled, in economic importance, the traditional occupations of yore.

Contemporary Brouage has many a memento of its important past as a port. There is a Blessed Virgin adorning the front of the Swedish Titus that stranded in the sixteenth century not far from the harbor’s entrance channel, or the masonry above the door of Antwerp merchant Mathias Hazeur’s home that has an advice chiseled, in Flemish, “He who puts his trust in God has wisely built”. A pun about Brouage is that instead of being Brouage-on-the-Sea it is Brouage-with-no-Sea. Just invert two letters: from “on” to “no”, and pass from Brouage-sur-mer to Brouage-sans-mer.

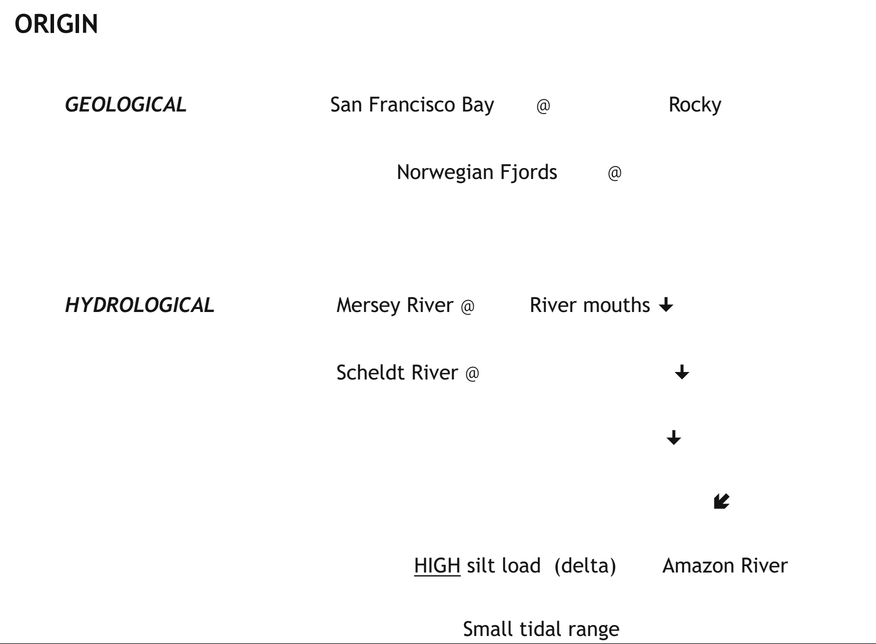

Fig. 36.9 Development of Tidal Inlets

36.5 The Phoenix Emerging from Its Ashes

It is not until the early 1900s and the creation of the Port of Zeebrugge, Bruges' new sea harbor, that the Belgian port began its return to powerhouse status. Not only Antwerp, but Bruges itself benefitted from the interest of their often misunderstood and unappreciated King Leopold II (1835–1909, King of the Belgians 1865–1909). He put pressure on his governments to rescue Bruges. It took a world war in which both Belgium and The Netherlands were on the same side to put an end to the Dutch control on all ships sailing upstream the Scheldt. The toll exacted by the Dutch was abolished when Baron de Lambermont bought it off in the late nineteenth century.

Thanks to Leopold II the Belgian government decided to construct a new port on the coast of the North Sea. On 1 June 1894 the Belgian government, the city of Bruges and Messrs. L. Coiseau and J. Cousin reached an agreement stipulating the conditions regarding the construction and management of the new port. This agreement was approved and ratified by Parliament on 11 September 1895 and the Royal Decree was published in The Belgian Law Gazette of 13 September 1895.

There were three components to the new port:

- an outer port on the coast to be called "Zeebrugge", or "Bruges-by-the-sea";
- an inner port in Bruges itself, north of town;
- a sea canal linking the outer port from a point located in the dunes between Blankenberge and Heist to access the improved facilities of the port of Bruges.

Fig. 36.10 Inauguration of the port in 1907 by His majesty Leopold II. (Charlier, R. and Chaineux, M.C. Private collection)

The work began in 1896 by Coiseau and Cousin's company "Compagnie des Installations maritimes de Bruges", today "Maatschappij van de Brugse Zeevaartinrichtingen" or M.B.Z. It was funded 50% by the city of Bruges and 50% by Coiseau, Cousin and other private investors. Finished in 1905 (Fig. 36.10), M.B.Z. also managed the new port complex. This canal and port complex continue to flourish today although other links exist via the sea canal Terneuzen-Ghent and a third one by way of the Scheldt River and Antwerp. Since 2016 the latter is the sole one offering the world's largest sea locks.

Zeebrugge has a role in military history as well. In both world wars the Germans tried to use the port as a base for submarines. In WWI the British HMS Vindictive was scuttled (deliberately sinking the ship by allowing water to flow into the hull) blocking the entrance and thereby foiling the plan. Sadly, as they left, the Germans destroyed the port in their wake. During World War II, once again the Germans holding control of the port during tried a renewed plan for submarines it too proved impracticable thanks to Allied artillery making their construction efforts impossible (Mastny et al. 2013). The port was a success and especially during the post-war decades grew considerably. The original mole (a large, powerful machine for boring through sand, earth or rock, and used in dredging) has been dwarfed by two bigger moles. Had it not been for living accommodations, neighboring touristic resorts, and/or environmental considerations, such as the crossing of the Heist Claypits, Zeebrugge might also have become a munitions port for NATO and/or a methane terminal for Norwegian STATOIL's gaso-ducts [gaslines] (Stoddart 2014).

Re-attached to the municipality of Bruges and baptized Zeebrugge the port has known a meteoric rise and continuous expansion with the two additional and larger moles; it is administered by its own autonomous Port Authority of Zeebrugge

Fig. 36.11 Zeebrugge circa 1930 (Charlier, R. and Chaineux, M.C. Private collection)

Fig. 36.12 Port of Zeebrugge, circa 2010 Public Domain as posted on portofzeebrugge.be

(Figs. 36.11 and 36.12). Due to the barrier constituted by the new patterns of moles slowing down currents a very large expanse of sands has accumulated and transformed Zeebrugge into a touristic resort as well as a major coastal port. The

Fig. 36.13 Zwin, Cadzand, Belgium (C. Charlier 2016)

site has acquired a residential quarter, restaurants and tourist activities. The port itself is a naval base, a starting point for excursions-at-sea, the embarkation area for oceanographic campaigns, a ferry boat station, a freight transshipment point with "Ro-Ro" facilities, a pleasure craft harbor, and is still a fisheries landing port (Cook 2002).

In 1921 the coast of Flanders suffered a major flood and the Zwin broke through as it did again in 1973 the year of the great flood. It reached the outskirts of Damme, but the waters receded after a relatively short period. Today the remnant of the inlet fills partly at high tide, but the area is an ornithological refuge in collaboration with the French National Park of Marquenterre (Herrier and Leten 2010). The Dutch undertook the gigantic Delta Works to protect the land even cutting off one the Scheldt's arms, not without creating problems downstream of Antwerp. If Bruges found a new economic spurt as a tourism destination nearly equaling that of its Mediterranean counterpart, a new life as a port was in the making completely separate from developments in the Zwin region, some even surprising. Until recent history an international dike linked the last Belgian shore resort and the remnant of the Zwin inlet. It has since been dismantled so as to let the sea waters return to their natural course and miradors (watch towers) installed for serious observers, particularly ornithologists (Charlier et al. 2005, 2012). At high tide the inlet itself is a canoe splashing basin and shallow swimmers' pool. Cadzand is today a very small gently slumbering port hosting this beautiful nature refuge, preserve and park (Fig. 36.13) (Charlier 2010).

36.6 Back to the Future: Bruges-la-Belle

Travel writers call it a beautiful city frozen in time, tourists never forget their visit, even jaded American teenagers are awed by its buildings and pause to enjoy its beautiful canals and unforgettable bridges. Bruge la morte is now Bruges la belle (the beautiful). Bruges' history began its second act when tourists, writers and artists started passing through in the nineteenth century. Perhaps King Leopold II was just as entranced as the tourists and thus motivated to fight for her. Wealthy visitors injected much-needed cash into the local economy through tourism, and the 1905 completion of the canal linking the city to the new port of Zeebrugge assured her place in history as the "parent" of this important port. The new canal was named the Boudewijnkanaal (English: Baldwin Canal, French: Canal Baudouin) a name now better known for the King of the Belgians Baudouin, grandson of Leopold II, son of Leopold III.

The port of Zeebrugge was heavily damaged by World War I (when the departing Germans destroyed it) and World War II (when Allies sought to defend it). Remarkably, the city of Bruges emerged quite unscathed. It remains home to The Madonna of Bruges, a marble sculpture by Michelangelo of Mary with the Child Jesus (Insight Guides 2014). Wars have caused its removal twice since it first arrived in Belgium. First it went to Paris after the French Revolution took Belgium. The second and most recent removal was in 1944, during World War II, when retreating German soldiers smuggled the sculpture to Germany wrapped in mattresses in a Red Cross truck. It was discovered a year later in Altaussee, Austria and once again returned to its rightful place in Bruges (Kurtz 2006). The story of this nocturnal adventure was featured in the popular film by Columbia Pictures entitled The Monuments Men (2014). The Madonna of Bruges now sits once again in the Church of Our Lady in Bruges.

The city's lovely historic center was beautifully preserved with its modern economy based around tourism. In 2000 it was declared a World Heritage site and in 2002, Bruges reigned as the annual title holder of a Capital of Culture in Europe (UNESCO 2016). The European Capital of Culture is a 1 year designation by the European Union during which the recognized city organizes cultural events. In Bruges several striking buildings like the Concertgebouw concert hall and the Toyo Ito Pavilion were built for the occasion, thereby bringing some modern style to the historic heart of the city.

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Part IX
Miscellanea

Chapter 37
The Potential of Airborne LiDAR for Detection of New Archaeological Site in Romania

Ioana Vizireanu and Răzvan Mateescu

Abstract The introduction of laser scanning has triggered off a revolution in topographic terrain capturing, especially in the generation of digital terrain models (DTM) and it is beginning to find success in archaeological survey. To explore its potential for archaeology, a LiDAR survey covering the Cornești landscape, in the west part of Romania, was carried out. This paper presents a GIS approach to discover new characteristics of the archaeological site. First, the DTM of the surface has been generated in order to produce the local relief model (LRM). A data processing approach is presented to enhance the visibility of the new site and to allow their relative elevations as well as their volumes to be measured directly. In the second part of the paper, a GIS workflow is presented which provides a well-structured descriptive and analytical tool for identifying spatial patterns. Finally, the potential of LiDAR to transform our future management of the historic environment will mark the archaeological activities.

Keywords LiDAR • Laser scanning • GIS • Archaeology • LRM

37.1 Introduction

Light Detection and Ranging (LiDAR) is an active remote sensing technique (Jie and Charles 2009) which enables the obtaining of very accurate data about the topography of terrain, vegetation or different structures and construction. According to the experts, this technology uses three basic systems: the laser scanning that measure distances, the global positioning system (GPS) and inertial measurement unit (IMU) for orientation recording (Baltavias 1999). The technology involves the use of computers with high storage capacity and computation.

I. Vizireanu (✉)
National Institute for Aerospace Research "Elie Carafoli", Bucharest, Romania
e-mail: vizireanu.ioana@incas.ro

R. Mateescu
National Institute for Marine Research and Development "Grigore Antipa", Constanța, Romania
e-mail: razvan_doru@yahoo.com

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With laser scanning, the time differences between laser pulses sent from the aircraft that perform the flight and reflected by the surface of the terrain are recorded, and the GPS receiver continues to record its position.

Initially used for urban planning projects or planetary exploration, LiDAR has also proven its useful in archeology (Mehrer and Wescott 2006). If aerial photography was until now the only modern tool that could help traditional archeology, LiDAR technology facilitates the archaeological research by mapping of hundreds of square kilometers at once. In this way, an overview of ancient civilizations organization is provided, but more importantly, information regarding the causes of their collapse is provided which should be taken into account when it is trying to find the source of contemporary world.

In the field of archeology, the main theoretical developments that have arisen from the development of GIS applications, refer to scale changing where archaeological sites are viewed and understood (Dorogostaisky 2013). The research of an archaeological site is no longer limited to the boundaries of areas of several hundreds of square meters or, eventually, to several hectares where excavations were made. The outlook has been much larger and the sites are increasingly integrated at micro regional level, linked with other contemporary sites, especially with the environment. This development has contributed to the evolution of archaeological topography.

Last but not least, with GIS, archaeologists have become more conscious of the interdisciplinary nature of their profession and the environmental importance in the assessment of historical and archaeological phenomena (Conolly and Lake 2006).

Archeology defines its object of study and methods by reference to two fundamentals variables: time and space. The chorology, as a classical instrument of investigation, is recently completed by anthropological dimension exploration of space through archaeological landscape, also as a consequence of the development of GIS applications.

The main advantage of GIS lies in the ease of managing and producing spatial data but also in the flexibility of handling enormous samples of archaeological data.

This paper presents a geomorphological, topographical and cartographic analysis of the Cornești site in order to determine the limits, the morphology and the construction technique of such fortifications. This research is based on a digital terrain model and digital surface model analysis, archaeological topography, as a way to provide a comprehensive image through this interdisciplinary study of archaeological landscape.

37.1.1 Study Area

The geographical boundaries which provide support for this approach is an area of study, these are relatively arbitrarily drawn, unrelated to natural morphological units or with modern cadastral boundaries. In essence, when we decided to trace this area, we tried to include historical cadastral boundary of the Corneşti village. In

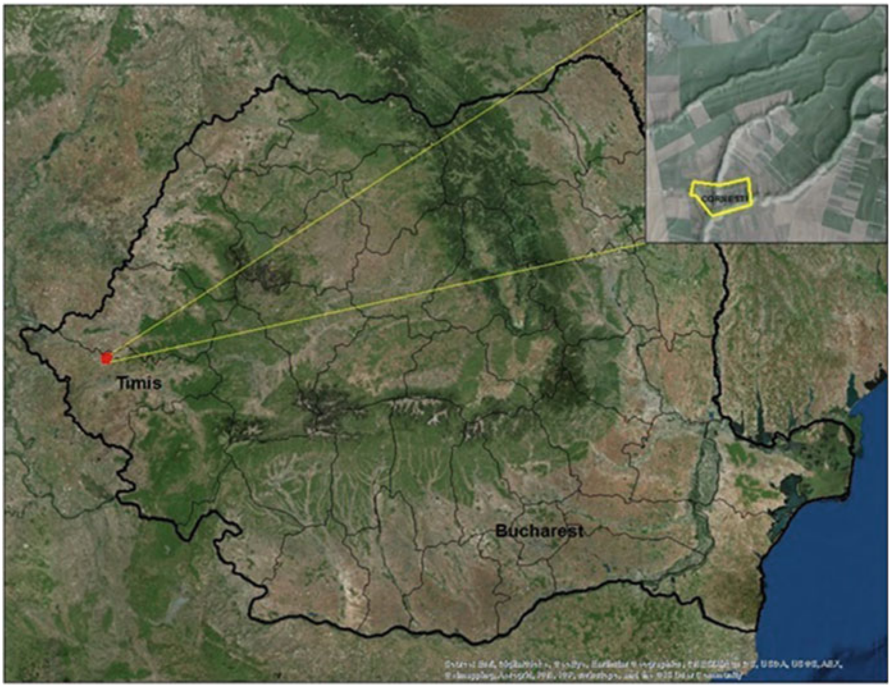

Fig. 37.1 Study area

terms of geography, the area, that was under investigation and which is the subject of this study, is located in the northern part of Timiş County, north of the Timişoara city.

The archaeological site, Corneşti-Iarcuri, covers an area of 1780 ha and consists of four concentric rings. They are actually the walls of the fortification (Fig. 37.1).

Fortification appears on the first Mercy maps (1723–1725) and then on all military maps by the end of the First World War. The first excavations were carried out in 1939 by archaeologist Marius Moga.

In 2007, due to Alexandru Szentmiklosi (Szentmiklosi et al. 2011), director of the Archaeology Section of the Banat Museum, and to investment received mainly from Germany, searches and archaeological work abandoned 80 years ago were resumed.

There were three hypotheses: a fortification during Avar domination, could be the capital of a state that 200 years was the strongest in Central Europe, a large settlement from the Bronze Age, and the third, who went from a researcher in Canada it can be the ruins of the capital of Attila, king of the Huns.

37.2 Methods

37.2.1 Techniques

In order to achieve this paper and to obtain a high quality representation of land, there were used data using an airborne laser scanning system (ALS), known most commonly referred to as LiDAR. Besides the lidar data taken in the field, a set of digital images was also needed, taken also in the area of interest during LiDAR data collection.

The LiDAR flight was over the Corneşti village, Timiș County, on 27 June 2014, the total number of flight lines being 26.

The LiDAR and digital imaging data were acquired by using the National Institute for Aerospace Research "Elie Carafoli" (INCAS, Bucharest) airborne platform, Hawker Beechcraft King Air C90-GTx equipped with an airborne laser scanning system (ALS) – Riegl LMS-Q680i and a digital camera DigiCAM-60 (Fig. 37.2, Table 37.1).

Fig. 37.2 Hawker Beechcraft King Air C90-GTx

Table 37.1 Flight parameters and scanning system settings

Flight parameters	Corneşti-Timiș
Flight year	2014
Coordinate System	UTM North-WGS84 SPH-EGM96:34
Scanner	RIEGL LMS-Q680i
Pulse repetition rate (kHz)	120
Scan Frequency (Hz)	77,3
Half scan angle	30
Flight height (m)	553–580
Laser footprint (m)	0.3
Theoretical point spacing (m)	0.6
Flight strip overlap (%)	50
Num. Segm.	26
Segm. Length (nm)	69.3
Operation time (h)	3.843 m
Time per turn (s)	480
Mean speed (kts)	136.069

37.2.2 Procedures – Digital Terrain Model

For the purposes of this paper, the digital terrain model from LIDAR data was done using TerraSolid software where generation is automatic and 80% of the whole process is represented by the editing step (Fig. 37.3).

The steps of obtaining a DTM are represented in Fig. 37.4.

Generating DTM refers to data acquisition module, the actual realization of the model by different interpolation methods and the choice of data representation structure – raster or TIN (Fig. 37.5).

The digital model resulted by editing allows us to obtain a surface model and also a terrain model: DSM and DTM (Fig. 37.6).

For a good interpretation of LiDAR data, an orthophoto plan, made by a mosaic of all images taken during the LiDAR flight, has been used.

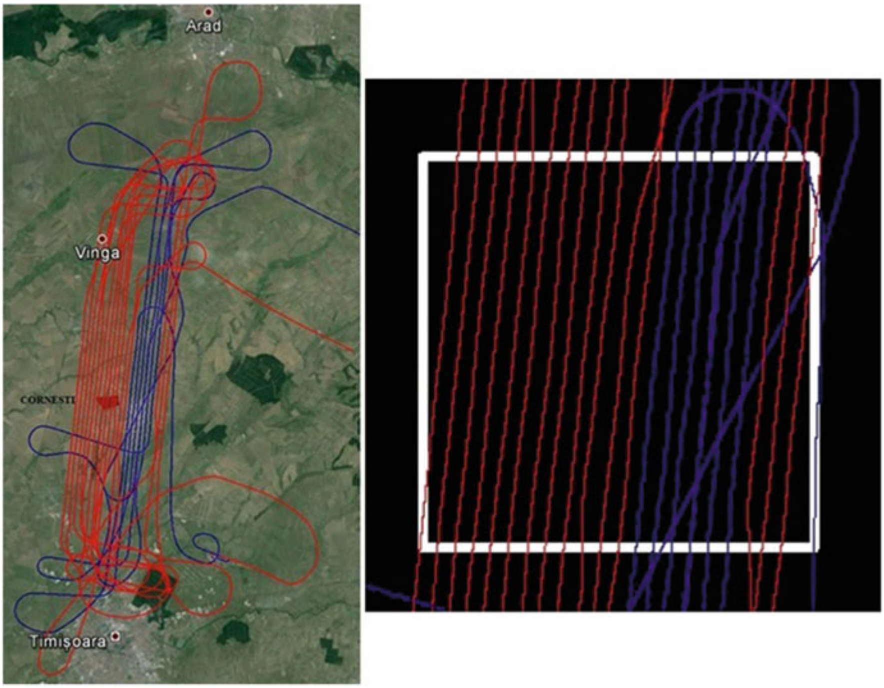

Fig. 37.3 Flight lines

Fig. 37.4 Digital terrain model

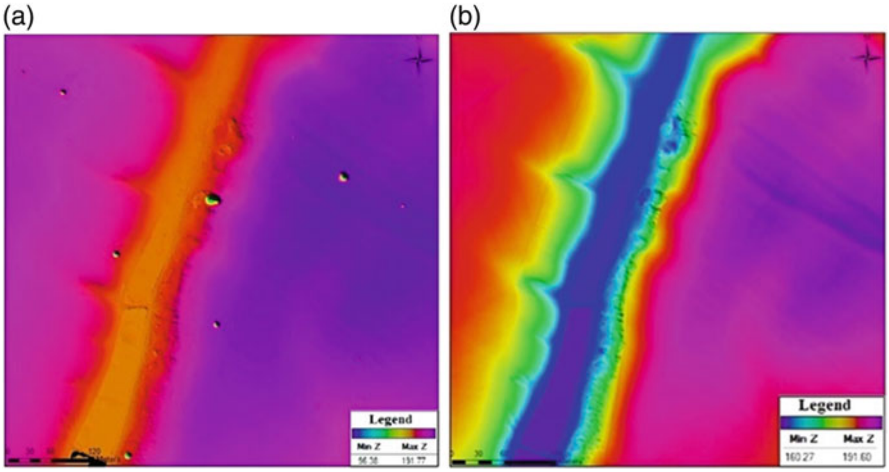

Fig. 37.5 (**a**) Automatic generation of DTM, (**b**) DTM editing

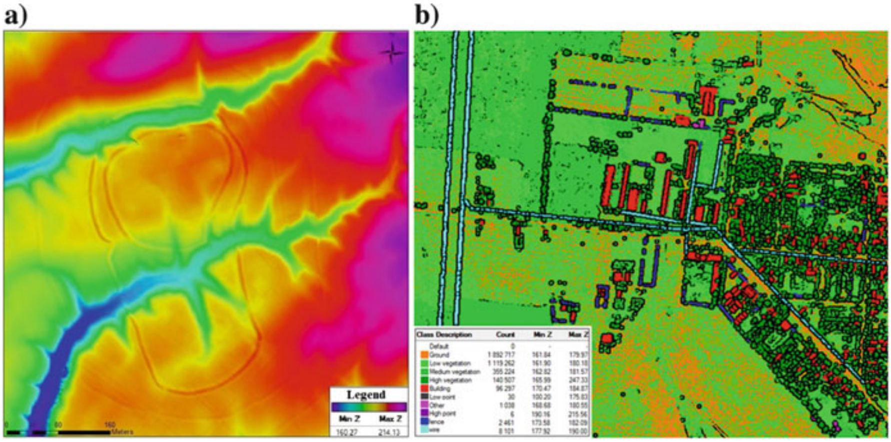

Fig. 37.6 (**a**) DTM, (**b**) DSM

An accuracy study has been made by calculating the RMSE for digital model, using 24 GCPs (Table 37.2) (Fig. 37.7).

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (Z_{DTM} - Z_{REF})^2}{n}} \tag{37.1}$$

Where:

Z_{DTM} – the points elevation from the model
Z_{REF} – the points elevation as references
n – the number of ground control points.

Table 37.2 Ground control points elevation

ID	Z (DTM LIDAR)	Z(TERRAIN)
1	174.192	173.982
2	184.922	184.711
3	208.405	208.158
4	188.280	187.796
5	200.050	199.931
6	176.846	176.990
7	171.316	171.083
8	211.567	211.239
9	192.053	191.703
10	202.506	202.415
11	206.309	206.739
12	169.762	169.464
13	173.577	173.649
14	170.084	171.434
15	169.127	168.983
16	174.877	175.166
17	175.996	175.928
18	179.783	180.257
19	186.577	186.266
20	180.986	180.939
21	180.384	180.212
22	190.394	190.140
23	194.854	194.554
24	210.560	210.269

In this case, the root mean square error is a statistical evaluation of ensemble that actually shows how well the model corresponds with data from where it was generated and not how accurately it represents a cell of the model (Table 37.3).

From the above, it is points out that in term of altitude, the digital terrain model derived from LiDAR data is of high accuracy.

Greenwalt and Schultz, 1968 (Greenwalt and Shultz 1968) said that the 1.96 factor is applied to calculate the linear error at 95% confidence level. Therefore, the vertically accuracy A_z, according to the American Standard NSSDA (National Standard for Spatial Data Accuracy) can be calculated as follows:

$$A_z = 1.96 \times RMSE_z = 0.521 \tag{37.2}$$

This result means that we can be sure for 95% that the measurements are somewhere in a circular error of 52 cm and there is a 5% chance that the error is bigger than this value.

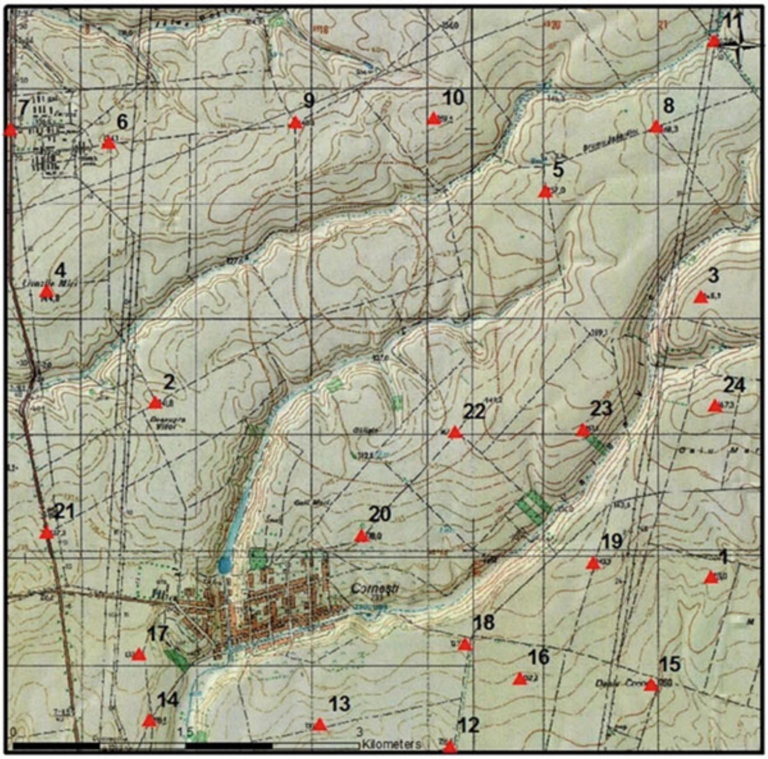

Fig. 37.7 Ground control points on topographic map 1:25,000

Table 37.3 The value of root mean square error

DTM	RMSE
DTM LIDAR	0.266

37.2.3 Local Relief Model

Visualization of elevation data (Novák 2014) collected by aerial laser scanning for archaeological use is a widely discussed topic. Every method has its advantages and disadvantages in usability, efficiency, time consumption. It is obvious that simple shaded relief model (hillshade) is not sufficient for archaeological research and there are much better ways of visualization. Local relief model (Bofinger and Hesse 2011) (LRM) is one of the most useful and efficient way to visualize elevation data stored in raster as digital elevation model (DEM). The basic idea behind the method is “filtering out” terrain surface leaving just archaeological features and their relative elevation above or below the terrain. The simplest way to do so is to generalize DEM by low pass filter and subtract it from original DEM (Davis 2012).

In order to automate all the steps for LRM generating of the study area, a model builder was used in ArcGIS software, 10.3 version (Fig. 37.8).

The entire process for obtaining a local relief model has the LiDAR point cloud classified as input for "natural neighborhood" (Fig. 37.9.) interpolation method in ArcMap. The next step is applying the first low pass filter "smoothing 5 × 5" (Fig. 37.10) twice for DTM (the data was smoothed by reducing local variation and noise removing) and then applying the second one with a 15 m kernel size and a

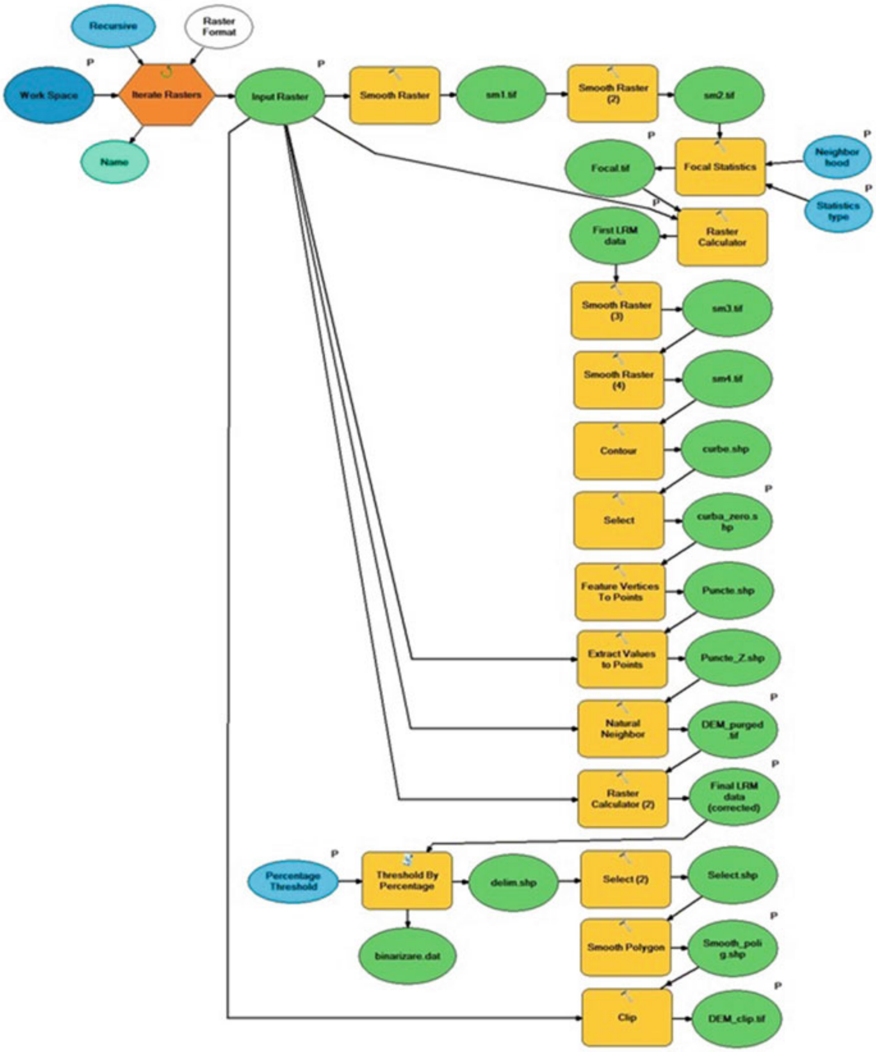

Fig. 37.8 Local relief model

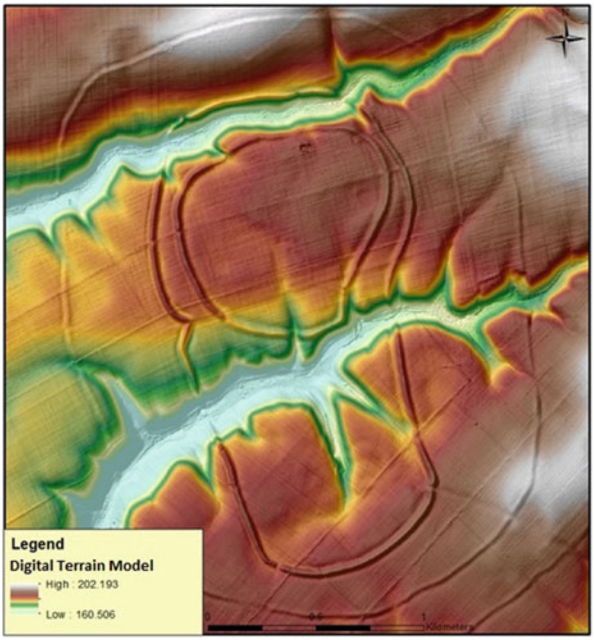

Fig. 37.9 DTM –"natural neighborhood"

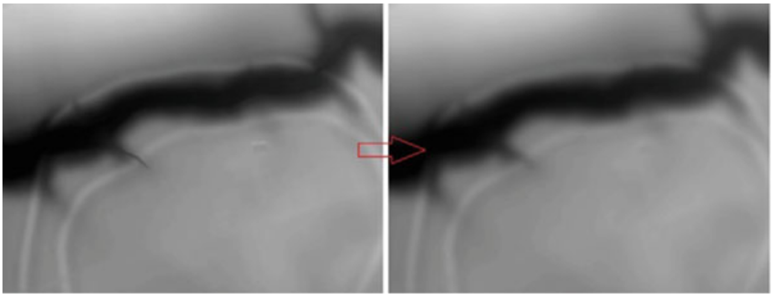

Fig. 37.10 *Left*: "smoothing 5 × 5" filter. *Right*: "low pass" filter with 15 m kernel size

circular neighborhood to approximate large scale landforms (this size has been found experimentally to be the most suitable to represent especially the first two walls of the fortress).

37.3 Results and Discussions

The initial LRM (Fig. 37.11) has resulted from the difference between the original raster and the one from the previous step, applying again a "smoothing 5 × 5" filter twice to reduce the red lines that could be seen on arable land.

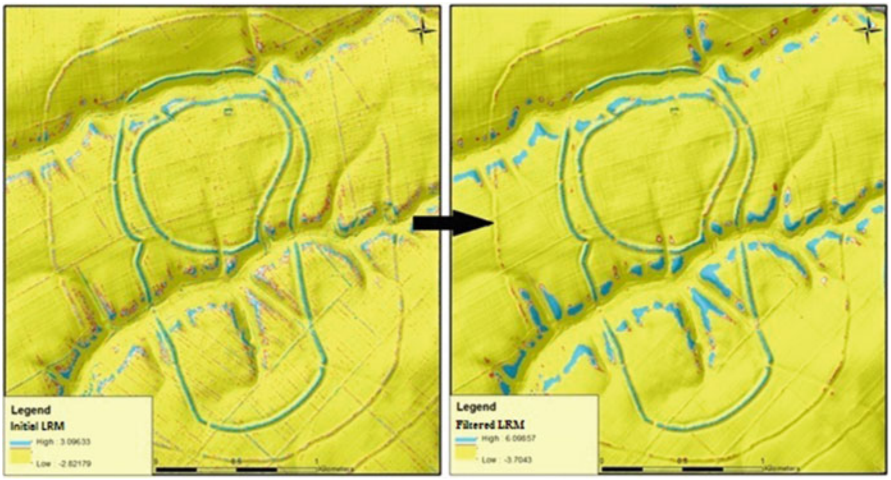

Fig. 37.11 Initial LRM filtering

Fig. 37.12 Contour extracting from LRM and zero contours extracting

On the other hand, extracting contour lines (Fig. 37.12) from the filtered raster (the boundaries between positive and negative features of the local landscape were delineated in order to determine which positions are zero raster values), selecting the zero contours (meaning the limits of small scale positive and negative topographic characteristics) and converting these contours into points allowed us to extract the elevation values and create a purged DTM (Fig. 37.13).

The final LRM has resulted from the difference between the original raster and "purged" DTM. (Fig. 37.14).

Fig. 37.13 Purged DTM

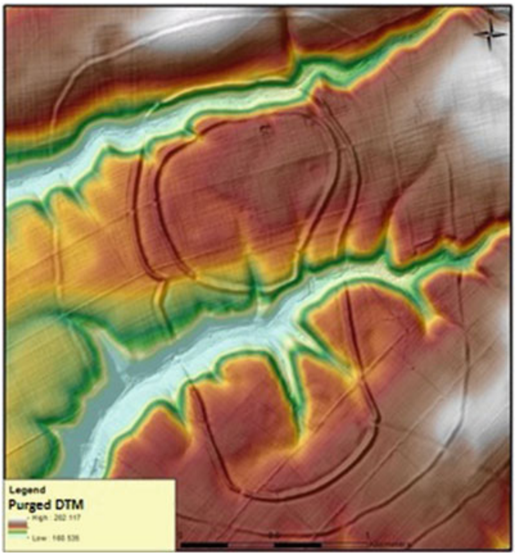

Fig. 37.14 The final LRM

In the final local relief model, the first two walls were highlighted but the third one, being shorter and narrower, could not be highlighted as well as the first two by applying the 15 m kernel filter.

This complex process of generating a LRM actually leads to the creation of a “flat terrain” because the values show the difference between the calculated DTM altitude and the real value of the initial DTM.

A few advantages of using a local relief model are: the final or improved LRM is relatively simple to calculate and implement, the topographic parameters can be visualized as well as the linear, circular, rectangular, convex and concave, the local relief model is independent of brightness, some very fine characteristics that differ only by 0.1–0.2 m compared to the surrounding area can be detected, the LRM provides means of determining perimeters, areas, volumes and shapes related to the surrounding area.

At the end, GIS facilitates mapping to analyze depositional patterns as well as catalog and quantify artifacts. It can provide a well-structured descriptive and analytical tool for identifying spatial patterns.

37.4 Conclusion

Through this study case, it has been shown the benefits of using LiDAR technology in archaeological investigations by generating DTM, DSM, LRM and analyzing the results.

The main advantage of this technique is the full automation of the acquisition process, storage and processing of data based on specialized programs, finally leading to a set of geographic spatial information, as the possibility of laser beam to penetrate the vegetation up off the ground, essential feature for the activity of archeology.

The particularities of relief, printed through altitude, favor the development of different sub-areas, therefore different analyzes using combined techniques (DTM, DSM and LRM’s generation) can be made.

The aerial images also provide a range of advantages in archaeological investigation: high resolution, georeferencing in national projection system (Stereographic 1970) and the possibility of multiple analyses using GIS programs.

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Chapter 38
Genetic Versus Han-Type Algorithms for Maritime Transportation Problems

Doina Carp, Constantin Popa, and Cristina Şerban

Abstract The maritime transportation problem was first formulated by T.C. Koopmans (1957) as a transportation problem related to specific maritime activities. Across time, several classes of Simplex-type algorithms have been developed to find the numerical solution when the problem has a non-empty set of feasible solutions. Often, the mathematical model of a real world context will provide an unbalanced and inconsistent maritime transportation problem, i.e. when the set of classical feasible solutions is empty and the least squares one must be considered. In such cases, the linear programming solutions techniques cannot be applied, and one way to find an optimal solution is to reformulate the problem as an inconsistent (incompatible) system of linear inequalities, for which several Han-type iterative algorithms have been proposed. In this paper, we attempt to solve an unbalanced and inconsistent maritime transportation problem by two approaches. One of them refers to the application of the MH algorithm, a modified version of Han's original algorithm, previously proposed by the authors. The other one involves a soft computing technique that produces an original formulation of a genetic algorithm (GA) over a maritime transportation problem. The results are discussed and a comparative study is given, aiming to provide a cost optimized solution to some real world maritime transportation problems.

D. Carp (✉) • C. Şerban
Faculty of Mathematics and Computer Science, Ovidius University of Constanta, Mamaia Blvd. 124, Constanta 900527, Romania
e-mail: doina.carp@gmail.com

C. Popa
Faculty of Mathematics and Computer Science, Ovidius University of Constanta, Mamaia Blvd. 124, Constanta 900527, Romania

Gheorghe Mihoc – "Caius Iacob" Institute of Statistical Mathematics and Applied Mathematics, Calea 13 Septembrie 13, 050711 Bucharest, Romania

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38.1 Introduction

The transportation problem, in its classical formulation involves sources $(S_i)_{i \in \{1, \ldots, n\}}$, where supplies $(s_i)_i = 1, \ldots, n$ of some goods are available, and destinations $(D_j)_{j \in \{1, \ldots, m\}}$, where some demands $(d_j)_{j=1, \ldots, m}$ are requested (see Table 38.1). The costs of shipping $(c_{ij})_{i \in \{1, \ldots, n\}, j \in \{1, \ldots, m\}}$ for the transportation of one unit from source S_i to destination D_j become the entries of the $C : n \times m$ cost matrix.

If x_{ij} denotes the number of units transported from source S_i to destination D_j, we get the following mathematical model:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij} \tag{38.1}$$

$$\text{s.t.} \quad \sum_{i=1}^{n} x_{ij} \geq d_j, j = 1, \ldots, m \tag{38.2}$$

$$\sum_{j=1}^{m} x_{ij} = s_i, i = 1, \ldots, n \tag{38.3}$$

$$x_{ij} \geq 0, i = 1, \ldots, n, j = 1, \ldots m \tag{38.4}$$

If

$$\sum_{i=1}^{n} s_i < \sum_{j=1}^{m} d_j, \tag{38.5}$$

the linear program (38.1) becomes inconsistent (i.e. the set of feasible solutions is empty) and classical Simplex-type algorithms are no more applicable. This is the reason for which we consider in this paper special algorithms which can handle this inconsistency. In Sect. 38.2 we present an equivalent reformulation of the problem (38.1) together with the Modified Han algorithm for solving it. Section 38.3 presents the genetic – type algorithm designed for the same purpose, while Sect. 38.4 is dedicated to some experiments and comparisons involving the two methods.

Table 38.1 The classical transportation problem

	D_1	D_2	D_3		D_m	Supply(s)
S_1	c_{11}	c_{12}	c_{13}	...	c_{1m}	s_1
S_2	c_{21}	c_{22}	c_{23}	...	c_{2m}	s_2
...	...	...	...	...	...	...
S_n	c_{n1}	c_{n2}	c_{n3}	...	c_{nm}	s_n
Demand(d)	d_1	d_2	d_3	...	d_m	

38.2 Modified Han Algorithm

In order to present Han's algorithm together with its modified version proposed by Carp et al. (2015), we first reformulate the problem (38.1), (38.2), (38.3) and (38.4). In this respect, first we renumber the unknowns as

$$x_{ij} \to y_l, i \in \{1, \ldots n\}, j \in \{1, \ldots m\}, l \in \{1, \ldots mn\} \tag{38.6}$$

Let now $c \in \mathbb{R}^{mn}$ be the cost vector of the above problem, B_1, B_2 the $m \times mn$, $n \times mn$ matrices corresponding to the m inequalities from (38.2) and the n equalities from (38.3), respectively. Moreover, let $d \in \mathbb{R}^m, s \in \mathbb{R}^n$ be the demands and supplies vectors, respectively (see Table 38.1). Then, the problem (38.1), (38.2), (38.3), and (38.4) can be written as

$$\min\langle c, y\rangle \text{ s.}t. \ B_1 y \geq d, \quad B_2 y = s, y \geq 0 \tag{38.7}$$

If we define the $(m+2n) \times mn$ matrix B and the vector $\delta \in IR^{m+2n}$ by

$$B = \begin{bmatrix} B_1 \\ B_2 \\ -B_2 \end{bmatrix}, \delta = \begin{bmatrix} d \\ s \\ -s \end{bmatrix}, \tag{38.8}$$

the problem (38.7) becomes

$$\min\langle c, y\rangle \ \text{ s.}t. \ By \geq \delta, y \geq 0, \tag{38.9}$$

together with its dual

$$\max\langle \delta, u\rangle \text{ s.}t. \ B^T u \leq c, u \geq 0. \tag{38.10}$$

Let $\mathcal{P}$, $\mathcal{D}$ the set of feasible solutions of the primal (38.9) and dual (38.10) problem, respectively. The following result (see for the proof Andrei 2011, page 181) connects this pair of problems to a system of linear inequalities

Proposition 38.1 *Let us suppose that both problems (38.9)–(38.10) have feasible solutions, i.e.* $\mathcal{P} \neq \varnothing$, $\mathcal{D} \neq \varnothing$ *Then the following assumptions are equivalent:*

(i) $\widehat{y} \in \mathcal{P}, \widehat{u} \in \mathcal{D}$ are optimal solutions for problems (38.9) and (38.10), respectively.
(ii) the vector $x = [\widehat{y}^T, \widehat{u}^T]^T \in \mathbb{R}^{m \times n}$ is a solution of the system of linear inequalities

$$Ax \leq b, \tag{38.11}$$

where

$$A = \begin{bmatrix} c^T & -\delta^T \\ -B & 0 \\ 0 & B^T \\ -I & 0 \\ 0 & -I \end{bmatrix}, b = \begin{bmatrix} 0 \\ -\delta \\ c \\ 0 \\ 0 \end{bmatrix} \tag{38.12}$$

Hence, from the above result it holds that solving a pair of *feasible (consistent)* primal-dual linear programs is equivalent with solving a certain system of linear inequalities. According to Theorem 5.1, page 181 in Andrei (2011), there are two more possible cases that can occur beside the feasible one: one of the problem has feasible solutions and the other does not, and both problems do not have feasible solutions. In these cases, as Han himself mentioned in Han (1980), the system (38.11) and (38.12) provides a kind of *least squares solution* for one or both linear programs, respectively. Such a situation will be considered in our paper.

In the inconsistent case of (38.11), it results that at least for one index i the corresponding inequality is violated, i.e. the set $I(x) \subset \{1, \ldots, m\}$, defined by

$$I(x) = \{i \in, \langle A_i, x \rangle \geq b_i\} \tag{38.13}$$

is nonempty for any $x \in \mathbb{R}^n$. Moreover, let us suppose that the set $I(x) = \{i_1, \ldots, i_p\}$ is ordered such that $i_1 < i_2 < \ldots < i_p$; then, $A_{I(x)}, b_{I(x)}$ will denote the submatrix of A with the rows $A_{i_1}, \ldots, A_{i_p}$ and the subvector of b with components $b_{i_1}, \ldots, b_{i_p}$, respectively. For any vector $y \in \mathbb{R}^m$ we define $y_+ \in \mathbb{R}^m$ by $(y_+)_i = \max\{y_i, 0\}$. Han (1980) proposed the following algorithm for numerical solution of the inconsistent system (38.11).

Algorithm H *Let $x^0 \in \mathbb{R}^n$ be arbitrary fixed; for $k = 0, 1, \ldots$ do:*

Step 1. Find $I_k = I(x^k)$ and compute $d^k \in \mathbb{R}$, the minimal norm solution of the linear least squares problem

$$\| A_{I_k} d - \left(b_{I_k} - A_{I_k} x^k\right) \| = \min! \tag{38.14}$$

Step 2. Compute $\lambda^{k,j} \in \mathbb{R}$ as the smallest minimizer of

$$\theta(\lambda) = f\left(x^k + \lambda d^{k,j}\right), \lambda \in \mathbb{R}.$$

Step 3. Set $x^{k+1} = x^k + \lambda^{k,j} d^{k,j}$.

Remark 38.1 In Carp et al. (2013) *we presented an accurate procedure for the computation of the smallest minimizer from* **Step 2.** *of the algorithm* **H**.

Han proves that the sequence $(x^k)_{k \geq 0}$ generated with his algorithm converges to a least squares solution of the inconsistent system (38.11). Unfortunately, in **Step 1** of the algorithm he proposed the usage of the Moore-Penrose pseudoinverse of A_{I_k}, which is not a good choice for large and sparse matrices. In order to overcome this difficulty we proposed in Carp et al. (2015) a modification of **Step 1** of Han's algorithm as follows:

Step 1p. Find $I_k = I(x^k)$ and compute an approximation $d^{k,j} \in \mathbb{R}^n$ of the minimal norm solution of the linear equalities least squares problem

$$\| A_{I_k} d - \left(b_{I_k} - A_{I_k} x^k \right) \| = \min! \tag{38.15}$$

by performing $j \geq 1$ iterations of the Extended Kaczmarz algorithm from Popa (1998), with 0 as initial approximation on (14).

We will call **MH** the Han algorithm with **Step 1** replaced by **Step 1p.** In Carp et al. (2015) we proved a convergence result similar with Han's one, for the sequence $(x^k)_{k \geq 0}$ generated with algorithm **MH**.

38.3 The Genetic Algorithm

Genetic Algorithms (GAs) are adaptive heuristic search algorithms, specially designed to find good solutions to problems that were otherwise computationally unsolvable. GAs are based on the evolutionary ideas of natural selection, applying the principle of 'survival of the fittest' on a population of potential solutions encoded as chromosomes, selecting individuals according to their level of fitness, and mating them together using some recombination operators to produce better approximations to a solution (see Sivanandam and Deepa 2008).

38.3.1 Encoding and Initialisation

A GA starts by chromosome encoding and initialisation. A chromosome is a feasible sequence of genes and in our model is encoded using an integer array having size equal to *mn*; each element of this array denotes the number of units transported, y_l (see (38.6)). In order to generate feasible chromosomes, the equality constraints from (38.7) are imposed for each chromosome by applying a procedure that randomly generates appropriate integers. After encoding the chromosomes, we set the genetic algorithm parameters (population size, maximum number of generations, crossover and mutation probabilities) and generate the initial population.

38.3.2 Evaluation

Our proposed genetic algorithm goal is to find an optimal solution of the linear program stated in (38.7), so the objective function is $f_{obj}(y) = \langle c, y \rangle$. Being a constrained optimization problem (with inequality constraints $g_i(y) = d - B_1 y, i = \overline{1, n}$), we must add penalty functions to the objective function:

$$\psi(u) = \begin{cases} 0, & u \le 0 \\ -u, & u > 0 \end{cases}$$

(without penalty if restriction is met; the penalty corresponds to the level the restriction is unmet), so the new objective function will be

$$f(y) = af(y) + \sum_{i=1}^{n} b_i \psi(g_i(y)) \tag{38.16}$$

where the penalty parameters $a, b > 0$; $a + b = 1$ control the weights of the two components of the problem: optimization of the objective function or meeting the restriction.

The objective function f provides a measure of individuals performance with respect to the problem domain. In a GA, the fitness function F transforms this performance into a measure of allocation of reproductive opportunities for individuals. The fitness function is problem specific and is derived from the objective function. In our model, the fitness function will be the most commonly adopted fitness mapping for minimization problems, which does not alter the location of the minimum, but converts a minimization problem to an equivalent maximization one (the smaller the value of fitness obtained, the better the solution), and is given by the following relation:

$$F(y) = \frac{1}{1 + f(y)} \tag{38.17}$$

38.3.3 Selection, Crossover and Mutation Operators

The genetic operators used in GAs maintain genetic diversity and are analogous to those which occur in the natural world: selection (or reproduction), crossover (or recombination) and mutation. These operators are implemented to produce new offspring, which are in charge of exploration and exploitation of the feasible solution space.

Selection determines the number of offspring that an individual will produce. In our model, the parents were selected by the tournament selection method, which works by running several tournaments, i.e. selecting a number of individuals from the current population at random and then selecting only the best of those individuals (with the best fitness).

Recombination is the process by which chromosomes selected from a current population are recombined to form members of the next population. The crossover operator is applied to two individuals, randomly paired with a user-definable probability, *cp*. To avoid having violations of the equality constraints in (38.7), we used the arithmetic crossover with the user-defined parameter α, that randomly selects two parents, P_1, P_2, and breeds two children, C_1, C_2, which replaces the parents in the next population.

$$C_1 = P_1\alpha + (1-\alpha)P_2$$
$$C_2 = P_1(1-\alpha) + P_2\alpha$$

Mutation is used to maintain genetic diversity from one generation of a population to the next: it alters one or more gene values in a randomly chosen chromosome with a user-definable probability, *mp*, and produces a new genetic individual. We used the swap mutation operator to change the sequence of genes for some randomly chosen chromosomes. This operator works by generating two different random numbers within the length of the chromosome that will specify the places of the genes that will be swapped. To keep the chromosome a feasible one, the swap is performed only between the genes that contribute to the same equality constraint from (38.7).

Evaluation, selection, crossover and mutation forms one generation in the execution of a GA, and after several generations, the best individual is obtained. In cases where the problem to be solved does not have one individual solution, as is the case in multi-objective optimization, the GA is useful for providing a number of potential solutions at once, letting the user to choose the best one.

38.4 Numerical Experiments

In our numerical experiments we were essentially concerned with the unbalanced inconsistent transportation problem described in Table 38.2 (called **P2**), but we also considered the unbalanced consistent transport problem described in Table 38.3 (called **P1**), for calibration of the genetic algorithm from Sect. 38.3 and for comparison with the Simplex-type Matlab implementation.

According to the considerations and constructions in Sect. 38.2, each of our problems can be written as a pair of primal-dual problems (38.9 and 38.10), which is equivalent through the considerations in the same Sect. 38.2 with a system of linear inequalities $Ax \leq b$, where $x = [y^T, u^T]^T \in \mathbb{R}^{49} \times \mathbb{R}^{21}$, and A , b are constructed as in (38.12).

For the transportation problem **P1**, the linear problems and the system of linear inequalities $Ax \leq b$ are consistent, while for problem **P2**, they are inconsistent. The linear problems were first solved with *linprog* Matlab R2011a implementation of Simplex algorithm, whereas the associated system of linear inequalities with **MH** algorithm presented in Sect. 38.2.

In our computations implemented in Matlab R2011a, all runs with respect to **MH** algorithm are started with the initial approximations $x_0 = \left(y_0^T, 0\right)^T$, $\widehat{x}_0 = \left(\widehat{y}_0^T, 0\right)^T$, with $y_0 \geq 0, \widehat{y}_0 \geq 0$, and are terminated if at the current iterations $x^k, \widehat{x}^k$ satisfy

Table 38.2 The unbalanced inconsistent transportation problem

	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Supply(s)
S_1	3	3	4	12	20	5	9	850
S_2	7	1	5	3	6	8	4	350
S_3	5	4	7	6	5	12	3	470
S_4	4	5	14	10	9	8	7	400
S_5	8	2	12	9	8	4	2	300
S_6	6	1	8	7	2	3	1	380
S_7	9	10	6	8	7	6	5	350
Demand(d)	450	500	420	420	460	520	530	

Table 38.3 The unbalanced consistent transportation problem

	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Supply(s)
S_1	3	3	4	12	20	5	9	1050
S_2	7	1	5	3	6	8	4	350
S_3	5	4	7	6	5	12	3	470
S_4	4	5	14	10	9	8	7	850
S_5	8	2	12	9	8	4	2	600
S_6	6	1	8	7	2	3	1	480
S_7	9	10	6	8	7	6	5	450
Demand(d)	450	500	420	420	460	520	530	

$$\| A^T\left(Ax^k - b\right)+ \| \leq 10^{-14},\ \| \widehat{A}^T\left(\widehat{A}\widehat{x}^k - \widehat{b}\right)+ \| \leq 10^{-14}. \tag{38.18}$$

The genetic algorithm proposed in Sect. 38.3 was implemented in Matlab R2011a and the terminating condition was to either a predefined number of generations reached or 97% of the population had same fitness value. After several generations, the best individual (solution) is obtained, the one with the smallest numerical value of the fitness function.

First, the genetic algorithm was applied over the consistent linear problem of **P1**, in order to calibrate some of the control parameters of the GA (the penalty parameters $a\,,b$ and the arithmetic crossover parameter, α). Then, the calibrated GA attempted to solve the inconsistent linear problems of **P2**. In both cases, we evaluated the performance of the proposed GA through several test cases on the rest of control parameters of the GA: the crossover/mutation probabilities. Currently, there are no well-established optimum values for these parameters and they are problem specific (see Kumar et al. 2005). In order to get statistically robust results, each of the test cases (see Table 38.4) was solved using the proposed GA for 15 runs. All the cases have the same population size (50) and the same maximum number of generations (300).

The results of the test cases are presented, in terms of the mean of the fitness values and the standard deviation (SD), in Figs. 38.1, 38.2, 38.3 and 38.4. The standard deviation values are less than 10% of the mean values for these test cases, which means that the GA can find solutions close to each other in its various runs. Also, the best combination of crossover and mutation probabilities for each problem is chosen, as the best (minimum) mean fitness value (Tables 38.5, 38.6 and 38.7).

Tables 38.8 and 38.9 indicate the solutions obtained for the consistent transportation problem **P1**. We observe that both GA and **MH** solutions satisfy all the inequality constraints from (38.7).

Tables 38.10 and 38.11 indicate the solutions obtained for the inconsistent transportation problem **P2**. We observe that GA solution satisfies three inequality constraints from (38.7), whereas **MH** solution violates them all.

Table 38.4 GA control parameters

Case number	*cp*	*mp*
1	0.90	0.01: 0.1, step 0.01
2	0.75	0.01: 0.1, step 0.01
3	0.60	0.01: 0.1, step 0.01
4	0.45	0.01: 0.1, step 0.01
5	0.30	0.01: 0.1, step 0.01
6	0.15	0.01: 0.1, step 0.01

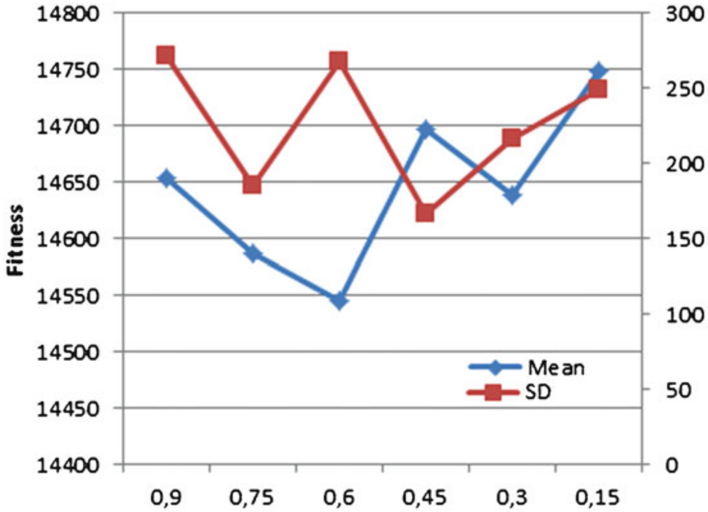

Fig. 38.1 Problem P1-average fitness using different crossover probabilities

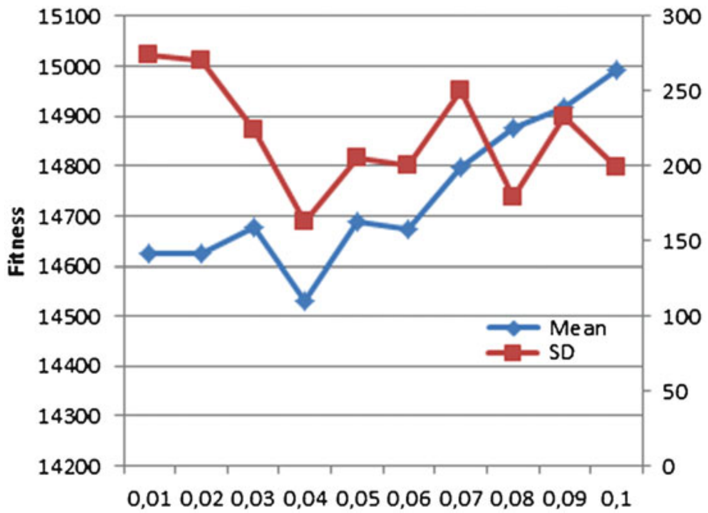

Fig. 38.2 Problem P1-average fitness using different mutation probabilities

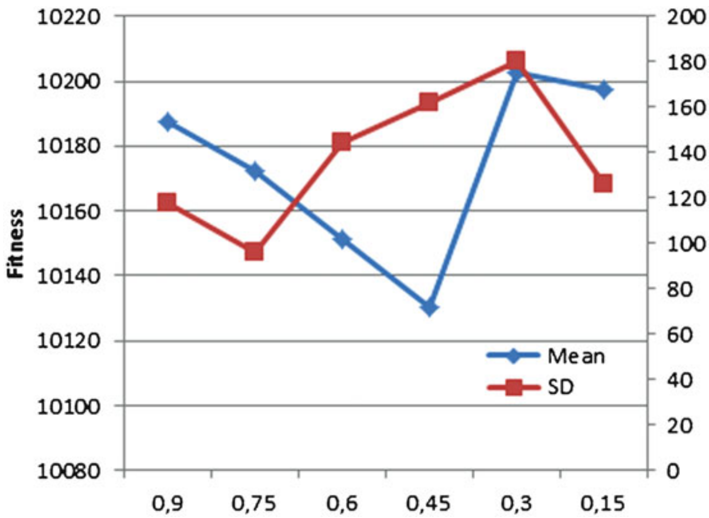

Fig. 38.3 Problem P2-average fitness using different crossover probabilities

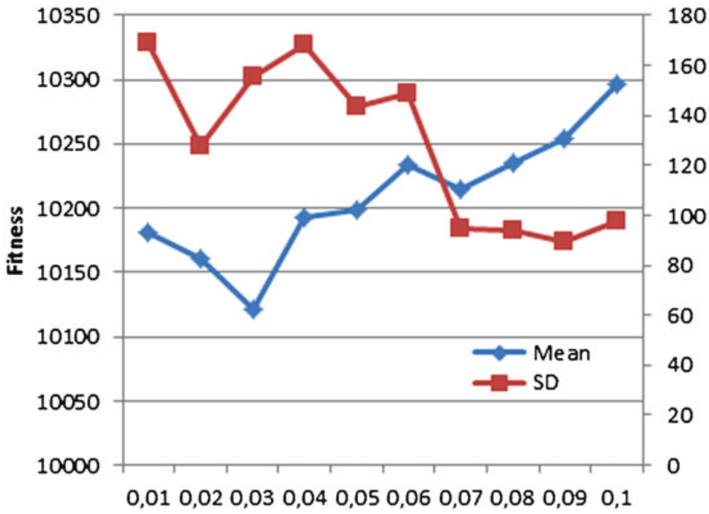

Fig. 38.4 Problem P2-average fitness using different mutation probabilities

Table 38.5 Best cases for GA (best control parameters) for problems **P1** and **P2**

Problem	Best cp	Best mp
P1	0.75	0.04
P2	0.75	0.07

Table 38.6 Results for problem **P1**

Algorithm	MH	Simplex	GA (best case)
Cost	14,620	14,620	14,529

Table 38.7: Results for problem **P2**

Algorithm	MH	Simplex	GA (best case)
Cost	11,500	21170*	10,253

where * denotes that the Simplex algorithm failed to solve the problem, returning instead a result that minimizes *the worst case constraint violation* (see Vanderbei 2001).

Table 38.8 The values x_{ij}, $i = 1, \ldots, 7, j = 1, \ldots, 7$ for the solution of problem **P1** with **MH** algorithm

ij	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1	376	254	420	0	0	0	0
2	0	0	0	350	0	0	0
3	0	0	0	70	0	0	400
4	850	0	0	0	0	0	0
5	0	400	0	0	0	70	130
6	0	20	0	0	460	0	0
7	0	0	0	0	0	450	0

Table 38.9 The values x_{ij}, $i = 1, \ldots, 7, j = 1, \ldots, 7$ for the solution of problem **P1** with GA algorithm

ij	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1	241	202	149	109	96	132	120
2	40	73	48	54	45	38	53
3	68	81	56	59	65	48	93
4	195	144	83	99	105	104	121
5	81	116	59	71	76	87	110
6	59	99	50	53	70	65	85
7	54	50	72	59	68	63	85

38.5 Conclusions

In the inconsistent case of a transportation problem, a genetic approach may give a cost smaller than the one computed by Han-based algorithm, and more constraints satisfied, which means that some of the destination demands are fully satisfied; given the layout of the two solutions (Tables 38.9 and 38.10), the remaining destinations demands are in some degree more satisfied by the GA solution. According to the solution provided by the "worst-case constraint violation" *linprog*

Table 38.10 The values x_{ij}, $i = 1, \ldots, 7, j = 1, \ldots, 7$ for the solution of problem **P2** with **MH** algorithm

ij	1	2	3	4	5	6	7
1	77	262	365	0	0	160	0
2	0	33	0	331	0	0	0
3	0	0	0	75	107	0	303
4	358	56	0	0	0	0	0
5	0	126	0	0	0	23	165
6	0	8	0	0	339	0	47
7	0	0	41	0	0	323	0

Table 38.11 The values x_{ij}, $i = 1, \ldots, 7, j = 1, \ldots, 7$ for the solution of problem **P2** with GA algorithm

ij	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1	197	165	123	84	78	111	94
2	43	70	48	53	46	41	48
3	72	73	57	54	65	47	103
4	83	67	41	46	52	56	55
5	40	55	32	35	39	42	56
6	51	73	42	45	56	51	62
7	44	42	54	46	45	56	64

Table 38.12 The values x_{ij}, $i = 1, \ldots, 7, j = 1, \ldots, 7$ for the solution of problem **P2** with Simplex algorithm

ij	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1	0	0	0	0	0	520	330
2	0	0	0	0	350	0	0
3	0	0	0	360	110	0	0
4	0	0	340	60	0	0	0
5	0	220	80	0	0	0	0
6	100	280	0	0	0	0	0
7	350	0	0	0	0	0	0

Matlab implementation of the Simplex algorithm (Table 38.12), we can observe that the units distribution is totally unrealistic.

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Chapter 39
A Three-Dimensional Approach to Oil and Gas Shale Exploitation in the US

Alexandre Charles Thys

Abstract For the last two decades oil and gas shale exploitation is going through a real revolution as on one hand the technology to extract those energy resources is improving at an impressive pace and on the other hand high gas price since 2003 made the winning of shale gas economically attractive. When some years later gas price started to show some signs of stagnation or even decline and that on the opposite oil price continued to rise, drilling companies improved their boring technology by means of horizontal drilling and hydraulic fracking. Although views differ as to the exact environmental impacts, it is indisputable that besides technical challenges and world market prices the ecological balance also has be taken into account while exploiting new or existing hydrocarbon reserves.

When analyzing the total quantity of available mineral resources versus the potentially exploitable mineral resources, the two traditionally used factors are technique and economics. This classic two-dimensional vision is displayed among others in an original diagram developed by McKelvey in 1976. In this chapter a three-dimensional approach of McKelvey's box is proposed. The third diagram dimension includes parameters - like the environmental approach - which cannot be neglected any longer today. This new angle will be applied to the exploitation of oil and gas shale.

Keywords Oil and gas shale • Oil price • Fracking • Environmental impacts • Land disruption • Pollution

39.1 Introduction

The invention of the steam machine and subsequently its utilization in many sectors of industry is considered as the milestone of our modern society. On the one hand it laid the foundation for total new production techniques and for most actual transport systems by land, air and sea. On the other hand it also implied the extraction of all kind of minerals like iron ore and the exploitation of fossil fuel, among others

A.C. Thys (✉)
Vrije Universiteit Brussel, Brussels, Belgium
e-mail: acthys@vub.ac.be

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coal, oil and natural gas. Those industrial changes had important repercussions on the existing economic, social and political structures, mostly in a positive way. Not only in the Western countries but also over all regions where they were introduced. In a first stage this industrial revolution barely had an impact on the environment. Two centuries later as a result of the increasing demand for mineral resources and the cumulated harmful effects in a specific region or even on a planetary scale, the consequences are disastrous in many fields. Cutting down tropical forests, clearing land for agriculture, roads, towns and open pit mining, laying pipelines through natural areas, contaminating water by fracking process, polluting coastal areas by crude oil spills or acid rains are just a few examples. Human activities related to the exploitation of mineral resources have in many cases revealed to be a catastrophe for the biodiversity of the exploitation places and even far beyond those areas. Many species of flora and fauna are threatened with extinction or have already disappeared. Innumerable human activities are not only harmful to the environment but also reveal to be a threat to public health and when the negative effects exceed recommended limits they considerably can reduce standards of living.

Claims have been made by specialists that the rate of disappearance of species is currently a hundredfold that which it was during past geological times. The share of vertebrates in the decrease of biodiversity is considerable. It is expected that, if current trends continue, several thousand plant and animal species would be lost in the next decades. Scientists estimate that various animal and plant species may be disappearing at the rate of one every day, with thousands more on the verge of extinction. 34,000 plant and 5200 animal species face extinction, as well as 30% of the main breeds of farm animals. The responsibility for this highly disturbing development lies clearly on the doorsteps of the human interference in natural ecosystems. The fault is placed with irrational, irresponsible and often wild exploitation of the resources.

39.2 The Original McKelvey Diagram

McKelvey designed a two-dimensional diagram reflecting the use of mineral resources by positioning the amount of identified resources in relation to its undiscovered resources. This diagram can be applied to all minerals. Since it was developed in the mid 1970s the fundamentals of the model are based on parameters that are a projection of the social concepts in use in the industrialized countries up to the 1960s, namely technique and economy. However the McKelvey box gives a quite appropriate summary of the various categorizations of mineral resources applied until then (Fig. 39.1).

The diagram depicts the variation between the possibly exploitable mineral resources versus the total quantity of available mineral resources on earth. In McKelvey's graphic illustration the geological certainty concerning the existence of the mineral reserves is represented on the horizontal axis while on the other hand the vertical axis is corresponding to the economic feasibility of extraction projects.

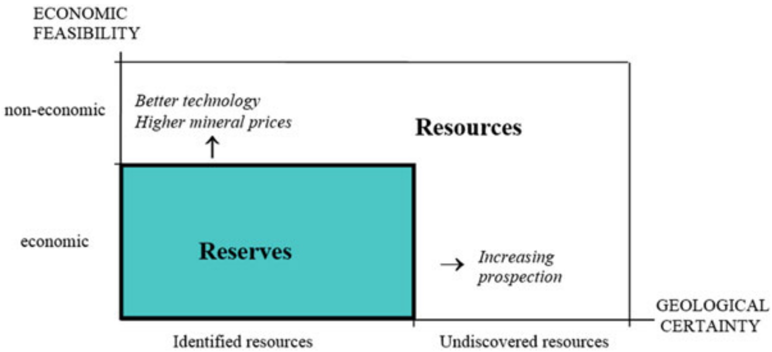

Fig. 39.1 The classic two-dimensional McKelvey-diagram

The X-axis represents the degree of geological uncertainty, whereas the Y-axis indicates whether the project is economically justifiable or not.

Nowadays only a certain surface – the part in blue – of the wide rectangle is being exploited. The total surface of this lower left quadrant (the reserves), can increase or diminish by means of the X-axis and/or by means of the Y-axis. It can for example happen by means of the X-axis if prospection is intensified. More prospection leads usually to the discovery of still undiscovered mineral resources. The reserve area can also expand through a better technology which is represented on the Y-axis. The use of new drill techniques or new processing methods of the minerals generally result in an expansion of the extraction quantity at equal costs. The currently exploitable reserves will also increase or decrease by means of the same Y-axis as a result of changes in mineral prices. Since higher prices mean larger income for the extraction project, exploitation companies will be inclined to find new locations to exploit minerals. On the opposite if the market price of a certain mineral drops too low a level, some exploitation projects will have to be terminated, though temporarily. In general, the scarcity of a mineral implicates higher exploitation costs and consequently higher mineral prices.

39.3 A New Three-Dimentional Vision

Although the technical and economic factor are incontestably correct, at present quite more other elements should be considered at the decision-making stage of exploitation projects. For example ecological problems caused by the winning of specific mineral resources are not taken into account. The same applies to the political aspects, the application of the law and legal obligations, both national and international. For instance until the middle of the twentieth century most present day African countries were still colonies of Western countries and political factors were not considered in the analyses concerning extraction of minerals. In the case of Portugal, Angola represented an immense source of economic and strategically important minerals. As a colony of Portugal, no international policy was needed to exploit those rich areas. Another very actual illustration is the Paris Agreement on climate change. In accordance with the Treaty on the Functioning of the European Union, the EU is competent to implement the obligations resulting therefrom, among others preserving, protecting and improving the quality of the environment; protecting human health; prudent and rational utilization of natural resources; promoting measures at international level to deal with regional or worldwide environmental problems, and in particular combating climate change.

A second critique of the classic two-dimensional model is that technology and mineral prices both lie on the same Y-axis while prospection has its own axis (the X-axis). Until recently the cost of technological progress indeed reflected the mineral prices on the world markets. Nowadays prices are no longer only dependent of the cost of technology. They are increasingly influenced by the prices on the world markets for crude minerals. In some cases big amounts of stocks are even deliberately kept back for speculative or strategic reasons. A good example was the price increase of crude oil on the world market since the end of the 1990s and the influence OPEC-countries can exert on price-setting. On the other hand prospection is actually influenced to a strong degree by technological progress. Instead of being individually represented on the X-axis like it is the case in the two-dimensional vision, it should be better treated together with the technological aspects on the Y-axis.

The incorporation on one hand of three important additional factors (legislation, political circumstances and environmental management) and the rearrangement on the other hand of the fundamental parameters (prospection, technology and price) lead to a more contemporary and more precise vision of exploitation project analyses which concords in a better way with the current situation. A three-dimensional model, where those quite important additional elements, factors and arguments are taken into consideration, is an actualized vision of the traditional two-dimensional model (Fig. 39.2).

The X-axis of the three-dimensional model reflects the new supplementary influencing factors, namely politics, jurisdiction and a greater regard for the environment. For example the extraction of a certain identified mineral resource that would produce an acceptable turnover in financial terms, might nevertheless not be carried out because it would mean too heavy a load for the environment. The reserves could subsequently shrink because of the implementation of stricter environmental standards. Another cause of exploitation project failure could be discordance with laws, ordinances and regulations (local, national or even international).

On the Y-axis one finds both the technological aspects and the geological certainty. Technological improvements influence both exploitation material and prospection techniques in a positive way. Finally the Z-axis reflects the price at which the exploitation of a certain mineral resource is economically feasible or not. For example oil shales and tar sands have not been exploited for years although extraction techniques were existing just because the global extraction costs were too high to be profitably exploited at the world market prices in that period.

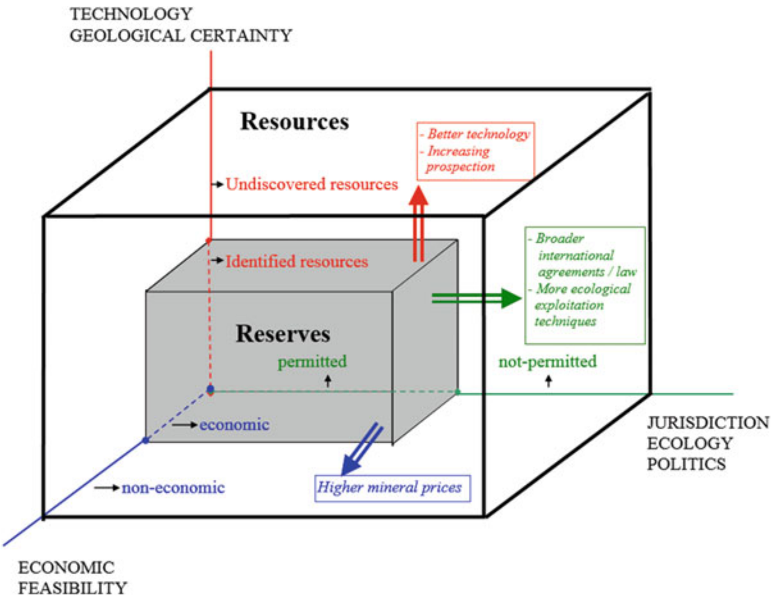

Fig. 39.2 A new three-dimensional vision

It must be stipulated that in this actualized model the three dimensions are interrelated. The supply of mineral resources could also be increased by a more efficient exploitation of existing sites. Therefore better technology is needed and economic motives can be decisive in attaining this higher efficiency. Also new technological developments can be used for the design of more environment friendly exploitation techniques. On the other hand those ecological techniques generally imply an extra financial charge for the project.

As an illustration of this three-dimensional approach, the model will be applied for the exploitation of oil and gas shale. Those resources are especially interesting since they require very special exploitation techniques, imply relatively high exploitation costs and undeniably have some negative effects on the environment. Last but not least the transport of the extracted oil and gas by means of pipelines like the Keystone XL and Dakota Access are subject to strict regulation and jurisdiction from several administrations.

39.4 Oil and Gas Shale Exploitation

39.4.1 Political Approach

Interest in shale oil production in the US started in the mid 1970s. The aim was achieving more independence in relation to oil import, especially after the oil embargoes of 1973 and 1979. Nevertheless, because of high extraction costs the resources remained mostly unrecovered until the late 1990s. But since 2001 shale oil and gas extraction has developed rapidly and taken a central place in the global oil market. This major rise in shale oil and gas production resulted in a much different view that analysts and policymakers originally had regarding the future of the US as a meaningful oil and gas producer. The Department of Energy projected that domestic oil production in the US would grow faster than consumption in coming years. Also outside the US forecast models had to be adapted. Even the International Energy Agency stated in 2012 that the US would become the world leader in crude oil production by the mid-2020s and would overtake Saudi Arabia as the world's biggest oil producer. The Agency also projected that the US would grow into a net oil exporter by 2030. The fast development of shale oil production has created a consequential threat to the conventional oil industry both in the US and in other oil producing countries (OPEC, Russia). When looking at the geographical distribution of shale oil and gas extraction in the US it is notable that the production is concentrated in only a few regions. More than half of the total US production is coming from shale fields in Montana, Texas and Dakota. The world's largest deposits of oil shale are located in the Green River Formation covering portions of Utah, Colorado and Wyoming. Also the need of Canada to export heavy crudes is the consequence of the lack of local refine infrastructure. The process of refining heavy crudes is quite expensive due to used technologies. In the United States, for instance, such infrastructure is principally present along the Gulf Coast. Whether or not to construct controversial oil pipelines connecting the northern oil shale fields with the southern refineries is thus an essential political decision.

39.4.2 Technical Approach

Oil shale deposits in the US were formed about 400 million years ago (Devonian). Although the first known extraction process in Europe dates from the tenth century, shale oil production became widespread in the nineteenth century. Shale oil production processes can be subdivided into open pit mining and surface retorting on the one hand and in-situ retorting on the other hand; retorting being the process of extracting oil from shale. Surface exploitations was by far the most developed process during the 1970s and 1980s but results were rather mixed because of the high costs involved in the extraction processes. The spectacular production boom after 2003 was principally provoked by the price increase of conventional crude oil, making new production technologies very competitive. Improvement in drilling engineering are likewise fundamental for the expansion in shale oil and gas production. Those advancements in drilling technology are the result of considerable technological ameliorations in horizontal drilling and hydraulic fracking. In a first stage the sedimentary rocks containing bituminous materials in solid form are exposed to horizontal drilling. Next, hydraulic fracturing (fracking) is used to make fissures and cracks in the rock formation. The latter allows crude oil to outflow from the rock layers and to flow into the drill hole from which it is collected. Fracking is generally amplified with advanced micro-seismic imaging. Thanks to this process extra more crude oil can be extracted from the rock layers, something not possible with conventional extracting methods.

39.4.3 Economic Approach

The boom in shale oil production triggered lower energy prices in the US and made the country less dependent on oil import. Lower energy prices brought about lower production costs and a rebirth of the US manufacturing industry. Consequently strong export growth resulted in a considerable improvement on the US current account. However, the quantity of future shale oil winning is not only based on the amount of recoverable oil shale present in the underground. The price of conventional oil on the world markets (Brent, WTI, Dubai/Oman) also plays a major role. Therefore crude oil price must remain at an adequate high level to maintain sustainable investments in shale oil projects. The development forecasts were hypothesizing a conventional crude oil price of about $100 a barrel but the latter declined from $106 in June 2014 to about $50 in January 2017. Furthermore the high expectations concerning future drilling of oil and gas shale are undergoing increasing pressure due to the requirement of large investment levels. There is also a constant need to drill new rigs since a location does not remain economically viable for a long period. Moreover it is very difficult to make a correct estimation of the amount of recoverable oil and gas in a well.

39.4.4 Environmental Approach

The most considerable environmental impacts of shale oil production and processing are land use, pollution (water & air) and waste management. Surface mining of oil shale deposits in the US and Canada caused severe disturbance, especially on land. For instance the region of the Green River Formation was previously a much appreciated area for fishing, recreational hiking, hunting, sheep and cattle grazing and fossil collecting. The basin had a significant ecosystem diversity and was a habitat for large herds of American elk, antelope, mule deer, as well as wild horses. However, this fragile equilibrium has been disturbed since the inception of shale oil development on the territory. Although it was postulated in the preparatory phase that shale oil winning would have minimal or no effect on the environment, practice has proved otherwise. The modified topography in situ affected the habitats of various plants and animals. The ecosystem was also wrecked as a result of the construction of, among others, roads, surface facilities (industrial, commercial and residential buildings), pipelines, power supply units, mud reservoirs and impoundments (for fresh water and fracking fluid). Pipelines transporting the extracted oil from the production place to the refineries constitute a threat to the environment as well. Since 1986 pipeline accidents have spilled more than 3 million gallons or an average of 76,000 barrels per year.

Concerning air pollution, the extraction and processing of oil shale release such pollutants as nitrogen oxides, ozone precursors, sulphur oxides, particulates, carbon monoxide and small amounts of other non-criteria pollutants. Notwithstanding official recommendations concerning precautions to be taken to preserve the air quality, acceptable pollution norms are regularly transgressed.

Furthermore the process whereby oil shale is heated to extract oil requires considerable energy inputs. To generate that heat many technologies burn other fossil fuels such as natural gas, oil or coal. As a result, energy consumption and carbon dioxide emissions from shale oil extraction is higher when compared to conventional oil production. Last but not least, underground water supplies can also be contaminated by fracking, through migration of gas and frack fluid underground or by leaks in impoundments containing toxic fracking fluid. Frack fluid encloses high quantities of heavy metals and radioactive elements that exist naturally in the shale. Hydraulic fracturing also necessitate tremendous amount of fresh water that must be acquired, transported and stored.

39.5 Conclusion

The exploitation of oil and gas shale in the United States had an extraordinary impact in many ways. It boosted the economy, improved the current balance of trade and made the country less dependent on energy supply. Although the presence of potential shale sources was identified since centuries, the industrial winning of shale deposits has been variating according to prospection, technology and oil price. Those factors are clearly integrated in McKelvey's two-dimensional diagram. Nevertheless, nowadays our modern society evolved significantly and viewpoints regarding mining have been revised. Other arguments and perceptions have to be taken into account when classifying resources for exploitation. A new three-dimensional diagram offers a convenient integration of those present-day statements and prevalent factors.

As seen, expansion of the potentially exploitable part (the reserves) is much dependent on the conventional oil price. High gas and oil prices on the world markets were indispensable elements for the rebirth of the industrial winning of shale hydrocarbons. Moreover, given that oil price is currently rather influenced by agreements between oil producing countries and speculation than by technology it has its own axis, namely the Z-axis representing the economic feasibility. The actual forecasts of shale oil production are based on the assumption that the price of crude oil remains sufficiently adequately high to make investments viable. A new drop in oil price would mean the stoppage of many projects.

Meanwhile, the Y-axis corresponds with technology and geological certainty, the second fundamental factor for the revival of shale oil and gas extraction.

Without innovations in the field of horizontal drilling, hydraulic fracking and micro-seismic imaging, shale oil production would have been at a lower level and at a higher price. Since technological improvements have not only an influence on the exploitation material but also on better prospecting techniques both are displayed within the same dimension in this actualized model. The use of far more precise maps, which are now obtained through the use of satellites and sonar systems, illustrates very well the latter. Unless new promissory shale oil deposits are found shale oil production is expected to decrease in the 2020s. Technological breakthroughs in the field of extraction and prospection could play a main role to reverse this expectancy.

On the X-axis of the three-dimensional model one finds the new additional influencing factors, namely jurisdiction, ecology and politics. Although those key-elements were for a long time considered as minor, at present they are judged as ineluctable in the framework of a sustainable exploitation of shale hydrocarbons. Environmental awareness and jurisdiction could mean a drastic slow down for the exploitation of oil and gas shale. In order to keep pollution in acceptable ranges legislation protecting the environment could oblige (local) authorities to control very carefully future exploitations and deliver exploitation licenses very strictly. On the other hand it is also important that the environmental standards be the same for all projects. Powerful companies could be tempted to shirk these standards.

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Chapter 40
A Glance at the Medical Activity of "Prof. Dr. V. Sion" Hospital of Constanta in 1931

Octavian Dumitru Unc and Alexandra Nicoleta Unc

Constanta today is known everywhere as Romania's Black Sea gate. Constanta is one of the oldest certified cities in Romania. The first documentary proof dates from 657 B.C., when, on the territory of the current peninsula, a greek colony called Tomis was formed.

At that time, the territory of Constanta today was separated by Moesia Inferior province, under the name of Scythia Minor (Radu n.d.). The territory of Dobrogea region, to which Constanta belongs, covers an area of 23,262 km^2, representing 1/13 of the reunited Romania. The importance of Dobrogea comes from its location at the Danube Delta and the Black Sea (Dobrogea cincizeci de ani de vieaţă românească – Bucureşti 1878). The shipping disposes of Constanta North and Constanta South harbours, these two together with Constanta South-Fluvial composing the big harbour of Constanta, the biggest harbour at the Black Sea and the fourth in Europe, as size. Throughout time, the health system of Constanta was influenced by the historical approach.

In 1931, Constanta county covered an area of 687 km^2 with a population of 193,655 inhabitants, in a disposal of 92 villages and 6 cities(called urban areas), with health services system organized at county level, inside a hospital known as "Prof. Dr. V. Sion Hospital".

The Health Service of Constanta county: the medical personnel consisted of a M.D. of the county; 4 administrative officials; 15 rural level doctors; 2 urban level doctors, at Mangalia and Techirghiol; 3 doctors for cities with hospitals; 34 rural sanitary agents; 6 urban sanitary agents; 6 urban midwives; 95 rural midwives. Two

O.D. Unc (✉)
Ovidius University, Constanţa, Romania
e-mail: unc_octavian@yahoo.com

A.N. Unc
Floreasca Emergency Hospital, Bucharest, Romania
e-mail: alexandra_unc@yahoo.com

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hospitals, Medgidia and Harsova, under county administration had 40 beds, Harsova hospital being later dissolved for lack of funds, and Cernavoda hospital working as a dispensary. Carvaclar and Parachioi hospital, destroyed by war could not be made operative, serving as dispensaries. Besides these, there were 5 more dispensaries, county property and one more dispensary purchased by the state. The remaining medical constituencies had rental houses as dispensaries, paid by the county. During 1931, 50,346 free consultations were given, 901 medical inspections in the county's municipalities were conducted, 6211 births benefited from graduated midwives medical assistance and the rest, of "empirical old women", which explains the high rate of infantile mortality. 69 BCG vaccines were performed without any accidents and also, 55 vaccinations with anti-diphtheria serum. In 1931 from the total of 8485 births, 4187 were boys and 4298 were girls, the registered mortality being of:

- 1597 deaths until the age of 1
- 568 deaths until the age of 2
- 386 deaths until the age of 5
- 2112 deaths from age of 5 up

The mortality causes were declared as follows:

- Congenital debility (because of parental diseases heredity)
- Gastro-intestinal affections
- Respiratory affections
- Infectious and contagious affections
- Trauma

Epidemic diseases combated in 1931 were the following: scarlet fever (483 cases from which 74 lethal); typhoid fever (95 cases with 13 lethal); anthrax (13 cases, 3 lethal); dysentery (7 cases); exanthematic typhus (1 case); lethargic encephalitis (11 cases); cerebrospinal meningitis (6 cases, 2 lethal); infantile paralysis (2 cases, 1 lethal); measles (626 cases, 35 lethal); flu (180 cases, 3 lethal); chickenpox (13 cases); whooping cough (233 cases, 2 lethal).

Social declared diseases in 1931 were the following: syphilis (1900 cases); tuberculosis (1056 cases); malaria (884 cases); pellagra (272 cases); cancer (40 cases); granulous conjunctivitis (858 cases).

In the entire county there were 196 school places in the service's property and 44 rented.

Regarding the housing, in Constanta county the first place in matter of space and hygiene was held by the German colonists established here for 30–40 years, and the second one by Romanians. Their houses had 2–3 rooms, from which one was the salon, another the bedroom and the last the kitchen, each of them with floors, for the wealthy ones. The third place belongs to the colonists, and the last to the native Tatars and the Romanian colonists, whom the state could not help. The Tatars houses were very low (cottages), having one room with small, immobile windows, blind stoves, in where 6–8 people lived, with 2–5 mats on the floor, and near which there were the cattle stables (2–3 cattle). At the recent established Romanian colonists, the living is similar, but with better houses and bigger, mobile windows.

The rural population, in majority, feeds with homemade bread, except the colonists and few old Romanians from Dobrogea that eat meat, eggs, vegetables, fish and polenta.

Besides villages that had the chance of having water sources, therefore drinking water free of infections, the other ones had water coming from rudimentary built fountains.

In the county there were: 17 petroleum products warehouses; 137 brandy making boilers; 24 sparkling water factories; 1 cement factory; 1 nail factory; 70 mills; 27 wool equipments; 11 oil factories; 11 brick factories; 520 taverns; 258 coffee houses.

Proposals for the future in year 1931 were the following:

– The transition of the entire medical staff to the Health Ministry
– Construction of dispensaries in the service's property at each medical circumscription residence and doctor's house
– Making Cernavoda and Harsova hospitals operational
– A disinfection team to combat infectious and contagious diseases
– Declaring the syphilis cases and compulsory treatment for each of them
– Better propaganda for tuberculosis fight
– The establishment of a hospital in Plopeni (Carvaclar) or Constanta with 30–40 beds, for granulous conjunctivitis
– Augmentation of the M.D. and county doctors allowances
– Movement allowance for sanitary agents
– Establishment of a hospital in Medgidia, with surgery and internal medicine
– On time drug supply for the sanitary institutions (Serviciul Judeţean Constanţa al Arhivelor Naţionale, fond Serviciul Sanitar al Judeţului Constanţa 1931).

The Health Service of Constanta county during 1931 was led by a chief physician helped by 3 district doctors, a school doctor, 8 sanitary agents, 4 midwives and a nurse care. For the external needs of the health service meaning: deaths verifications; epidemics combat; industrial and commercial places controls, there is only one carriage with a pair of horses, which serves for the contagious patients transport also. For disinfection there was a team consisting in: a health agent, a mechanic and a janitor with a Geneste-Herscher oven, pulled by 4 oxen, taken from the Sanitation Service. This oven was insufficient, especially during multiple epidemics, when this was not only in the in-fact town, but in the limitrophe neighbourhoods also: Anadolchioi; I.C.Bratianu; Viile Noi and Viile Vechi; Palaz; Medeea. Pacient transport to the hospital was made with a closed ambulance with no tires, that is why they suffered during this process. This ambulance was insufficient also. During 1931, 12,105 free consultations were given, 168 tuberculosis patients were visited, 3 with pellagra, and 185 syphilis patients were treated (Serviciul Judeţean Constanţa al Arhivelor Naţionale, fond Serviciul Sanitar al Municipiului Constanţa 1931).

„Prof. Dr. V. Sion Hospital" from Constanta, built over 20 years ago, the only hospital in Constanta except the military one, provided medical care for the city's and county's population in a space with a number of problems:

– The morgue was left in the streets after the new road alignement, so it had to be demolished and rebuilt in the hospital's courtyard
– The ice-house must be totally reconstructed, being shattered and so, unfit for its purpose
– The winter vegetable warehouse, which was destroyed had to be restored
– The cast iron water plant with a history of over 20 years, was almost entirely rusty
– The drainage was suffering from being clogged, because of the frequent lack of water
– The windows and doors carpentry, although from oak, was cracked and rotted
– Nonexistent bathrooms, because of the lack of water
– The water-closets, because of the complete lack of water, by inappropriate pressure, were unusable
– At Medical Department, the closets had no sewage system
– The roof had to be replaced, because rainwater was entering in the patients wards
– A special kitchen was missing in Isolation section
– The disinfection oven from Isolation had to be repared
– The motor from the circular saw was not working since 1930
– An incinerator for garbage combustion was needed
– The courtyard plantation was quite poor
– The terracotta stoves had to be redone
– Solid fencing of the courtyard, to prevent the escape of prostitutes and the wall climbing by parent or relatives of contagious patients.

The hospital functioned in 1932 with 5 departments led by 5 primary physicians and 2 secondary ones, having a total of 39 employees, with a number of 140 beds distributed as follows: 60 beds in Isolation, 55 beds in Surgery; 25 beds in Medical. Ophtalmology and Radiology departments were not hopitalizing patients (Serviciul Judeţean Constanţa al Arhivelor Naţionale, fond Serviciul Sanitar al Municipiului Constanţa 1932a).

Isolation Department started as a standalone unit on January1st 1919, with a primary physician, a secondary one, a health official, a midwife, 4 nurses, 2 laundresses and one servant. During 1932, the total of patients was 1190, and 13,597 injections with Neosalvarsan and Bismut at 884 patients, men and women. As for the pathology: scarlet fever (250 cases–23 lethal), malignant pustula (25 cases–18 males, 7 females, 6 lethal); typhoid fever (17 cases-7 males, 8 females, 15 cured, 2 females deceased); diphteria (26 cases – 21 cured, 5 lethal – 4 males, 4 females, 8 boys, 10 girls – at 2 of the children tracheostomy was made); erysipelas (27 cases, 9 males, 17 females and a girl – all cured); infantile paralysis (one man discharged, much improved); tetanus (10 cases – 7 cured, 3 lethal); granulous conjunctivitis (5 cases); influenza (23 cases, 14 males, 13 females, 3 boys, 3 girls – all cured);

mumps (6 cases); scabies (6 cases – 2 males, 4 females); syphilis (374 patients – 85 males, 289 females, one girl). From 01.01.1932 an Outpatient for syphilis begins functioning, and 13,597 injections are performed (Serviciul Judeţean Constanţa al Arhivelor Naţionale, fond Serviciul Sanitar al Municipiului Constanţa 1932b).

Medical Department, allowed in 1932 the hospitalization of 570 patients from whom: 225 cured, 274 improved; 55 deceased; 16 remained hospitalized, with the following pathology:

- Poisoning: 44 cases, most with caustic soda (31); Iodine (3); denaturated alcohol drugs (2); corrosive sublimate (1); and sulfuric acid (1); stomach and esophageal stenosis complications.
- Tuberculosis
- Pleurisya – almost all of them with tuberculosis origin (32 cases)
- Syphilis (26 cases – the biggest number belonging to foreign patients from various parts of the country)
- Cancer (8 cases) – stomach, liver, uterus, bladder
- Pellagra
- Rheumatism (28 cases)
- Pneumonia (18 cases) (Serviciul Judeţean Constanţa al Arhivelor Naţionale, fond Serviciul Sanitar al Municipiului Constanţa 1932c)

Surgery Department benefited of a primary physician, Dr. V. Vasilescu and a secondary one, Dr. Guthy Eugen, 2 health officials, one health official; a midwife, 1119 patients being treated, with 503 operations and 104 births.

- Operations on the head and cervical region (45): trepanations – 11; tracheostomies – 3; eyeball enucleation – 4; phlegmons – 10; malignant tumor excision – 3.
- Operations on the thorax and the upper limbs (34): amputations – 7; disjoints – 9; flegmons –10; costotomies – 3; tumor excision – 5.
- Operation on the abdomen and the lower limbs (321): gastro-enteroanastomosys – 3; hysterecomy – 10; neoplasms – 12; appendectomies – 78; inguinal hernia – 32; thigh amputations – 9; colecystectomies – 7; thyroidectomy – 3; hemorrhoids – 13; hydatid cysts – 3; cervix operations – 7.

There were 54 deaths, in almost all of the violent cases, but in spine fractures also – 5; scrotum gangrene – 3; sepsis – 5; bowel obstruction – 1; cancer of the bladder – 1; intrahepatic abscess – 1; combustion – 2; isolated ovarian TBC – 2.

The operations results were good, and all the operations were closed per-primam; sterilization was performed in admirable conditions, the sterilization equipment being new and operating all the time. Spinal anesthesia with Novocaine was regular, except the thorax interventions where chloroform and rarely ether were used. No complications from anesthesia were registered.

As means of clinical research, the two services from the Hygiene Harbour Laboratories – Bacteriology and Chemistry were used for blood, urine and bacteriology analyzes (Serviciul Judeţean Constanţa al Arhivelor Naţionale, fond Serviciul Sanitar al Municipiului Constanţa 1932d).

The above, are few data about 1931–1932 medical year, reported by the director, county's chief doctor Dr. Bârsănescu, belonging to Dobrogea, the only Romanian territory without historical discontinuity (Vasile 2010).

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Chapter 41
Land and Water in Romania's Food Economy

Aurel Lup, Indira Deniz Alim, and Liliana Miron

Abstract This article aims at presenting the American public with an overview of Romania's agriculture – a medium-sized European country with an area of 238.391 km^2 and a population of 19.3 million. It is worth noting that 45% of Romania's population live in rural areas while 30% of the country's active population is involved in the agricultural sector.

Thus, Romania's 14.685 thousands hectares (ha) of agricultural land and 9.455 thousands ha of arable land is one of the best land per capita hectarage in the world with a 0.68 ha of agricultural land and 0.44 ha of arable land per capita compared to an average of 0.27 ha per capita in Europe and, indeed, the World.

Due to the fact that large parts of these agricultural lands are being plagued by drought rather frequently, more than three million ha of land in areas most affected by this phenomenon, such as in the Romanian Plain – which is abutting the Danube River – as well as the country's South-Eastern reaches – made up of the historical provinces of Dobrogea and Moldavia – were prepared for irrigation, during the period 1965–1989.

The aquatic resources' management is hardly better. Fish stock yields of just a few tens of kilos per ha at angling and a few hundred kilos per ha in fish farms and the poor management resources led to the extinction of valuable species of their becoming now endangered species, such as the sturgeon while even the rather common turbot is now an expensive delicatessen. There aren't any local fish farms of marine species as over 80% of fish products are being imported.

Due to the poor management of fish stocks and the critical lack of investment in fishing boats, tackle and the entire infrastructure supporting the fishing industry that would make trout farms affordable in mountainous regions, Romania is about to become a 100% importer of fishery products.

Keywords Romania • Land • Water • Land reclamation • Foodstuffs

A. Lup (✉)
Academy of Romanian Scientists, Bucharest, Romania
e-mail: lupaurel@yahoo.com

I.D. Alim • L. Miron
Ovidius University of Constanta, Constanta, Romania
e-mail: alimindira@yahoo.com

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41.1 Introduction

This volume pays homage to our friend, adviser and collaborator, Alexandru Bologa, on the occasion of his anniversary, which avails me of an opportunity to tackle a most important subject in Romanian economics i.e. the use of the country's two most important resources: land and water, over the period between 1945 and 1989.

It is well known that following the end of WW2, Romania had been obliged to adopt the Soviet planning system in the management of its economy. This was a highly centralised, top-down and dictatorial system. In such a system, economic policy decision making was the preserve of a restricted group of Communist Party activists which became restricted, in the final years of the regime to just one person.

The economic policies of the Romanian Communist Party and of its leader, Nicolae Ceausescu, were aimed at transforming an underdeveloped, agrarian country, into a developing industrial and agrarian powerhouse. To this end, the country's financial resources had been geared towards the advancement of heavy industry, whereas the agricultural sector was demoted into a supporting role, providing the nourishment of the country's workforce while providing additional revenues by exporting food abroad.

In order to achieve these objectives, arable lands had to be reclaimed by 1000 thousands ha and, to increase productivity more than 55% of it needed proper irrigation. Yet, a mere three thousands ha were reclaimed in the process (with many components missing from the system and of a poor technological quality at that) which resulted in a failure to achieve the projected yields while the most adequate crops for the quality of this land incurred losses instead of the profits that were needed to support the country's heavy industry.

As regards Romania's second available resource, freshwater, this was equally poorly managed to a degree where it failed in providing the yields needed to feed the populace.

Compared to other countries, Romania has relatively modest freshwater resources, which amount to some 39.78 billion m^3 (cubic meters). Yet, even these resources would meet the country's needs, if used rationally, given that these needs do not exceed 50% of the existing resources (National Commission of Statistics 1990).

As regards salty water, this resource is still largely underused given its potential contribution as a food resource. Romania's Black Sea coastline, which is the country's Eastern (maritime) border, has a length of 244 km, yet, the share of the marine products that could be used to feed the population is relatively small. While the estimates point to animal products being the leading food resource globally, only 3% of this (food) resource is provided by fishery products, including here, marine fish.

41.2 Land

41.2.1 Agricultural Land vs. Cultivated Agricultural Land Viewed from a Global Perspective

Nowadays, a total of 5.01 billion hectares – representing 3.07% of the Earth's overall land mass – is being used for agricultural purposes (Lup 2014).

Out of this hectarage, 1.4 billion hectares (i.e. 29%) represents arable land, while 69% is made up of permanent meadows and pastures, and 2% is made up of perennial crops. When considered against the world population, agricultural resources ensure an average of 0.82 ha per capita of which 0.23 ha is made up of arable land.

As with the world population's uneven distribution across the globe, the agricultural resources' irregular spatial distribution from one geographical region to the next results in the asymmetrical distribution of reserves that are providing people with the means needed for their subsistence (see Fig. 41.1).

Thus, the arable land per capita ratio varies considerably across the globe. Whereas in Asia – where half the world's population now lives – only 0.15 ha of arable land per capita is available, in the territories of the former Soviet Union the availability of arable land stands at 0.81 ha per capita. In other geographical areas (on different continents), the availability of arable land per capita is as follows: 0.19 ha in Oceania, 0.27 ha in Europe, 0.28 ha in Africa, 0.39 ha in South America and 0.65 ha in North and Central America. (Agriculture Mondiale horizon 2015/2030, 2002; Farming Agricultural Organization - FAO) (Fig. 41.1).

Naturally, the current allocation of both the available agricultural land and of the world's population is the result of a long-term evolutionary process (which is thousands of years' long) hence, its distribution is likely to remain the same in the future – a factor which will have significant consequences over the future generations' way of life.

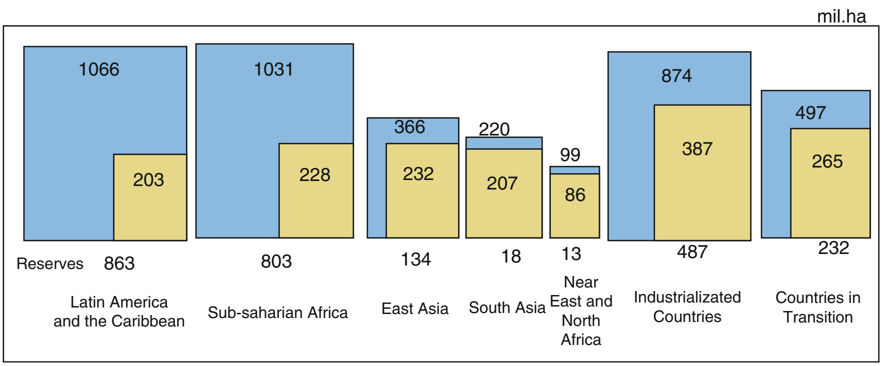


Fig. 41.1 Cultivated land and cultivable land in the World (Source: FAO, Fisher and other)

41.2.2 Romania's Land Resources

Romania is a medium-sized country, measuring 238,391 km^2 (being the twelfths country by size in Europe) with a population of 21,431,298 people (2010) of which 55% live in urban areas and 45% live in rural areas. Romania is the seventh largest country in the European Union as regards its size, the fifth largest as regards its agricultural surface and the sixth largest in terms of the arable land it has. As regards Romania's land surface vs. population ratio this is as follows: 0.68 ha of agricultural land and 0.44 ha of arable land per capita – which almost twice the global and European average. (Statistical Yearbook Romania 1990).

As regards Romania's land quality, 40% of its arable land is of a good and very good quality, 26% is medium quality while 34% is of poor quality. In absolute terms, Romania's agricultural land expanse measures 14.685 ha, with arable land measuring 9422 thousand ha. The agricultural policies of the communist state were geared towards expanding the country's agricultural area up to anywhere between 10 and 15 thousand ha with an arable stretch of up to ten thousand hectares. To this end, large thwaites of pasturage lands – that were located on steep hills, which made their exploitation difficult on top of their being susceptible to erosion – were reclaimed for arable purposes (Fig. 41.2).

According to the data provided by Romania's Yearbooks, published during the final years of the totalitarian communist regime, fifteen million ha of agricultural land as well as ten million ha of arable land were claimed to exist in Romania yet, this was never really the case.

Subsequently, these figures were revised downwards, to match an expanse of 14.685 ha of agricultural land and 9422 thousands ha of arable land, as mentioned previously.

Fig. 41.2 Pastures with steep slopes predisposed to erosion that had been turned into arable land (Source: Aurel Lup's personal photo archive)

Between 1950 and 1989, a comprehensive land reclamation programme was undertaken. During this time, some 3100 thousands ha (i.e. 56.5% of a 5500 thousands ha programme) as well as 2959 thousands ha (i.e. 56.8% of an envisaged 5530 thousand ha programme) had moisture control equipment put in place, while 2220 ha (i.e. 41.9% out of a 5300 ha programme) were (Lup 2014).

41.2.3 Irrigations Systems

Owing to the climate's characteristics, a large part of Romania's territory is affected by drought – something that reduces the land's production capacities to a large extent and, sometimes, even leads to the complete destruction of crops. Such adverse natural conditions were compounded by the communist regime's eagerness to raise the yields per ha (which, incidentally, were among the lowest in Europe!) while plagued by severe cash shortages, in a race against time to meet the ever-ambitious if unrealistic quotas set in The Communist Party's 5 year-long central planning programme (Fig. 41.3).

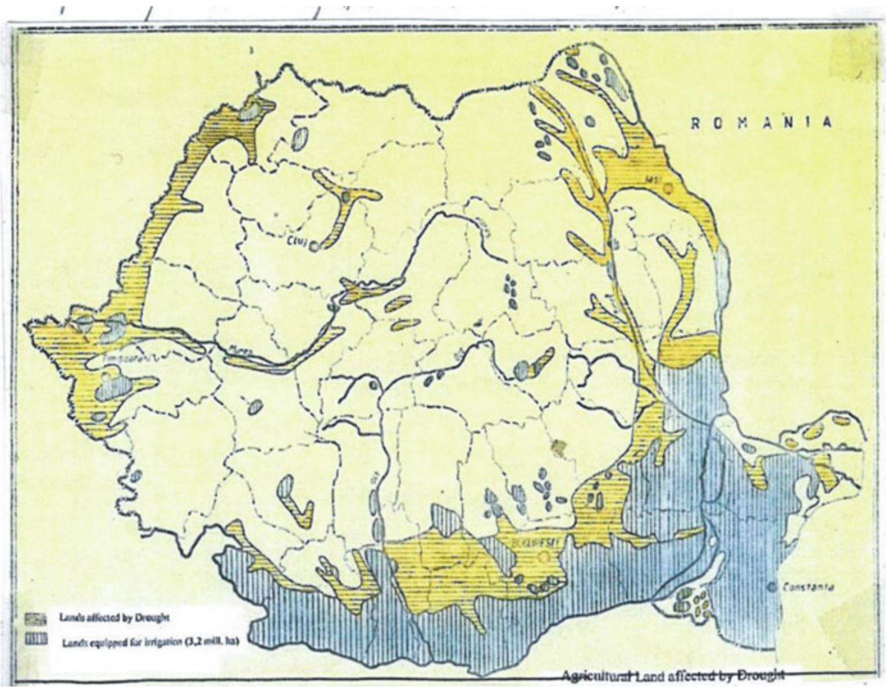


Fig. 41.3 Lands affected by drought to be equipped for irrigation (*yellow*) and lands equipped for irrigation (*blue*) (Source: The Ministry of Agriculture's Land Reclamation Department)

To this end of offsetting the difficult climatic conditions, while meeting the five-year plan, ambitious complex irrigations systems were built at too great a speed – sometimes at a rate of more than 200.000 ha annually (see Fig. 41.3). Thus, many of these systems' essential components, such as the dewatering systems, the water-proofing of the canals that were supposed to bring in water to the crops, or the automatic water-meters were missing (Lup 1997).

41.2.3.1 The Romanian Irrigation Systems' Main Characteristics

One of the main characteristics of the irrigation systems in Romania was the size. On average, they had over 100 hectares, some of them belonging to the "giant" category (see Table 41.1).

The decision to irrigate large areas in the Danube Delta's floodplains, due to the availability of water supplies, resulted in a number of features that would influence both the investments made at the time as well as their corresponding exploitation costs.

Firstly, in order to save time and money, the irrigation systems were never completed. In a report of the Romanian government's Commission (1990) it was stated that: "The land reclamation works that were started in 1966 were carried out with irrational haste which lead, in some cases (N.B. 'in all cases, in actual fact' – my personal comment), to a number of undiscriminating shortcuts being made with respect to these systems' design, execution and environmental protection criteria. Some 40% of the irrigation canals' system has no waterproofing which leads to water seepages of between 30 and 60%... (Fig. 41.4).

Due to the fact that the areas equipped for irrigation are located on lands which have higher elevation levels compared to the Danube's, a number of eighty-two pumping stations – of which forty-six are floating, as is the one in the picture below (see Fig. 41.5) – had been built to bring the water upwards, at heights of up to 260 m. This is one of the costliest technical solutions to the elevated lands' irrigation problem compared to the dams of water supplies higher up rivers being practiced around the world (for example in California, USA; see Fig. 41.5).

Table 41.1 Classification of main irrigation systems by size

Size class	Number of systems	Medium surface ha	Weight in equipped surface
Giant systems over 100,000 ha	4	126,139	21.5
Very grate systems: 50,000–100,000 ha	13	72,954	32.4
Grate systems: 25,000–50,000 ha	18	37,176	22.9
Middle system :10,000–25,000	29	16,653	16.5
Little systems: under 10,000	39	5018	7.6
Total/average ha	104	28,144	100.0

Source: A. Lup (1997) Irrigation in Romanian Agriculture

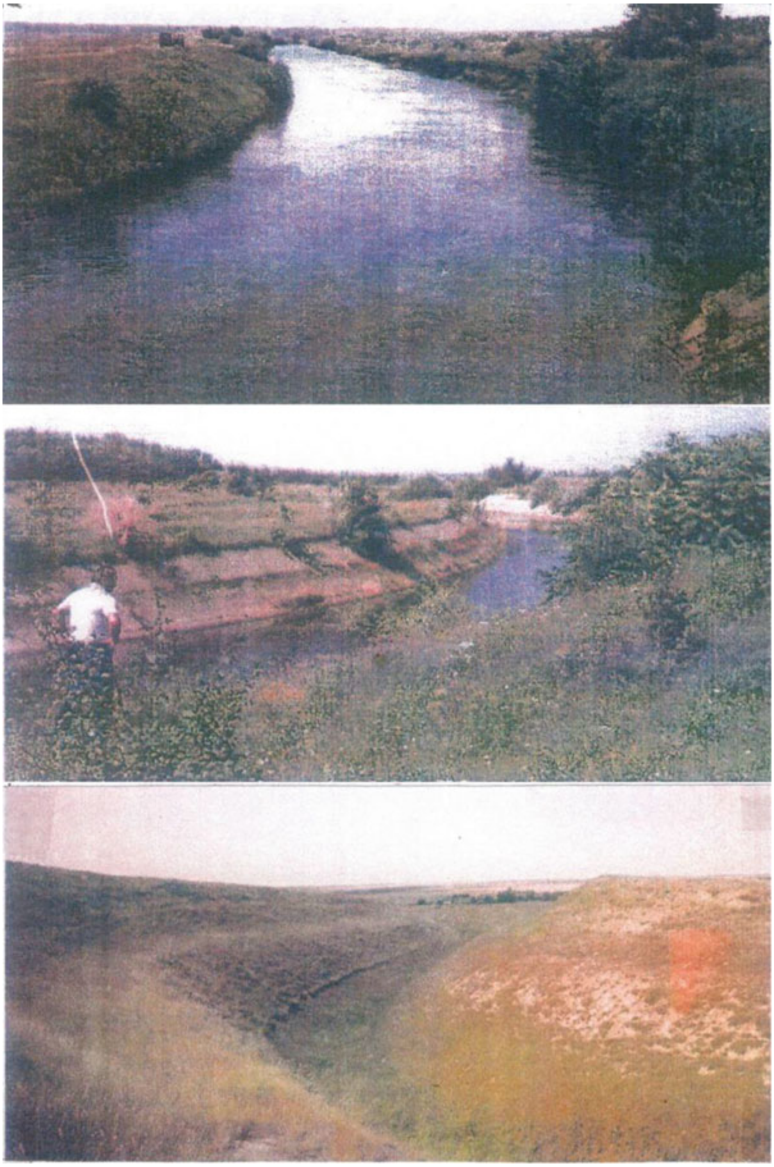


Fig. 41.4 Main water transportation canals in the Romanian county of Constanta that are lacking waterproofing systems to a full or partial extent (Source: Author's personal photo archive)

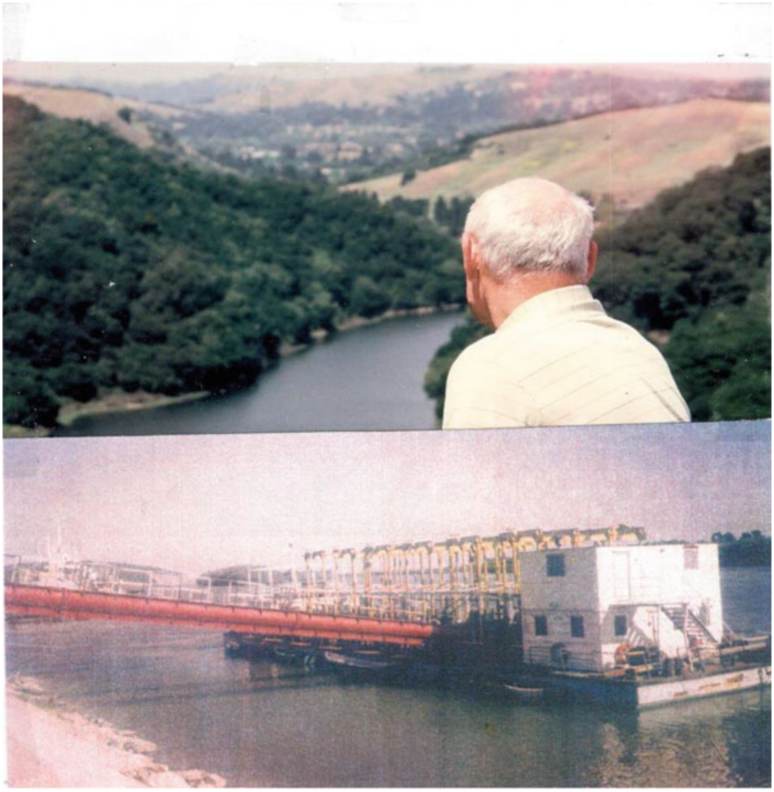


Fig. 41.5 A dam up of a surface to be irrigated (California, USA) and a floating pumping station below the surface to be irrigated (Constanta county, Romania, on the Danube river) (Source: Aurel Lup's personal photo archive)

A dire consequence of the elevation levels to which water has to be pumped is the high energy costs involved in the process:

Low levels:	0–700 kWh/ha...	10% of the land
Medium:	700–1400 kWh/ha...	28.6% of the land
Medium–High:	1400–2100 kWh/ha...	48.2% of the land
High:	over 2100 kWh/ha...	13.2% of the land

During the exploitation phase of the irrigation systems in Romania, the share of the areas where the applications were administered reduced gradually, which is one of the causes wherefore the projected yields were not achieved (see Fig. 41.6). Moreover, the inadequate watering equipment quality also caused water losses and puddles (water stagnation) during the applications (Fig. 41.7).

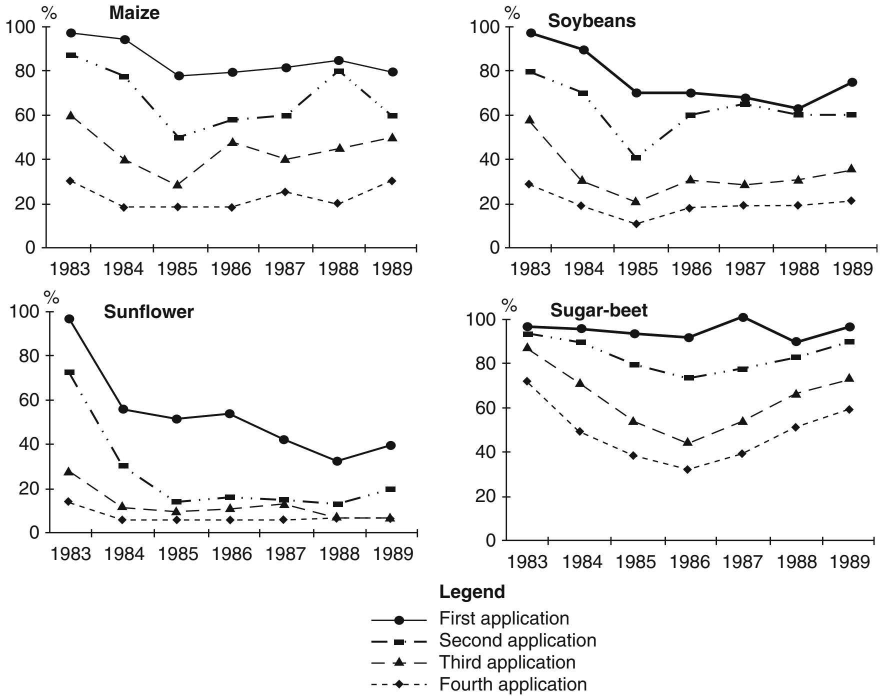


Fig. 41.6 The evolution of the applications degree for the main cultures in the Irrigations System in Romania in 1983–1989 years (Source: A. Lup (1997) Irrigation in Romanian Agiculture)

41.2.3.2 Investments in Romania's Hydro-technical Systems

Romania's communist government had invested hugely in land irrigations, prioritising these as the most important factor in raising production per unit area of land.

Faithful to Marxist principles that prioritised industrial output in Romania's overall economic growth strategy, Nicolae Ceausescu saw it personally that more than 30% of the country's national revenue went to investments (a very high rate).

Yet, the petrol crises of 1973 and 1979 struck a heavy blow to the heart of Romania's refining industry. These crises compounded the already heavy burden placed on an increasingly energy-dependent economy by forcing the regime to take on petrodollar-denominated debt, with sky-high interest rates to boot (Cioroianu 2013).

This period coincides with a fast-paced programme of supplying Romania's agricultural lands with much-needed irrigation systems, and this is hardly accidental. Obtaining the production yields per unit area of land (ha) at levels projected in its 5-year plans would have allowed the substantial growth in the export of agricultural products needed to pay for the importing of raw materials on which the industry depended.

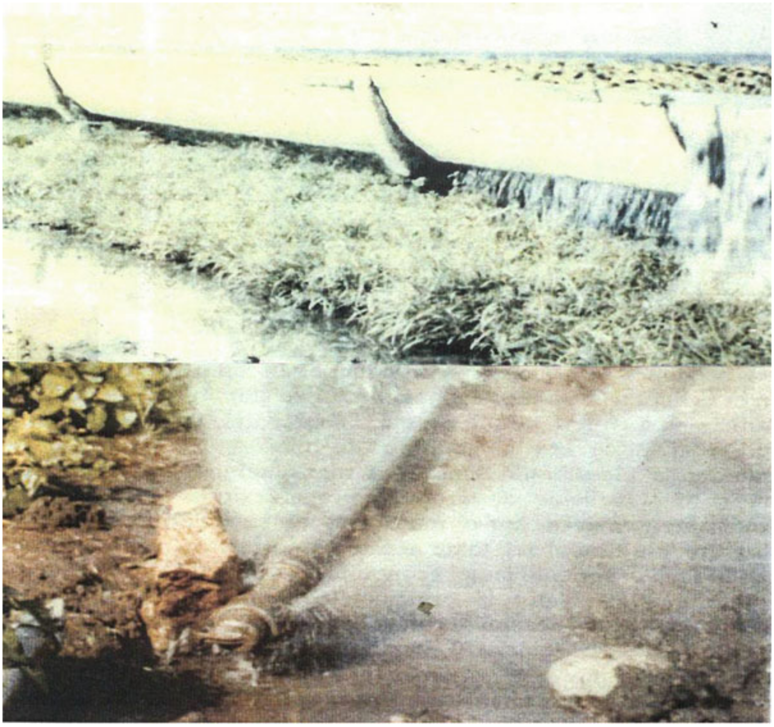


Fig. 41.7 Water loss owning to inadequate transport and distribution equipments of water to parcel (Source: Aurel Lup's personal photo archive)

In such daunting conditions, it is difficult to evaluate accurately the true value of the investments made in hydro-technical systems – as these require complex and most expensive works prior to their deployment, such as the fitting of dewatering systems or the waterproofing of the canals supplying water to the crops. Therefore, the Head of the National Institute of Research and Development for Land Reclamation "ISPIF" described the costs involved in reclaiming an area of 224 thousands ha in the Danube Delta's floodplains as follows: "The defence works i.e. the canal embankments of 1158 kilometres in length and the adjacent dewatering and excess water drainage systems represent a fourteen billion US$ investment." Yet, the World Bank's global estimated that the costs of the land reclamation investment that was needed here were fifty billion US$.

41.2.3.3 The Exploitation of the Irrigation Systems

Upon becoming operational, these systems were plagued by never-ending dysfunctions and penury affecting the resulting yields – which were way below their projected parameters – thus undermining the entire land reclamation system's economic efficiency.

The defective exploitation and the resulting low yields were known at the highest executive levels yet, the land reclamation programme was being continued at too great a speed (261.6 thousands ha are being made available in 1985) and this goes on into the regime's final years, by which time the economy had become unable to support such obsessive delusions of grandeur (with only 45.0 thousands ha, in 1988 and 27.7 thousands ha, the following year being made available for exploitation).

All of this took place with the manifest connivance of the communist authorities, as even the Head of state and President of the Romanian Communist Party, Nicolae Ceausescu appeared to be admitting, in a speech made at the beginning of 1981: "I do not wish to revisit the problems encountered with our irrigation and land reclamation programmes yet, since some of our comrades have raised the issue of supplementing investments to this end, I would wish them to note that for the period 1981–1982 there will be no new works being started. Let us complete the irrigation systems that were done, let's fix the systems that are in place – because some of them have already started degrading. Let us ensure their proper functioning first. Only after all the systems that are currently in place will operate properly will we go on to building new ones." Footnote 2: the Programme.

Thus, the continuation and expansion of the land reclamation works while neglecting the proper functioning of the systems that had been put in place is the first and foremost mistake made concerning the issue of resource management. Some of the main deficiencies that became manifest during these systems' usage will be looked at over the following chapters.

(a) *The degree to which reclaimed land was being irrigated and its irrigation norms*. The land that had been equipped for this purpose over the period 1986–1989 grew from 2731.1 thousands ha to 3280.8 thousands ha, with an average of 2988 thousands ha over these 4 years. The actual surface being irrigated (at least once) stood at an average of 2406 ha, representing 80% of the total surface of equipped land (Table 41.2).

The irrigation norm varied between 2000 m^3/ha in 1988 and 1310 m^3/ha in 1986, with an average of 1746 m^3/ha against average projected norms of 2700 m^3/ha ensuring a 50% Active Humidity Interval (AHI) or 3550 m^3/ha ensuring an 80% AHI. In reality, the water provided for the irrigated areas stood at 64.3% and 48.9% respectively.

The failure to ensure the irrigation norms as projected was partly caused by the fact that the pumping equipment had been substandard; however, this failure was mostly the result of water losses that occurred through seepages due to the inadequate waterproofing of the canals.

(b) *The failure to water the crops as many times as it should have been necessary*. Statistically speaking, the area where at least one watering was applied is considered irrigated. For most crops though, several watering sessions are

Table 41.2 Equipped surface for irrigation, surface effective irrigated and Irrigation norms applied in irrigation systems in 1986–1989 years

Year	Surface equipped for irrigations Thon. hectares	Surface effective irrigated from equipped surface		Irrigation norm cm/ha
		Thon. hectares	%	
1986	2731.1	2212.2	81.0	1310
1987	2877.8	2287.9	79.5	1740
1988	3065.5	2597.2	78.2	2000
1989	3280.8	2527.0	81.3	1933
1986–1989 Average	2989.0	2406.0	80.0	1746

Source: The Ministry of Agriculture's Land Reclamation Department

Table 41.3 Surface equipped for irrigations, surface effective irrigated and pumping the water at source in 1986–1989 years

Year	Surface equipped for irrigations Thon. hectares	Surface effective irrigated Thon. hectares	Irrigation norm at source m^3/ha	Ensuring degree with electric power for pumping the water %
1986	2731.1	2212.2	2182	62.4
1987	2877.8	2287.9	1978	47.4
1988	3065.5	2597.2	2200	49.4
1989	3280.8	2527.0	2322	49.3
1986–1989 Average	2989.0	2406.0	2171	52.1

Source: The Ministry of Agriculture's Land Reclamation Department

usually required. Yet, judging by the data provided by most agricultural territorial units, it appears that at least some of the crops had not even had their first watering administered, as the agricultural area under their jurisdiction had not been effectively irrigated in its entirety, rather, it had merely undergone field preparation. Meanwhile, all the other management applications were being made on increasingly smaller areas (Table 41.3).

(c) *The failure to provide the electric energy needed to pump water and ensure its transport to specific locations so as to enable the watering of the plants*. This was one of the main causes, if not the most important one, that hindered the achievement of the projected yields. Consider, for instance, the degree of providing the electric energy needed to pump water over the reclaimed areas between 1986 and 1989 (Table 41.3).

On average, over the 4 year period being considered here, the degree of providing the electric energy needed to pump water over the reclaimed areas had been a little over half what would otherwise have been needed to irrigate these lands properly. This dire situation was compounded by the fact that land irrigations did not require consistent consumption levels over the entire duration of a year. As such, there was an absolute need for irrigation during the summer season, comprising the interval June–August. Yet, considering the 1988–1989 period, more than 27% of the country's energy production capacities at the time would have been needed to achieve the proper irrigation of the country's entire hectarage (Lup 1997).

(d) *"Water losses per allotment."* To enable the water distribution on irrigated lands there were reinforced concrete ditches being built. Yet, the joints of these ditches were not properly sealed which resulted in great losses of water. Even more water was wasted because of the poor quality of the aluminium pipes used for this purpose (Lup 2012).

(e) *"The penury of fertilizers."* Despite the fact that Romania's chemical fertilizer plants' capacity was 4.5 million tonnes of active substances annually, the highest production ever yielded occured in 1986, when 3278 thousands tonnes were produced. On average, for the period 1985–'89 some 15.092 thousands tonnes of fertilizers were claimed to have been produced, i.e. 3018.4 thousands tonnes annually, which would have provided 318 kgs of fertilizers per ha of arable land. In reality though, the Romanian agricultural sector only received 1140 thousand tonnes, which meant 120 kgs of fertilizers per ha of arable land, the rest of the production being exported. At the time, Western European countries were using for their crops around 300–400 kgs of chemical fertilizers (Lup 2014) per ha of arable land.
(f) *"A variety of shortages compounding a host of managerial and organisational deficiencies"*. The entire period during which Romania's agriculture had been organised according to socialist principles was plagued by a multitude of penuries, ranging from petrol and spare parts shortages, and the poor quality of the machineries working the fields. All of these shortcomings are compounded by frequent political interferences.

41.2.4 Irrigation Efficiency

When all these technological deficiencies are added up they are ultimately reflected in low yields and an overall poor economic performance particularly when considering Romania's freshwater resources.

The figures in the table below show that the inadequacy of the main production factors, which were compounded by managerial mistakes, brought about significant losses not just to the agricultural production cooperatives and the people working there, but to the Romanian state also (Table 41.4).

To add insult to injury, beyond the losses that these agricultural cooperatives were registering, they were being penalised twice after being denied their due supplementary income – which was made dependent on their meeting the planned

Table 41.4 Yield per hectare and efficiency of any cultures irrigated. Partial irrigated and country average in 1986–1988 periods

		Yield kg/ha		Value of prod lei/ha		Costs lei/ha		Profit/loss lei/ha	
Culture	Zone	State farms	Cooperatives	State farms	Cooperatives	State farms	Cooperatives	State farms	Cooperatives
Wheat	Zone I Total	3368	2880	6095	5843	4544	4906	1551	337
	Zone I Irrigated[a]	3509	3083	6364	5592	4723	5237	1641	355
	Country average	3229	2545	5848	4631	4347	4513	1501	118
Maize	Zone I Total	3518	3656	5109	5583	7233	6520	−2124	−937
	Zone I Irrigated[a]	3492	3816	5147	5827	7230	7005	−2083	−1178
	Country average	3126	3043	4450	4646	6155	5290	−1705	−644
Sunflower	Zone I Total	1608	1621	5625	5013	5121	4461	504	552
	Zone I Irrigated[a]	1570	1603	5538	4955	5178	4584	360	371
	Country average	1582	1530	5400	4731	4944	4250	456	481
Soybeans	Zone I Total	1035	764	3903	2491	5287	3894	−1384	−1403
	Zone I Irrigated[a]	1010	765	3774	2493	5350	3982	−1576	−1489
	Country average	997	761	3738	2480	4775	3748	−1037	−263
Sugar-Beet	Zone I Total	–	22,901	–	8683	–	10,399	–	−1716
	Zone I Irrigated[a]	–	23,909	–	9097	–	10,852	–	−1755
	Country average	–	22,869	–	8900	–	9346	–	−1046
Potatoes	Zone I Total	14,829	9717	16,286	9514	26,426	16,718	−10,140	−7204
	Zone I Irrigated[a]	15,024	10,167	16,815	9884	26,587	17,130	−9772	−7246
	Country average	22,140	14,587	26,710	13,109	28,174	16,745	−1464	−3636

Source: The Ministry of Agriculture’s Economic Department
[a]65% irrigated

Table 41.5 Freshwater costs and the state revenues from running the irrigation systems' network in the period 1971–1989

Period	Irrigated areas thousands ha	Costs thousands US$	Revenue thousands US$	Percentage of subsidizing (%)
1971–1975	4335.3	637.647	482.378	75.6
1976–1980	7097.8	1.258.676	749.212	59.5
1981–1985	9388.0	2.363.690	1.721.133	72.8
1986–1989	9424.3	2.309.521	1.548.765	67.1
Total	30,245.4	6.569.534	4.501.488	68.5

Source: The Ministry of Agriculture's Land Reclamation Department & the author's own calculations

yields: 6 tonnes/ha of wheat, 10 t/ha of maize, over 3 t/ha sunflower, 50–60 t/ha sugar beet or 30–40 t/ha potatoes.

As for the people working in these cooperatives, their already meagre wages were further undermined after their piece rates' accord was replaced with a so-called "global agreement", initiated at Ceausescu's behest, who had been angered by these agricultural units' failure to meet the planned yields' quotas. Consequently, the work carried out on allotments, such as seeding or weeding was not to be paid in full, but only in the percentage of the yields matching the planned quotas, rather than in the percentage of outputs per man-hour.

On the one hand, as the planned quotas per ha were being raised constantly, especially on those allotments that had been equipped for irrigation, the due wages for those working in these cooperatives were being slashed at an alarming rate. On the other hand, the state too was unable to receive any income that would've been generated by the sale of the crops despite the fact that it was selling these cooperatives water at heavily subsidised prices (Table 41.5).

The data presented in the Table above shows that, over the period between 1971–1989, by subsidizing the freshwater costs to the levels it did, the Romanian state had registered a loss of 2.068.046 thousands US$.

The authors were able to see yield increments on irrigated lands of just 80% of the projected levels and only for wheat and maize crops.

These increases, which were at the level at which they had been back in 1980, the year when Romania was plunged into a sovereign debt crisis, were valued at 2.5 billion US$. At that stage, Romania had an area of 2.2 million ha equipped for irrigation. Yet, putting all the necessary efforts of getting these two million hectares of land equipped with proper irrigation systems on hold was well-nigh suicidal as this would have easily allowed Romania to pay all of its sovereign debt without inflicting such penuries that impoverished its people to the point of near-starvation (Cioroianu).

Political interference was unduly exerted to enable the reclamation programme to continue unabated. Consequently, up to 3100 ha of land were newly reclaimed for agricultural purposes. Yet, this only aggravated the country's indebtedness levels to such a degree that primary agricultural products had to be exported to extinguish some of this debt while the population was starving, had no electricity and was freezing during the bitterly cold winters.

To round up the first part of this article, we can conclude that during the communist dictatorship, Romania's land and freshwater reources had been poorly used and did not play their part in raising the population's welfare and living standards.

At present, it is thought that in the medium-term, i.e. over the next 5–6 years, between 1 and 1.5 million ha of land will be reclaimed for irrigation purposes with the help of EU loans and the new landowners' direct contributions – people for whom agriculture represents a most profitable venture.

41.3 Freshwater Resources and the Black Sea in Romania's Food Economy

41.3.1 A Bit of a History Lesson

Fishing and agriculture have always had long-standing traditions in Romania – a country whose population is steeped in orthodox religious customs that see Christmas and Easter fasting being observed rather rigorously. Elderly women in rural areas – which still account to almost half the country's population – go even further than that by fasting every Tuesday and Friday of every week. Medieval chronicles attest the existence of thousands of ponds and stew ponds around the meandering inner rivers that led to the flooding of plains and were systematically broken up for this reason (Lup 2006).

At present, Romania's hydrographical network is 844 thousands ha wide, which is 3.5% of the country's overall surface. Fishing, aquaculture and the commercialisation of fishery products occurs nation-wide though it would be true to say that such activities occur on an unjustifiably small scale, even in typical areas, such as the Danube meadows and Delta, or the Black Sea's Exclusive Economic Zone. A recent study of Romania's National Agency of Fisheries and Aquaculture catalogues something of a national fishing patrimony viewed from an anglers' perspective (Rudescu et al. 1965).

1075 km surfaces permanently or temporarily covered by water, 500 thousand ha, ...] running water, 300 thousand ha natural lakes and marshes, 98 thousand ha barrier lakes and polders, 940 aquaculture farms with a capacity of 9200 (plan), 160 salmon farms with an overall surface of 83 ha. the structuring on family species freshwater (carp) of indigenous and Asian origin 85% with the rest of 15% being Wels catfish, freshwater sturgeon (National Agency for Fishery and Aquaculture 2016).

41.3.2 Romania's Fish Stocks' Long-Term Evolution

Despite this wealth – both quantitative as well as in terms of the variety of species, that help diversify one's dietary needs, create environment values, generate and

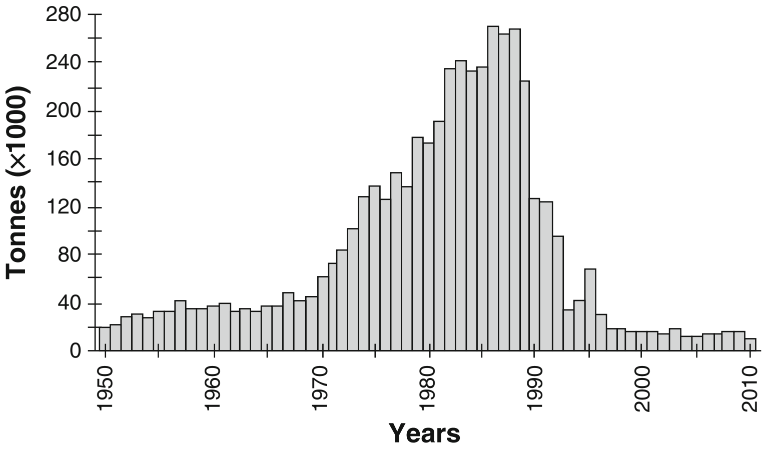


Fig. 41.8 Reported fishing & aquaculture production in Romania (FAO Fishery Statistic)

maintain wetlands, fauna and ichthyologic biodiversity, the fishing industry has a minute contribution to the country's GDP, 0.007–0.009%. Over the long-term though, commercial fishing productions had been in ascendance all the way up to 1988, when a 91,990 tonnes catch – made up of mostly offshore (ocean) fish species – was registered.

Starting in the 1960s, an impressive fleet of trawlers had been built for this purpose yet it collapsed after corrupt politicians had sold Romania's commercial fishing fleet in its entirety, following the Regime-change in December 1989, for next to nothing prices. As a result of this, Romania's commercial fishing output went downhill in the 1990s to the totally insignificant quantities that are seen today (see Fig. 41.8).

Whereas the production obtained over the period between 1985 and 1990 ensured a national yearly consumption level of 8 kg per capita, this fell to just 2.3 kg per capita over the following decade, 1990–2000. Over this same period, the average consumption levels of fish and sea food in the EU is 24–26 kg per capita. Over the period 2008–2012, a slight increase in the domestic consumption of fish products and seafood has occurred yet this is quite a long way away from the levels being registered in the EU.

It would be fair to point out the fact that most of these EU nations are surrounded by seas and oceans and have lengthy maritime borders while some are downright insular. That said, it is surprising to notice that although Romania's fishing and aquaculture production is one of the largest there is – at least in its inland waterways – its fishery production comes not so much from commercial fishing but from its aquaculture (Table 41.6).

In the Black Sea, several species of fish make up the catch in commercial fishing activities, such as: turbot, gobies, Black Sea shad, European sprat, European anchovy, mullet, piked dogfish (a species of shark), Mediterranean horse mackerel, mussels and others.

Table 41.6 The inland fisheries' production as regards import & consumption per capita in the period 2008–2011

Item	UM	2008	2009	2010	2011
Fish farms	thou. tonnes	12.53	13.13	8.98	8.34
Fisheries	th. t	3.75	4.02	2.69	3.25
TOTAL	th. t	16.28	17.15	11.67	11.59
Fisheries	%	29.9	30.6	30.0	39.0
Import	th. t	88.62	78.08	72.11	36.92
Consumption	Kg/capita/year	5.23	4.57	4.08	3.14

Source: The National Agency for Fisheries and Aquaculture (18)

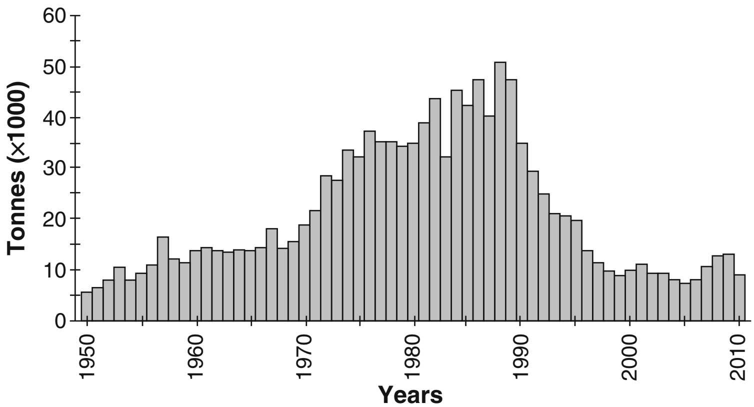


Fig. 41.9 Reported aquaculture production in Romania (from 1950) (Source: http://www.fao.org/fishery/countrysector/naso_romania/en)

41.3.3 Aquaculture

According to the data provided by Romania's Ministry of Agriculture and Rural Development, in 2005, aquaculture facilities occupied an area of over 100.000 ha. The Fig. 41.9 above captures the long-term evolution of the aquaculture production in Romania (Hâncu 2009).

41.3.4 The Case of the Danube Delta

41.3.4.1 Description and Economic Importance

This area's importance hardly needs additional emphasis given the extremely valuable species that live there, such as the sturgeon, for example.

As a physical geography unit, the Danube Delta is the catchment area of the three arms through which the river flows into the Black Sea: Chilia, Sulina and St. George (Sf. Gheorghe). This area of over 430.000 ha makes it one of the largest deltas in the world – more precisely, the world's 22nd and Europe's second largest. Considering the adjacent lagoon complex, "Razim–Sinoe", it is also one of the largest wetlands.

As an ecological resource, the Danube Delta is important both in terms of its length and breadth – stretching for more than half of the Tulcea County (51%) and almost a third of the entire Dobrogea region (27.9%) – as well as in terms of the richness and the sheer variety and specificity of its resources. The Danube Delta Reed Monograph details the manner in which the Delta's wetlands had been used in the 60s: pisciculture (fish farming) – 323.100 ha, reed crops and pisciculture – 213.900 ha, agriculture – 62.300 ha, forestry – 18.800 ha, land within built-up areas, dam-banks and coastal belt (Staraș and Năvodaru 1995).

Due to the richness and the biodiversity of its specific flora and fauna, forming the best preserved European Deltas, in 1990 the Danube Delta was been acknowledged globally, and listed as "The Danube Delta Biosphere Reservation". Over 5000 ha of forests have thus been declared "world heritage sites".

The Danube Delta's fauna comprises of seventy-five species of fish (including sturgeon), 280 species of birds – some of which were also listed as World Heritage sites – mammals – from wild boars to ermines and reptiles.

41.3.4.2 The Commercial Production of Fish in the Danube Delta

Following a period of growth, the commercial production of fish has started decreasing again. From a yield of around 8000 tonnes in 1973, to a mere 1300 tonnes in 1993 (Fig. 41.10).

The graph above shows the downward spiral in the main species' structure. The largest share here is made up of less valuable species, such as the crucian carp – whose overall share appears to undergo an upward trend – while other species of fish, such as the bream or the roach are shrinking. Meanwhile, more valuable species, such as the pike, the perch or the tench have disappeared almost entirely. As far as the sturgeon is concerned, this species is no longer listed. An assessment of the sturgeon catch in the Romanian Danube Delta and river, made by researchers from the Delta Research Institute, show a steady decrease from approximately 250 t per year, during 1951–1955, to around 50 t, during 1981–1985, to only 20 t per year after 1990 (Lup et al. 2016) (Fig. 41.11).

The dramatic reduction in the sturgeon catch owes greatly to the embankment works on the Danube river, and the draining of some 418.000 ha of wetlands, where the sturgeon had been depositing its eggs (Hâncu et al. 2009).

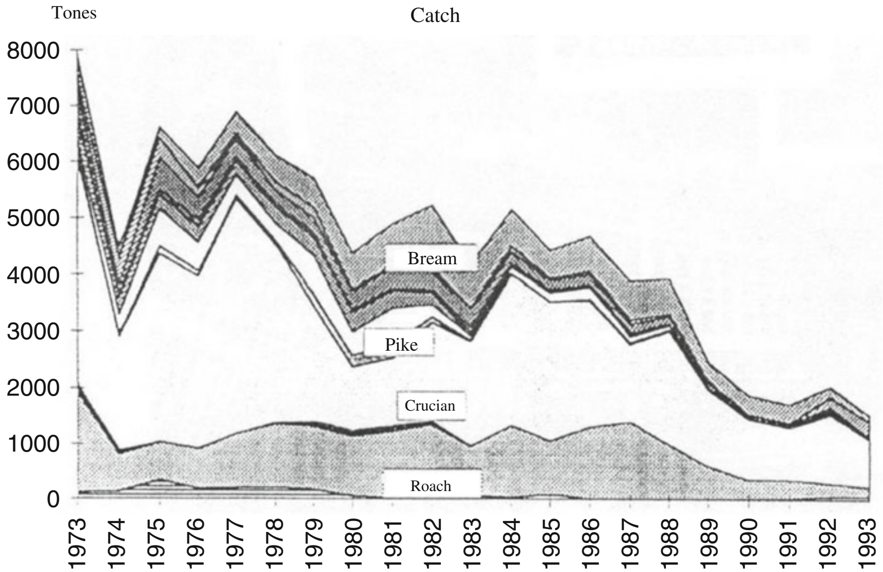
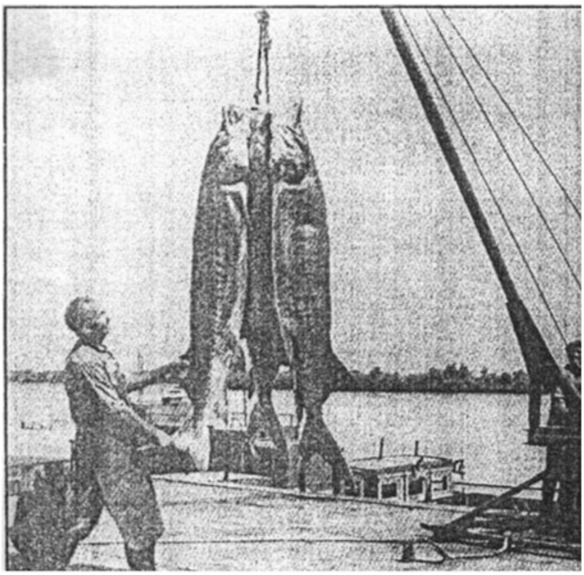


Fig. 41.10 The evolution of fish yields per total number of species, in the Danube Delta, during the period 1973–1993 (Source: The Danube Delta Research Institute)

Fig. 41.11 Sturgeon capture in Danube Delta in 50'–60′ years, 20′ century (Source: Danube Delta Research Inst.)



41.3.5 Marine Fishing

Romania's national fishery sector in the Black Sea extends between the city of Sulina (in the North) and Vama Veche (to the South) at a length of 243 km. The distance between the sea shore and the continental platform boundary (at depths of 200 m) varies between 100 and 200 km in the Northern sector to 50 km in the Southern one. The Delta's waters bordering the Black Sea to the north, on a fathom line of 20 (twenty) metres, are included in "The Danube Delta Biosphere Reserve", as these are both traditional areas where trans-border sturgeons are laying their eggs as well as passage ways for the Danube mackerel. In the long-term, Black Sea catches go up until 1987 only to be reduced to insignificant levels over the past years.

Over the years for which data on the catches of Black Sea fish exist, the situation was the following:

2008	443.9 tonnes
2009	331.8 tonnes
2010	230.9 tonnes
2011	537.2 tonnes
2012	690.0 tonnes (estimate)

Source: the National Agency for Fisheries and Aquaculture

According to the National Agency for Fisheries and Aquaculture data, the predominant species currently harvested are smaller-sized ones, such as: the European sprat, the European anchovy and the saurel fish.

As such, the Black Sea fishing industry's mainstay is the European sprat, being commercialised in the "salty sprat" variety. Other species that are to be found in these fish catches are the golden grey mullet, the piked dogfish, the turbot flatfish and the Pinchuk's goby.

The National Institute for Marine Research and Development "Grigore Antipa", analyses the Black Sea's species of fish – in terms of their density, fishing techniques, nutrients and their health state. As such, researchers there are pointing to the fact that, whereas 50 years ago, the turbot (*Scophthalmus maximus*) was one of the cheapest available species of marine fish, nowadays this fish is quite a treat for it is one of the most expensive dishes around. The dwindling turbot stocks are the result of fishing on an industrial scale. Thus, from harvests in excess of 10.000 tonnes annually, in the decade 1980–'89, by the year 2000, this was down to some 2000 tonnes per year and a paltry 258 tonnes in 2010 (Fig. 41.12).

41.3.6 Research in the Field of Aquatic Resources

Out of the many research institutes dedicated to the Romanian fishing industry, we will mention the existence of three institutes specialised in inland waterways: The

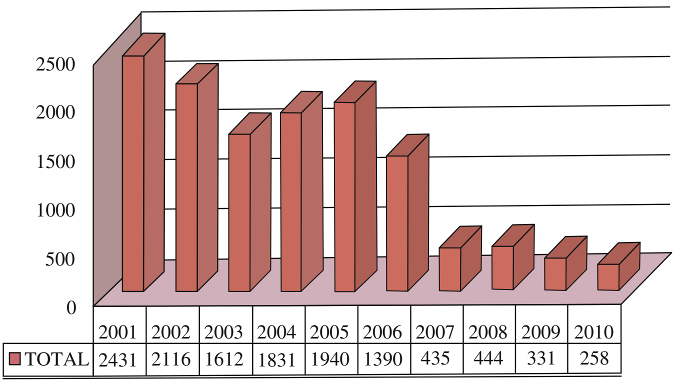


Fig. 41.12 The total catch (in tonnes) in the Romanian sector in the period 2001–2010 (Source: Maximov V., (2012) "Sustainable management of turbot at Romanian Seaside" Ed. Boldas, Constanța, România)

Institute of Research and Development for Aquatic Ecology, Fishing and Aquaculture, from the city of Galați, the Danube Delta National Institute for Research and Development, from the city of Tulcea, and the Fishery Research Station Nucet, in the Dâmbovița county. Added to these, there is a National Institute for Marine Research & Development "Grigore Antipa", from Constanța and a National Institute for Research and Development in Forestry, in Bucharest, which, apart from forestry, researches salmonids i.e. a family of ray-finned fish, including salmon, trout and other freshwater whitefishes.

These institutes avail themselves of specialists, research and micro-production stations yet, the scientific research being carried out here suffers as a result of prolonged underfunding – from both the public as well as the private sector – and inadequate technological transfers. The latter of these negative aspects is the result of a palpable lack of a sense of direction in adapting such research endeavours towards the demands of the market. Moreover, there is a chronic lack of an adequate infrastructure to allow the research results to be turned into applicable innovations.

As regards the technological transfers from research institutes towards commercial production units, there seem to be significant differences between freshwater and marine water research. Whereas the first of the two types of research trickles down with varying degrees of commercial success towards dedicated production units, the latter sees no such transfers whatsoever, with the sole exception of a rather timid upturn in the commercial farming of sturgeon. And all of this occurs despite there being plenty of positive micro-production results on species such as oysters and shrimps, for example.

A far from comprehensive list of publications includes fourteen books and more than two hundred peer-review papers being released by the Marine Research Institute. Yet, fishery products, the sought-after seafood delicatessen are still being imported into Romania.(Bologa 2000; Bologa and Charlier 2011; www.rmri.com).

In a SWOT analysis of the Romanian fishery sector, while its "Strengths" lie with the country's undeniable abundance of fish, the "Threats" that appear to be lurking in the Danube's muddy waters point to the rather unfair competition that Romania is facing on the international markets. Thus, out of the four kilos of fishery products being consumed by every Romanian person in 2016, only 0.56 kg were produced locally, with the rest of the 3.44 kg being imported (National Agency for Fishery and Aquaculture 2016).

41.4 Conclusions

1. After all the national assets – land, natural resources, domestic and foreign trade enterprises etc. i.e. the entire economy – were nationalised without any reparations to their previous owners, the totalitarian state grew extremely wealthy.
2. The country's economic resources that had become state property allowed for nationwide investments to be made in the country's heavy industry, in particular and also in the agricultural sector.
3. There were insufficient raw materials allocated for the gigantic investment projects being envisaged by the country's leaders; moreover, the management was poor hence the overall inefficiency that plagued the country as a whole. In spite of this, Romania registered economic growth up until the mid 1980s after which the country went into decline and bankruptcy ensued. Given the worsening economic climate it is remarkable to note that Romania's debt to international foreign creditors was extinguished at an inhumanely high cost inflicted on its population which suffered extreme austerity and famine.
4. The so-called 'successes' registered in the country's agriculture and aquaculture had extremely high costs attached to them all of which was done in the context of chronic inefficiency.
5. After 1990, during the country's transition to a market economy, all of the totalitarian state's accumulated wealth was transferred to the private sector while the rest of its assets were wasted as a result of poor management.
6. This led to the paradoxical situation in which the overwhelming majority of the population of a country with plentiful mineral, natural and water resources is currently living on the brink of indigence without any hope of a better future.

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ACADEMIA ROMÂNĂ

Bucureşti, 20 iulie 2016

Domnule dr. Alexandru Bologa,

Sunt bucuros să remarc progresele considerabile înregistrate în domeniul ştiinţelor mării şi al cercetării marine româneşti în ultimele decenii. Ele s-au făcut remarcate prin participarea la numeroase programe şi proiecte de profil în context naţional, european şi extracomunitar. Precum şi prin recunoaştere în publicaţii ştiinţifice de prestigiu.

Îmi reamintesc totodată, în particular, cu plăcere şi activitatea fructuoasă pe care aţi desfaşurat-o în cadrul Institutului Oceanic Internaţional (Malta), ca director al Centru-lui Operaţional Marea Neagră între 1996–2004, după ce v-am recomandat fondatoarei devotate şi inimoase a acestei reţele de instituţii dedicate cunoaşterii şi guvernării cât mai înţelepte şi armoniase a mărilor şi oceanelor care a fost Elisabeth Mann Borgese; graţie şi susţinerii Dvs. a devenit *membru honoris causa* a Universităţii „Ovidius" din Constanţa (2000). Sper ca această activitate să continue.

Cu ocazia apropiatei sărbătoriri a vârstei de 70 de ani vă doresc sănătate şi continuarea cât mai îndelungată a activităţilor ştiinţifice şi conexe proprii.

Academician Mircea Maliţa

C.W. Finkl, C. Makowski (eds.), *Diversity in Coastal Marine Sciences*, Coastal Research Library 23, DOI 10.1007/978-3-319-57577-3

ACADEMIA ROMÂNĂ
Comitetul Român de Istoria
şi Filosofia Stiinţei si Tehnicii

Domnului
Dr. Alexandru S. BOLOGA
- preşedinte al Filialei CRIFST – Constanţa

Cu ocazia implinirii a 70 de ani, Biroul Executiv al Comiteului Român de Istoria şi Filosofia Ştiinţei şi Tehnicii (CRIFST) al Academiei Române adresează calde şi sincere urări de sănătate, fericire şi noi împliniri Domnului Dr. Alexandru S. Bologa – membru titular al Academiei Oamenilor de Ştiinţă din România, un foarte activ membru al CRIFST, fondator şi preşedinte al Filialei CRIFST – Constanţa.

Întreaga activitate ştiinţifică a acestei structuri importante a CRIFST a fost marcată de amprenta valoroaselor implicări ale Dr. Alexandru S. Bologa, în calitatea Domniei Sale de Director ştiintific timp de peste două decenii, al Institutului National de Cercetare-Dezvoltare Marină „Grigore Antipa" din Constanţa, ca delegat naţional pe langă Comisia Internaţională pentru Explorarea Ştiinţifică a Mării Mediterane (CIESMM) între anii 1994 – 2011 sau ca director al Centrului Operaţional Marea Neagră - Black Sea Operational Centre al Institutului Oceanic Internaţional (International Ocean Institute) din Malta în perioada 1996 -2004.

Fie ca sărbătorirea celor 70 de ani de la naştere să ducă spre o îndelungată continuare a implicarilor Domnului Dr. Alexandru S. Bologa în programele Comitetului Român de Istoria şi Filosofia Ştiinţei şi Tehnicii al Academiei Române, spre noi realizari ştiinţifice întru MULŢI şi BUNI ANI!

În numele Biroului Executiv al CRIFST,

PRIM-VICEPREŞEDINTE AL CRIFST
Dr.
DUMITRU MURARIU
membru corespondent al Academiei Române

Academia Oamenilor de Ştiinţă din România

Academy of Romanian Scientists

Add: Splaiul Independenţei nr. 54 sector 5, 050094, Bucureşti, ROMANIA, Cod Fiscal: 5091859
Tel. 00-4021/314.74.91; Fax. 00-4021/314.75.39, Web-site: www.aosr.ro, E-mail: aosromania@yahoo.com

Mesaj de felicitare

La această frumoasă sărbătorire a 70 de ani de viaţă dedicată cercetării ştiinţifice, cu rezultate remarcabile, Prezidiul Academiei Oamenilor de Ştiinţă din România vă urează domnule profesor dr. Alexandru Bologa, viaţă lungă, cu sănătate, bucurii şi împliniri.

Sperăm ca şi în anii care vor veni să fiţi la fel de ataşat idealurilor Academiei noastre şi să continuaţi să contribuiţi la creşterea prestigiului său.

La mulţi ani!

Prof. dr. ing. Adrian BADEA,
Preşedinte al Academiei Oamenilor de Ştiinţă din România

Bucureşti, 21 decembrie, 2016

Cluj-Napoca, 7 iulie 2016

Gânduri festive şi felicitări la o aniversare

În cariera de „didact”, de orice rang ai fi fost, suprema satisfacţie pe care o poţi avea este devenirea în viaţă a foştilor discipoli; realizările lor sunt, în parte, rodul înzidirii în personalitatea lor, în prelungirea competenţelor date de educaţia din familie, a zestrei culturale specifice unui anume segment cultural pentru care fiecare a optat şi cu contri-buţia, oricât de modestă, a foştilor lor dascăli.

Eu mă aflu în această postură binecuvântată: să-l fi avut discipol, ca student, pe *Alexandru Şerban Bologa*, unul din studenţii mei eminenţi care nu s-a oprit la treapta de diplomat universitar specializat ca biolog-algolog, ci, cu tot elanul şi o deosebită apetenţă pentru ştiinţă şi cercetare a devenit un om de ştiinţă împătimit cu o documentare aproape exhaustivă atât ca bibliografie cât şi privind cercetarea de teren navigând în apele terito-riale româneşti ale Mării Negre, dar şi pe întinsul apelor din oceanele lumii. Cercetările sale şi rezultatele ştiinţifice în algologie l-au făcut cunoscut şi apreciat în ştiinţa romă-nească şi în arealul ştiinţific românesc, precum şi internaţional. A publicat masiv şi este consultat ca voce autorizată în societatea academică românească şi din lume (ceea ce, de bunăseamă, va atesta şi fişa personală bio-bibliografică).

La ceas aniversar, este o onoare pentru mine, ca singurul său cadru didactic uni-versitar încă în viaţă, să-l omagiez şi să-i urez cu deplină amiciţie „La mulţi ani!” – toţi prosperi şi aducători de fericire !

Conf.univ.dr. Ana P. Fabian

Paris, le 15 août 2016

Cher cousin,

A l'occasion de ton 70ème aniversaire, une date de bilan dans la vie de chacun, je te prie de recevoir mes voeux les plus sincères de santé, de poursuite de ton remarquable activité scientifique et de ta présence et implication dans la vie de la cité, de bonheur auprès de ta famille en ton rôle de grand-père.

Issu d'une vieille famille de Transylvanie qui à partir du XIXème siècle s'est affirmée dans la vie politique, culturelle et scientifique roumaine tu as été un digne continuateur de son engagement, de sa tradition.

Né à Brasov, fils du médecin réputé Emil I. Bologa, Docteur en biologie marine de l'Université de Bucarest, ta carrière s'est déroulée à Constanta où tu as été pandant de longues années le Directeur scientifique de l'INCDM (Institut national de recherches et développement marin) „Grigore Antipa". Co-auteur du „*Traité d'algologie*" (4 volumes, parus entre 1976–1979), délégué national auprès du CIESM (Commission Internationale pour l'Exploration Scientifique de la Méditerranée) – Monaco, directeur du Centre Opérationnel Mer Noire de l'Institut Océanique International – Malte, membre titulaire de l'AOSR (l'Académie des hommes de sciences de Roumanie), tu as participé à plusieurs expéditions de recherches dans la Mer Noire, en Mer Méditerranée et l'Océan Atlantique. Tu as été également fondateur de la filiale Constanta du CRIFST (Comité roumain pour l'histoire et philosophie des sciences et des techniques de l'Academie Roumaine), participant à de nombreux congrès de l'UIHPS (l'Union Internationale d'Histoire et Philosophie des Sciences) et de l'Histoire de l'océanographie, partout dans le monde: d'Europe en Australie, des Etats-Unis et Mexique en Chine.

Mais tu n'as pas été un scientifique cloisonné dans sa tour d'ivoire, tu t'es impliqué également dans la vie de la cité; tu as ainsi été membre de la délégation de Roumanie qui a participé aux négociations Roumanie-Ucraine concernant la voie navigable Bystroe dans le Delta du Danube, tu as délivré une conférence à l'association française La Maison Roumaine sur la situation des biologistes dans la Roumanie sous le régime communiste, affirmé tes positions concernant l'identité roumaine et la situation politique en Roumanie et Bessarabie.

Je suis persuadé que ton dynamisme et ton énergie, tes compétences et ton savoir, ton sens civique et ton amour pour tes racines vont, pendants de longues années, alimenter tes recherches et ton engagement en faveur de la Roumanie.

Alexandru Herlea
Professeur émérite des universités – UTBM – France
Membre titulaire de l'AIHS (Académie Internationale d'Histoire des Sciences)
Ancien Ministre de l'Intégration Européenne du Gouvernement de la Roumanie

"In honorem" profesor dr. Alexandru Bologa

Nicolae Dură
Universitatea Ovidius Constanţa

Când ajungem la un popas aniversar, ne vin desigur în minte şi cuvintele Cronicarului, care ne aminteşte că „vremea vine", „vremea trece", şi ne „vremueşte". Această „vreme" a venit şi pentru distinsul nostru coleg, Alexandru Bologa, profesor universitar asociat de vocaţie şi cercetător ştiinţific de excepţie, care a împlinit frumoasa vârstă de şaptezeci de ani. Or, în mod inevitabil la acest popas aniversar, este şi vremea bilanţului împlinirilor sale atât pe tărâmul didactic şi cărturăresc, cât şi în domeniul cercetării ştiinţifice.

În virtutea colegialităţii noastre, universitare şi academice, şi a amiciţiei noastre, sunt fericit să depun o sinceră mărturie – fie ea şi destul de succintă, datorată spaţiului disponibil, – privind aceste împliniri fericite ale Domniei sale.

Ca om, Alexandru Bologa, se distinge printr-o nobleţe sufletească ce-i trădează descendenţa sa dintr-o aleasă familie de români intelectuali, născuţi şi crescuţi în spaţiul mioritic al omeniei şi al respectului faţă de marile valori ale omenirii, între care a excelat întotdeauna dragostea faţă de semenii noştri, indiferent de etnia sau crezul lor religios.

Ca profesor, s-a impus în lumea universitară atât prin erudiţia sa – în domeniul care l-a consacrat, adică Biologia marină, – cât şi prin calităţile sale de pedagog, care l-au ajutat să dăruiască cu tact şi prisosinţă, tinerilor doritori să-şi construiască şi ei statura intelectualului desăvârşit, suma acelor cunoştinţe care te fac să-ţi depăşeşti „Magistrul".

În calitate de cercetător ştiinţific – cu o bogată recunoaştere naţională şi internaţională – dr. Bologa s-a distins atât prin lucrările sale de referinţă, care l-au impus de altfel în literatura de specialitate, cât şi prin activitatea sa profesională.

Ca traducător, Domnia sa a oferit cititorului român lucrări de referinţă din spaţiul de expresie germană, pe care le-a glosat şi comentat cu competenţa unui traducător avizat, dublat de talentul scriitorului.

La acest fericit popas aniversar – din viaţa Domniei sale – nu ne rămâne deci decât să-l încredinţăm pe distinsul nostru coleg şi prieten de dragostea noastră frăţească, care să-i potenţeze pe mai departe râvna cunoaşterii, astfel încât să poată lăsa drept mărturie generaţiilor care vin şi alte lucrări ştiinţifice de înaltă ţinută academică, şi să-i urmăm: „Ad Multos Annos!"

Constanţa, 18 ianuarie 2017

Constanţa, 10 august 2016

La mulţi ani, Domnule coleg,

Dragă Sandule (îmi permit ca decan de vârstă), am avut bucuria să te cunosc printr-o întâmplare fericită (pentru care îi mulţumesc colegului meu de liceu, Marian Traian Gomoiu). Pentru „terţi" pot spune că am cunoscut un Om deosebit, pe care l-am perceput ca pe o rudă apropiată; ardelean ca şi mine; el braşovean (după tată), eu (semi)sibian (după mamă); el fost elev la Johannes Honterus (Andrei Şaguna) din Braşov (Kronstadt), eu la gimnaziul liceului Samuel von Bruckenthal din Sibiu (Hermannstadt); el doctor în biologie, eu în teoria elasticităţii; amândoi veseli, optimişti şi cu încredere în viaţă; el membru titular al Academiei Oamenilor de Ştiinţă din România, eu aşişderea, dar al Academiei de Ştiinţe Tehnice, tot din România; ambii membri titulari ai Comitetu-lui Român de Istoria şi Filosofia Ştiinţei şi Tehnicii (C.R.I.F.S.T.) al Academiei Române.

În ce privesc deosebirile, rezultă „prin definiţie". Fiecare specialist (din fericire) în „altceva", deci fără concurenţă, dispute sau contraziceri profesionale; să ne ţină Domnul tot aşa, sănătoşi, veseli, optimişti.

Nu-mi cereţi să-i fac o caracterizare profesională de specialitate, pentru că nu mă pricep; iau de bun ce spun „ceilalţi". Ştiu că scrie şi publică („în libertate"), că tra-duce (cărţi şi alte texte), că merge (ca la 30 de ani), e activ, călătoreşte şi e la curent cu noutăţile şi cu ce mai fac şi alţii, drept pentru care semnez,

Prof.univ.dr.ing. Garabet Kümbetlian
(în traducere: Înaintemergătorul, fiul celui Deladeal)

A tribute by Dr. Awni Behnam, Honorary President of IOI

Alexandru S. Bologa
former Scientific Director of the
National Institute for Marine Research and Development
"Grigore Antipa" Constanta/Romania

Very few scientists, philosophers and environmentalists have left such an indelible mark on human consciences when it comes to ocean and sea as has Professor Dr Alexandru S. Bologa.

It is not the many prestigious positions of responsibility at national and international level he assumed throughout his illustrious career that defines the man, nor the many high achievements and accolades he has received but much more noteworthy is that he was a close and trusted friend, confidant and collaborator of the founder of the International Ocean Institute (IOI) the exceptional Elisabeth Mann Borgese.

He accompanied Elisabeth in her three stages of intellectual struggle; in formulating the UN Convention on the Law of the Sea (UNCLOS), in the ratification process and in its implementation.

He led IOI centre based in Romania in the discipline and principles of his soul mate Elisabeth. Paying tribute to the achievements of Alexandru is to recognise the important legacy of that exceptional woman and that exceptional partnership.

Today the extended IOI family, and the ocean community owe a great debt of gratitude to the contribution of Alexandru Bologa for the wealth of knowledge in science and policy formulation through his struggle for intergenerational protection of oceans biodiversity. Both Elisabeth and Alexandru understood the pain of striving for perfection and having to settle for the next best solution, IOI will forever be his home away from home.

La Valetta, Malta
September 13, 2016

Alexandru Bologa als wissenschaftlichen Direktor des Rumänischen Institutes für Meeresforschung in Constanţa habe ich kennen gelernt dank unserer gemeinsamen Beschäftigung mit der Geschichte der Meereswissenschaften und der gegenseitigen Freude daran.

Das erste Mal sind wir uns 1993 auf dem 5. Internationalen Kongress zur Geschichte der Meeresforschung in La Jolla, California/USA begegnet. Seitdem haben wir uns auf allen nachfolgenden Konferenzen zu diesem Thema in Qingdao/China (1998), Kalinin-grad/Russische Foederation (2003) und in Napoli/ Italien (2008) wieder getroffen.

Als Vorsitzender der International Commission on the History of Oceanography habe ich ihn als einen der aktivsten Historiker im Bereich des Schwarzmeergebietes besonders geschaetzt. Unsere Begegnungen waren immer anregend und aufschlussreich. Auch an Humor hat es niemals gefehlt.

Unser letztes Treffen hätte in diesem Jahr auf der von mir geplanten IX. Konferenz in Adelaide (Australien) stattgefunden – erstmalig auf der südlichen Halbkugel! Leider mußte die Konferenz abgesagt werden wegen zu wenig Vortrags-Anmeldungen.

Offensichtlich waren die australischen Meeresforschungs-Institute beziehungsweise ihre Wissenschaftler nicht daran interessiert, ihre Forschungsaktivitäten international bekannt zu machen.

Im Gedächtnis unserer freundschaftlichen Bekanntschaft füge ich die vollständige Liste der erwähnten wissenschaftlichen Tagungen bei – zur Würdigung Deiner Beiträge.

Weiterhin Gesundheit, Lebensfreude, Humor, Streitlust sowie anhaltendes Interesse an der Geschichte der Meeresforschung.

Walter Lenz (inzwischen schon 79)
President of the International Commission of the History of Oceanography
2012–2016

Hamburg,
den 5. Oktober 2016

Romanian Participation at the International Congresses on the History of Oceanography

1. Monaco, 1966

Mihai Bacescu
(no contribution listed)

2. Edinburgh/Scottland 1972

no

3. Woods Hole/Massachusetts/USA 1980

no

4. Hamburg/Germany 1987

G. Serpoianu: „The History of Research on Physical Oceanography in Romania“.
Marinescu: „The First Romanian Scientific Exploration of the Black Sea Waters (1893)“.

5. La Jolla, California/USA 1993

G. Serpoinau & V. Malciu: „The Pionneers of Oceanographic Reseach in Romania“.
A.S. Bologa & A. Marinescu: „Romanian Developmental Contributions of Emil Racovitza and Grigore Antipa to the Scientific Exploration of the Mediterranean“.

6. Qingdao/China 1998
'Ocean Sciences Bridging the Millennia'

A.S. Bologa: „Development of Marine Biological Institutions around the Black Sea“.

7. Kaliningrad/UdSSR 2003
'History of Oceanography'

A.S. Bologa: „International Collaboration in the Research of the Black Sea“.

8. Neaples/Italy 2008

'Places, People, Tools: Oceanography in the Mediterranean and beyond'

A.S. Bologa, A.F. Bologa & R.H. Charlier:
„Ioan Borcea and the first Romanian marine zoological station at Agigea (1926)”.

Rimsting, Deutschland,
den 15. September 2016

Verehrter Herr Dr. Bologa,

zu dieser wissenschaftlichen Festschrift, welche Ihre großen Verdienste um die Meeresforschung würdigt, kann ich leider nichts beitragen.

Dennoch möchte ich Ihnen als dem Übersetzer meiner Bücher ins Rumänische von Herzen zu Ihrem Jubiläum gratulieren.

Sie sind nicht nur Meeresforscher, sondern ein hervorragender Kenner der deutschen Sprache. Sie haben mich mit Ihrem Feingefühl für die Subtilitäten des Deutschen immer wieder überrascht und erfreut, als wir im November 2014 zusammen mit Prof. Lupu, dem Direktor des Sapientia Verlages, eine Vortragsreise durch ganz Rumänien zur Präsenta-tion meiner Bücher unternahmen. Die globale sexuelle Revolution – Zerstörung der Freiheit im Namen der Freiheit trifft auch Rumänien. Mit Bewunderung höre ich, dass Millionen Rumänen sich gegen die Legalisierung der „gleichgeschlechtlichen Ehe" wehren, weil sie erkannt haben, dass es dabei nicht um die Rechte kleinster Minderheiten geht, sondern um die Zerstörung der Familie und der Werte, die die Familie tragen. Durch Ihre Übersetzungsarbeit haben Sie zu diesem Bewußtwerden beigetragen. Dafür gebührt Ihnen großer Dank.

Gabriele Kuby

Personalie

Gabriele Kuby hat Soziologie studiert. Als Buchautorin und internationale Vortragsred-nerin warnt sie unermüdlich vor der Zerstörung der Familie durch die Gender-Ideologie und die zunehmende Aushöhlung demokratischer Grundrechte. Ihr Hauptwerk *Die glo-bale sexuelle Revolution – Zerstörung der Freiheit im Namen der Freiheit* wurde bisher in sieben Sprachen übersetzt. www.gabriele-kuby.de

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