Tim R. New

Butterfly Conservation in South-Eastern Australia: Progress and Prospects

Springer

Butterfly Conservation in South-Eastern Australia: Progress and Prospects

Tim R. New

Butterfly Conservation in South-Eastern Australia: Progress and Prospects

Springer

Tim R. New
Department of Zoology
La Trobe University
3086 Victoria
Australia
T.New@latrobe.edu.au

ISBN 978-90-481-9925-9 e-ISBN 978-90-481-9926-6
DOI 10.1007/978-90-481-9926-6
Springer Dordrecht Heidelberg London New York

Library of Congress Control Number: 2010938449

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Australia's butterfly fauna is now reasonably well known, and most of the species can be recognised and named by non-specialists with the aid of the comprehensive text and later field guide by Braby (2000, 2004). Numerous localised subspecies have also been named and, although the acceptance and status of many of these is still open to debate, they clearly demonstrate the considerable additional variety present over the mosaic of the country's environments. Robust biological and distributional frameworks have been constructed for many taxa, even though many of the more intricate details have not been documented. Their very low abundance and narrow distributions, indeed, render some taxa formidably difficult to study. Interest in butterfly conservation has also increased markedly in recent years, and the butterflies are the only group of invertebrates in Australia so far accorded a National Action Plan to help define and focus their conservation needs (Sands and New 2002). Much of the historical and evolutionary background to Australia's butterfly fauna was summarised by authors in Kitching et al. (1999).

In this account, I deal with some aspects of the conservation of a restricted southern subset of Australia's butterflies, essentially those found in, and many of them endemic to, the East Bassian Province. In general, these butterflies have received far more attention than those elsewhere in the country. The region supports much of Australia's human population, and is that most intensively surveyed for Lepidoptera. It comprises Victoria and immediately adjacent parts of the south east corner of the Australian mainland (namely southern South Australia, the Australian Capital Territory, and most of New South Wales) as well as Tasmania, and the intervening islands of Bass Strait.

It is also the predominant region in which practical butterfly conservation in Australia has largely been founded, mainly during the last three decades. I bring together information accrued over this period on the conservation status, needs and management of several species and subspecies of conservation significance. These cases have helped to initiate, drive and develop interest and policy affecting insect conservation in the region. The wider values of this synthesis include demonstrating the development of some of the first insect species conservation programmes in southern Australia, assessing the needs for these, and how those needs were acknowledged and addressed. They revealed the massive contrasts between Australian knowledge and capability for butterfly conservation and that which may be 'taken for granted' in parts of the northern temperate region as an outcome of the much stronger historical and biological documentation extending over more than a century. Other than by coincidence and inference, we have little knowledge of historical changes in Australian butterfly abundance and distributions before the last quarter of the twentieth century, and interest in insect conservation is generally a modern development, largely in response to perceptions of influences of anthropogenic change and greater appreciation of Australia's biodiversity and its vulnerability to the massive losses of natural vegetation that have occurred so widely over the country. These gaps in knowledge ensure that the research component of management for most Australian butterflies assumes predominant importance in order to provide the basis for sensible knowledge-based and well-focused conservation, and to render management likely to succeed. Much of the limited background information on some taxa has hitherto been unpublished or is contained in internal or agency reports of limited circulation as 'grey literature', and the period covered and the cases treated are amongst those that have led to widespread acceptance of insects as 'worthy' of conservation attention in Australia. More generally, this account thus builds on an earlier published foundation perspective of insect conservation in Australia (New 1984) to illustrate increasing interest and maturity within this science.

The major current perspective is developed from discussion of conservation efforts for several species or subspecies that have helped to found interests in insect conservation in the region. Almost all the taxa involved are members of significant endemic radiations of butterflies. Most, such as myrmecophilous species of Lycaenidae, display considerable ecological complexity and are ecological specialists in some way – with, of course, features such as larval monophagy, other specialised requirements such as specific ant mutualists, and very limited habitat spectrum likely to increase their vulnerability and, hence, their conservation needs and profile. In addition to taxa being conservation targets in their own right, studies of butterflies have raised (and helped to clarify) the complex problems of defining and protecting 'communities' both in legislation and practice, and to draw attention to the vulnerability of habitats of very restricted extent. These cases have played substantial educational roles, not least in awakening young people and others to the intricacies of insect biology and the features affecting wellbeing, and several cases are discussed in some detail to illustrate these wider influences. They are complemented by briefer accounts of most other butterflies that have attracted attention for conservation needs in the region, although some of these taxa have not yet received detailed attention. Collectively, these examples demonstrate the range of regional concerns and threats for butterfly wellbeing, and how some of these concerns are gradually being translated into conservation practice. They demonstrate also that much remains to be learned, and done.

These examples are preceded by wider commentary to introduce the region's butterfly fauna and its conservation needs, and the development of relevant conservation legislation and practice for invertebrates. The final discussion synthesises some of the major issues facing butterfly conservation in the region, and prospects for the future, helping to place the progress made into a wider perspective. The book is thus divided into three parts, with the first part setting the perspective for the case histories and these, in turn, contributing to the fuller information needed for future use and development. The sequence of taxon-based cases discussed in

Part II runs from the comparative conservation of intraspecific forms (subspecies) through comparison of closely related species within a genus (one case of two congeneric species, a second of a more diverse array), to a broader appraisal of taxa depending on a vulnerable restricted ecosystem (alpine grasslands), and finally to the wider issues involved in transforming butterfly conservation planning from strict taxon-focus to that of a 'community' in which individual butterfly taxa may be threatened. Part 3 integrates these examples with other taxa for which conservation is warranted, and discusses the considerable effort and involvement needed to assure Australia's butterflies a more secure future.

Acknowledgements This book draws on the work of many enthusiastic people to whom the conservation of butterflies in Australia is important, and it is a pleasure to thank them for their advice, opinion and friendship. Long term cooperative work on butterflies with Dr Don Sands, Dr Alan Yen, Dr Michael Braby, Dr David Britton and Andrea Canzano has helped to clarify much of the conservation need. Other colleagues, including Mike and Pat Coupar, David Crosby, Fabian Douglas, Dr Ross Field, Ann Jelinek, Dr Beverley Van Praagh and Megan Relf, have also provided comments, copies of reports or publications and, in some cases, unpublished information with permission to cite it. I am very grateful to the following for use of their photographs, as attributed individually in the legends: Andrea Canzano, Mike and Pat Coupar, David Crosby, John Homfray, Phil Ingamells, Simon Nally, Mark Neyland and Megan Relf. Unattributed photographs are by myself, and set specimens of butterflies are from collections of Museum Victoria, courtesy of Dr Ken Walker.

Permission to reproduce published material is acknowledged gratefully from CSIRO Publishing, Collingwood; Museum Victoria, Melbourne; The Royal Society of Tasmania, Hobart; Springer Science and Business Media, Dordrecht; Wiley/Blackwell Publishing, Oxford; The Lepidopterists' Society. Every effort has been made to seek such permissions and the publishers would welcome news of any inadvertent oversights.

I also thank Zuzana Bernhart for her interest in this work. Production of the book has been facilitated greatly by the careful attention of Elisabete Machado and Arulmurugan Pavitra.

Victoria, Australia T.R. New

Contents

Part I
Setting the Scene: South-Eastern Australia's Butterflies and Their Conservation

Chapter 1
Australia's Butterflies: Some Background

1.1 Introduction

With only very few exceptions, interest in butterfly conservation in south eastern Australia has focused on members of four major endemic radiations, the trapezitine skippers, satyrine nymphalids, and thecline and polyommatine lycaenids. In part, this bias reflects the evolutionary interest of these insects as globally significant elements of the Australian butterfly fauna, but also that many of the constituent species/subspecies are both narrowly distributed and ecologically specialised, and so are prime candidates for becoming threatened as local environments are changed. Collectively, they are some of the most diverse groups of Australian butterflies and have diversified to produce complexes of daunting taxonomic and ecological complexity. This variety has generated considerable interest. They have long been attractive to collectors, so many are reasonably well known, at least in general terms. Several of the major components of these radiations are linked with equivalent diversification of southern groups of plants used as larval food plants: some Trapezitinae are associated intimately with *Lomandra* and, within the Lycaenidae, most species of *Ogyris* are found on mistletoes (and so are absent from Tasmania, where these plants do not occur), and *Jalmenus* on *Acacia*, the largest plant genus in Australia. Somewhat intriguingly, however, the vast genus *Eucalyptus* so characteristic of Australia's forests and woodlands, is food for caterpillars of very few butterfly species. The 600–700 species of *Eucalyptus* and its close allies support large numbers of moth species, together with substantial radiations of other plant-feeding insects such as Homoptera, Coleoptera and others but, whereas many butterflies occur in forest and woodland environments, they almost all depend on other plants for larval foods. Although our knowledge of larval foodplant ranges of many butterflies is still incomplete, it seems that no Australian butterfly depends wholly on this predominant plant genus – although some are indeed closely associated with particular eucalypts as hosts of the mistletoes on which caterpillars feed, or as providing pupation sites under bark.

T.R. New, *Butterfly Conservation in South-Eastern Australia: Progress and Prospects*,
DOI 10.1007/978-90-481-9926-6_1, © Springer Science+Business Media B.V. 2011

1.2 Diversity

The Australian butterfly fauna includes somewhat more than 400 species, although the precise total remains uncertain, and depends on the area included and the distinctivenesss accorded to some taxa, as below. Published figures include 416 species (Braby 2004), with Sands and New (2002) giving the slightly higher figure of 427 species from slightly different geographical coverage. The numbers of subspecies present will continue to arouse debate, simply because some have been raised (and some later discounted) on unconvincing scientific grounds – hence the equivalent uncertainty over precise species numbers. Sands and New (2002) adopted the stance for conservation evaluation of retaining as separate entities all those designated by that time, in the absence of convincing evidence to counter this. As New (1999) noted, the naming of many butterfly subspecies in Australia has been somewhat uncritical, in most cases on phenotypic grounds reflected as the adult wing patterning, but without quantitative or other direct scientific comparison with other populations. Some names may fall into Dennis' (1977) category of 'convenient labels' rather than necessarily designating evolutionary units. Indeed some names were apparently intended simply to be this and were applied originally by hobbyists to designate a 'race' or similar informal category to denote a distinctive entity recognised by contemporary collectors. In short, interpreting intraspecific variation in many Australian butterflies is difficult, and some members of all the above radiations have been given formal trinomial names without detailed analysis of the patterns that occur. Extensive clines of gradual variation, for example, may now be disrupted by habitat changes. Debate on the precise taxonomic status of some butterflies will assuredly continue, and several anomalous cases are discussed later. Problems of how to evaluate subspecies or other within-species entities in butterflies are by no means confined to Australia. In part because of the lability of conspicuous wing pattern differences in response to environmental features, small differences in appearance have led to erection of many putative entities of uncertain biological integrity. Darker individuals are often associated with cooler climates, for example, so that these might occur consistently in parts of the species' range. Butterfly variation, or undetected hybridisation, generates numerous more-or-less consistent forms that have been named formally for descriptive or taxonomic purposes.

In many cases, these have involved 'taxonomic inflation' (Descimon and Mallet 2009, on European butterflies). In the past, the contrasting practices of 'splitting' (multiplication of described species, by describing or delimiting them on small features that may in reality only reflect trivial variations within the population, and elevation of local populations to full species rank) and 'lumping' (amalgamation of described forms, such as non-recognition of named subspecies, or isolated populations) have both been common. The 'correct' situation is difficult to discern, and may depend on the particular characters (such as wing pattern, genitalic morphology, allozyme pattern, larval food plants, or other) considered important by an individual worker, or the significance accorded to patterns of continuous or more discrete variation. Workers on a regional fauna may hope for an eventual consensus of opinion, but this is still some way off for many Australian butterflies.

New (1999) noted that the components of ecological segregation noted by Gilbert and Singer (1975) that may lead to taxonomic distinctiveness remain a useful framework to consider, as: (1) specialisation on particular food plant taxa; (2) partitioning of food plant parts; (3) seasonality and voltinism; (4) partitioning of habitat, for example by altitude; (5) partitioning of adult resources; and (6) alternatives in escape from predators and parasitoids, including development of mutualistic relationships. For most of the complexes that need clarification in Australia, the geographical patterns of variation in these parameters are not wholly clear.

To illustrate just one of these, larval food plant specialisation, McLeay's swallowtail (*Graphium macleayanum*, Fig. 1.1) comprises two geographically disjunct subspecies in eastern Australia (Fig. 1.2). *G. m. moggana* occurs in Tasmania and on the south eastern mainland, and the nominate subspecies *G. m. macleayanum* is found further north along the coast and in New Guinea. The two subspecies differ in larval food plant range, with *G. m. moggana* normally feeding only on *Atherosperma moschatum* (southern sassafras, Monimiaceae), whose distribution coincides largely with that of the butterfly. In contrast, caterpillars of *G. m. macleayanum* feed on at least 13 host plant species, across seven genera and four families (Scriber et al. 2006). *G. m. moggana* thereby demonstrates an example of 'ecological monophagy' (Scriber et al. 2008), in this instance reflecting non-occurrence of other putatively suitable food plants in the subspecies' range and the habitats in which it occurs.

The extent of isolation that can occur even between nearby populations is exhibited well by the skipper *Hesperilla donnysa aurantia* in Tasmania (Couchman and Couchman 1977). Two populations near Hobart, separated by less than 2 km, showed very different characteristics. In one population, adults emerged, from

Fig. 1.1 *Graphium macleayanum moggana* (Photo: I.M. Coupar)

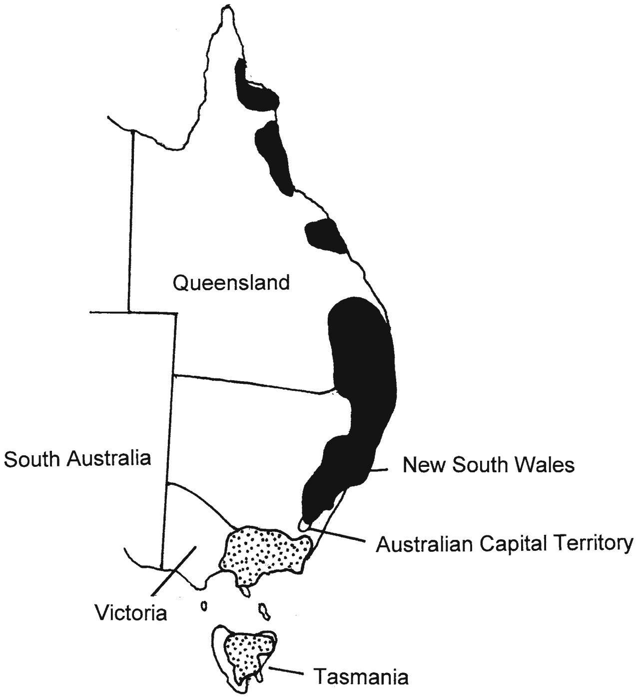

Fig. 1.2 Distribution of the two subspecies of *Graphium maclaeyanum* in eastern Australia: *black*, *G.m. macleayanum*; *dotted, G.m.moggana* (Distribution based on Scriber et al. 2006; major political boundaries of region indicated)

caterpillars feeding on the sedge *Gahnia radula*, in October and November. In the other population, caterpillars feed on *Gahnia psittacorum*, and adults emerged in January. Despite their close proximity, the two populations are thereby biologically isolated and cannot intermingle by cross-breeding, even if adults were able to move between sites.

Whatever the eventual formal status of many putative subspecies may prove to be (with the formal recognition perhaps of considerable relevance in indicating conservation importance, below), many are geographically isolated populations, probable narrow range endemics (New and Sands 2002), and have attracted attention as likely distinctive forms. In the absence of genetic analyses or other convincing information to confirm or deny their distinctiveness, judicious precaution to conserving butterfly variety suggests that a responsible approach at present should be to treat many of these as 'significant populations' or 'evolutionarily significant units' in conservation. Sands and New thereby distinguished a total of 654 species or subspecies of Australian butterflies, with the groups noted above the most diverse (Table 1.1**)**, and in general following the subspecies differentiations recognised by Common and Waterhouse (1981, following from a first edition in 1972). Whatever its shortcomings as revision of particular complexes proceed, the Common and Waterhouse arrangement has practical value because it is the one that

Table 1.1 Australia's butterfly fauna: summary of richness, as numbers of species and all taxa (that is including subspecies) of each family (From Sands and New 2002)

Family	No species	No taxa
Hesperiidae	124	190
Papilionidae	21	34
Pieridae	38	51
Nymphalidae	90	147
Lycaenidae	154	232
Total	427	654

has guided the generation of butterfly workers whose studies are the foundation of the last few decades of gaining information on Australian butterflies. But, as Common and Waterhouse emphasised, there is commonly an element of subjectivity in designation of a particular population or phenotype as a species or subspecies, and – as noted above – many butterfly subspecies in Australia have been designated as such by collector consensus rather than by analytical scientific study.

Some of these may eventually be accepted as trivial variants that do not merit nomenclatural recognition. However, the converse is also true. Progressively, taxonomic investigations are leading to elevation of some subspecies to full species status. One recent example is for the imperial hairstreak, *Jalmenus evagoras*, representing a genus endemic to mainland Australia and long regarded as comprising two distinct subspecies. Under this system, the nominate subspecies, *J. e. evagoras* in eastern Australia, has been a valuable study vehicle to elucidate some fascinating aspects of butterfly evolution (see Pierce and Nash 1999), and *J. e. eubulus* is restricted to the Brigalow Belt of inland Queensland (Fig. 1.3). The latter is now recognised as a distinct species (*Jalmenus eubulus*) (Eastwood et al. 2008) and, with substantial loss of its brigalow (*Acacia harpophylla*) habitat, is regarded as of serious conservation concern. In the far north of inland New South Wales, as the southernmost part of its range, it is under threat from habitat loss and has recently been nominated for consideration for protection under the state conservation act as 'critically endangered'.

In some other cases, in which localised butterfly populations have been suggested variously to be hybrids, clines, or sibling species groups, ambiguity (perhaps flowing from widespread individual variations, or lack of saturation characters) is likely to persist for the foreseeable future in objectively deciding the taxonomic status of populations, notwithstanding strongly held views for one or other category. Butterflies widely recognised as discrete and of conservation interest, such as the Altona skipper (*Hesperilla flavescens flavescens*, p. 55) and the Eltham copper (*Paralucia pyrodiscus lucida*, p. 71), demonstrate the questionable taxonomic status that may be allocated for highly localised and isolated populations that are presumed widely to be functionally isolated remnants from a formerly more widespread range. These two demonstrate rather different facets of the problems involved. *P. p. lucida* is differentiated from the nominate *P. p. pyrodiscus* on a relatively constant adult wing colour feature (the extent of orange suffusion)

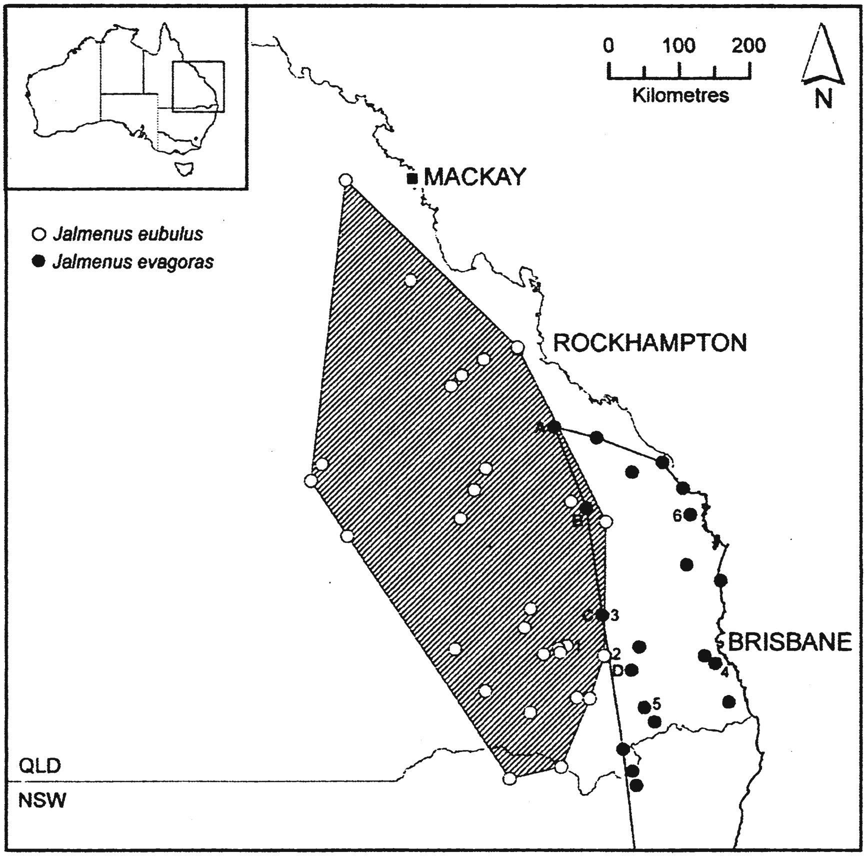

Fig. 1.3 *Jalmenus* spp.: distribution in central eastern Australia of *Jalmenus eubulus* (*open circles*) and its range interaction with *J. evagoras* (*solid circles*) (From Eastwood et al. 2008)

occurring in all individuals – although this is not accepted universally as meriting subspeciifc differentiation. In contrast, *H. f. flavescens* is the extreme of a continuous cline of intergrading variants, perhaps incorporating hybridisation in parts of the wider range, and with the integrity even of the two putative parental species not wholly agreed. The intergrading colour patterns between Victorian populations have been demonstrated clearly (Crosby 1990a), so that the status of populations referred to this subspecies is somewhat subjective – as paralleled at the far west of the species range, with another named subspecies, the pale *H. f. flavia* in South Australia (p. 55). The name '*H.f. flavescens*' is now by wide consensus restricted to a few near-coastal populations to the west of Melbourne, in which the yellowish suffusion of the butterfly wings is universal and more extensive than in more westerly or inland populations in Victoria. However, lack of agreement over such status may have important ramifications for conservation. The first nomination of *H. f. flavescens* for listing under Victoria's Flora and Fauna Guarantee Act 1988

(p. 36) was rejected on the grounds of lack of clear taxonomic definition. It was nominated as 'the phenotype equivalent to the type', and the advisory committee appraising the nomination noted that the special case then needed for an entity below the subspecies level to be listed was not made. From a subsequent nomination, it is now listed as full subspecies, with additional qualification. Whether *H. f. flavescens* truly differs from *H. f. flavia* is still debated (Braby 2000) but geographical separation of these two possible taxa again emphasises the importance of regionally disjunct populations which have clearly been separated for a long time.

Isolated butterfly populations may be subject to very different environments in different parts of a taxon range, so that local climate, resource spectrum, site features and genetic influences all contribute to development of unique population characteristics, in addition to phenotypic variation. Using the above examples: (1) the phenology of *P. p. lucida* differs considerably between populations near Melbourne and those in more arid or warmer areas to the north and west; and (2) the characteristic pale colouration of the coastal *Gahnia filum*-feeding populations of *H. f. flavescens* may in fact be related to use of that environment and larval food plant.

Perhaps an even more complex example is the Australian hairstreak, *Pseudalmenus chlorinda*. Variation has led to erection of seven subspecies, several of them very narrowly distributed in eastern Tasmania (Fig. 1.4, Couchman and Couchman 1977; Prince 1988b) and others on the south east mainland. Several are of particular conservation interest (Chapter 5) but in order to clarify their relationships *all* merit conservation and, without them as available reference points for future study, the full history may never be elucidated.

1.3 Biogeography

Many Australian butterflies are confined to the tropical north of the country (where relatively few of the tropical monsoon region taxa are endemic: Braby 2008) and, although the above-noted radiations are significant components of the south eastern fauna, many other taxa do not extend to this region. They may be considered against a very broad view of Australia's main faunal regions, the major divisions based on the scheme developed by Spencer (1896). Despite the very broad categorisation, which is somewhat simplistic for modern biogeographical interpretation (Cranston and Naumann 1991), these divisions have remained a useful framework for appraising distributional relationships. The three main zones (Fig. 1.5) are (1) the Torresian zone on the north and north east of the island continent, a tropical region characterised by a seasonal monsoon climate; (2) the Eyrean zone, delimited by the 500 mm isohyet, so comprising the arid to semiarid interior and central southern region of the continent; and (3) the Bassian zone, southern temperate to cool temperate regions and separated into three distinct provinces. The West Bassian Province incorporates the floristically rich Mediterranean climate corner of south Western Australia, and this is separated by the arid Nullarbor Plain from the East Bassian Province, the south eastern corner of mainland Australia. This, in turn,

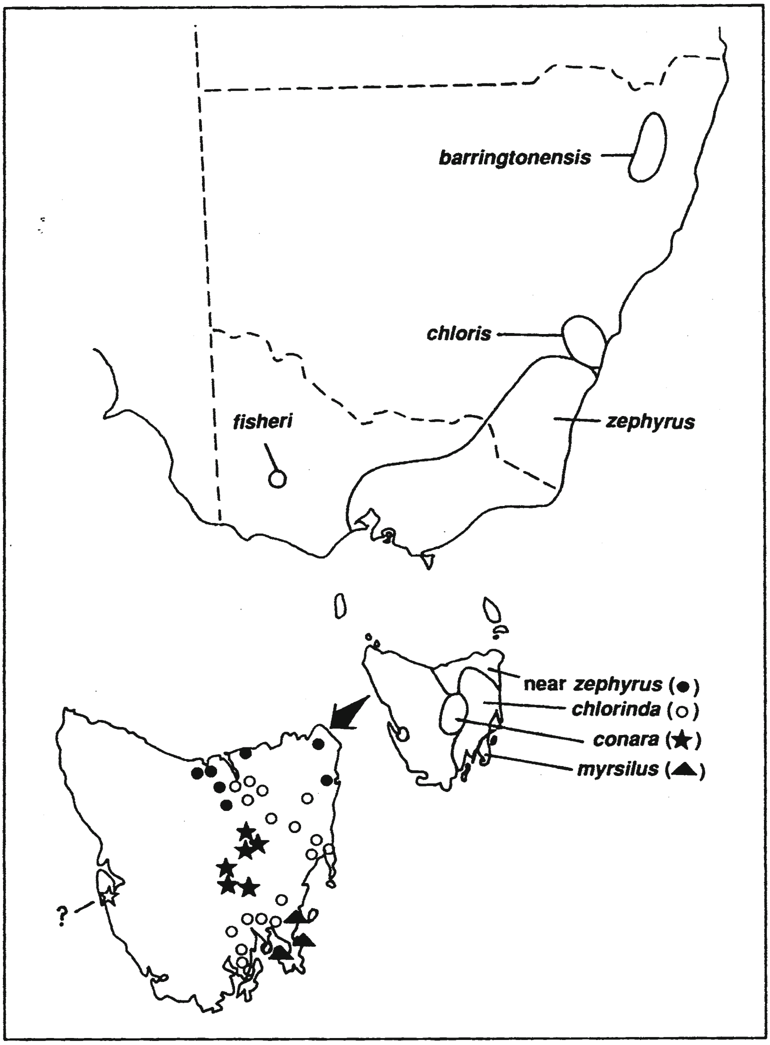

Fig. 1.4 The Australian hairstreak, *Pseudalmenus chlorinda*: distribution of subspecies in south eastern Australia with enlarged depiction of ranges of subspecies in Tasmania (From Prince 1993)

is separated by Bass Strait from the third component, Tasmania, although these areas were linked by land bridges only about 12,000–14,000 years ago. The Strait contains a number of small islands, the remnants of peaks along the former east and west land bridges formerly linking present-day Tasmania and Victoria, and across which a number of butterflies undoubtedly reached Tasmania. The 'boundary' between the Bassian and Torresian zones along the east coast has been defined in several places, reflecting the groups of interest to the delimiter, and butterflies typical of Torresian and Bassian environments intergrade along this region.

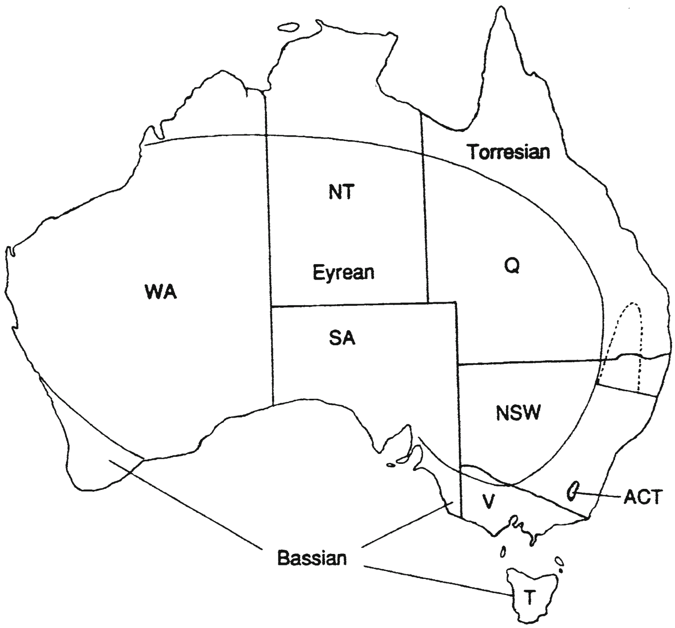

Fig. 1.5 Major traditional biogeographical regions in Australia, indicating position of 500 mm isohyet as boundary between central Eyrean and more coastal Torresian (northern) and Bassian (southern) regions

Nevertheless the three zones provide a framework for considering origins, relationships and distributional trends. The fauna of the Torresian zone has considerable affinities with that of New Guinea, and is mainly of northerly origins. Although separated from New Guinea by Torres Strait, this strait is relatively recent in origin and developed only around 7,000–8,000 years ago, and contains numerous islands that can act as ‘stepping stones’ for invaders from the north. The tropical butterfly fauna of the northern tip of Australia, Cape York, comprises the richest local fauna on the continent, much of it associated with tropical rain forests. The Torres Strait islands have yielded a number of butterfly records for species that have not yet been confirmed as breeding residents in Australia, and some are likely to simply be vagrants from New Guinea; some background to their affinities and peculiarities is given by Sands and New (2008). Eyrean butterflies are far less rich, reflecting the much less hospitable environment of hot semi-desert regimes, and the separation from the Torresian and Bassian zone along its eastern margin by the Great Dividing Range. The Bassian areas harbour many ‘southern elements’, with many insects in the south east and Tasmania derived from older Gondwanan elements and with their closest extant relatives on the other southern continents which are fragments from the break-up of Gondwana. Many of the insects are isolated lineages without close relatives elsewhere in Australia. Within the Bassian zone, the three disjunct regions are now to a large extent functionally isolated, so that each has locally endemic biota and, so, characteristic faunal elements. However, the faunas of the south east mainland and Tasmania have much in common, and closely related butterfly subspecies endemic to either region occur on either side of Bass Strait. The butterflies of these two nearby Bassian provinces are the theme of this book and only about half the Tasmanian taxa occur in the same forms on the mainland (Couchman and Couchman 1977).

Many mainland butterflies found in this region extend northward to varying extents along the eastern seaboard, some at higher elevations along the Great Divide, whilst Torresian species correspondingly extend southward. These opposing range extensions create a range of transition zones, and regions of high butterfly diversity in south east Queensland and north east New South Wales. The geographical origins of some species are thereby obscure, but nearly all the butterflies of primary conservation interest are indeed 'southern' taxa, and many are now entirely or largely found in part of the Bassian region, with no evidence of them occurring (or previously having occurred) further north. It is thus feasible to be reasonably certain about their broad distributional latitudinal and altitudinal limits at present, as baselines for evaluation and detection of possible range changes as climates change, and for longer term conservation planning. The ecology of various taxa of conservation concern can also be appraised individually within the context of the evolution and distribution of their closest relatives, also limited to the region. Patterns of speciation can be suggested in some of the more complex radiations, and several of the taxa discussed later exemplify the interpretative difficulties that arise in attempting to delimit functional units for conservation.

The east Bassian region butterflies are the most intensively investigated butterfly fauna in the continent. Both Victoria and South Australia support butterflies of conservation interest in their inland northern regions, in Eyrean sites that are remote and visited only sporadically by enthusiasts. The New South Wales fauna includes a strong representation of rain forest/wet forest butterflies (59 species reported from this habitat by Nadolny 1987, but only 14 species depending completely on it), in part representing southern attenuation of the northern Torresian fauna in forests and along the warmer coast. Some of these are prominent conservation foci, but are largely outside the main geographical scope of this book, in which the more southerly taxa are given prominence (but see the extensive campaign for the Richmond birdwing (*Ornithoptera richmondia*: Sands et al. 1997; Sands and Scott 2002; p. 144). Interests clearly overlap, not least because other taxa fall under the aegis of the same conservation agencies for protection. The mixing of faunal elements in New South Wales provides high butterfly richness, mirrored in the list of 138 species recorded from around Sydney (Herbison–Evans and Newman 2008). Comments in that list indicate that many more southerly species occur in central New South Wales at higher elevations than elsewhere, and that many northern species are on the southern fringe of their range, some as vagrants seen only sporadically, but suggestive of range being limited by temperature regimes.

1.4 Collecting and Recording

However, despite a solid foundation of basic knowledge on their distributions and relationships in the region, it is important to recognise that finer scale information on butterflies is commonly fragmentary, and it is consequently sometimes very difficult to interpret the conservation needs of butterflies that are at present known from very restricted areas but which may, in reality, prove to be far more widespread and secure than currently supposed. Unlike the tradition in Britain, for example, butterfly collecting and study in Australia has never (in the country's short Europeanised history of slightly more than 200 years) been a major hobby for large numbers of people. Australia, understandably, has a more impoverished legacy of natural history documentation and, in any given decade, no more than a few dozen hobbyists (at most) have collected butterflies actively. Moulds (1999), in tracing the history of butterfly research and collecting in Australia, noted that 203 species (of the 405 enumerated in his total) had been described by 1873, but documentation was generally very brief and mainly accomplished by expatriates. The first Australian resident to publish text on butterflies was George Angas (1847), with Lewin's (1822) frontispiece the first published illustration of an Australian butterfly by a resident naturalist.

Professional lepidopterists, likewise, have always been few in Australia, and butterfly collecting has never become a widespread hobby. Nevertheless, the relatively small numbers of avid enthusiasts in that cohort have contributed much of the foundation information on Australian butterflies, and the high proportions of hobbyist-collected specimens in the country's major institutional butterfly collections are impressive testament to their legacy. Moulds (1999) designated the period of 1950–1980 as 'The Amateur Renaissance' marking the contributions of 'a new generation of amateur enthusiasts'. This era saw the flowering of several regional entomological societies acting as foci for their activities and conduits for distributing information through newsletters and in some cases leading to substantial publications. Moulds (1999) calculated an overall figure for five major Australian institutional butterfly holdings of 80% (of 249,000 specimens) collected by 'amateurs' – a term used not in any pejorative way, but to encompass the great majority of informed lepidopterists in Australia who do not study butterflies as a professional duty.

Enthusiasms over this period contributed to an equivalent new generation of books on Australian butterflies to replace and augment the earlier classics by Waterhouse and Lyell (1914) and Waterhouse (1932), and led by Common and Waterhouse (1972, 1981) as the forerunners to Braby (2000). Both historically and as a prospect for the future, the contributions of people other than professional lepidopterists have been and will continue to be a resource of critical importance in furthering knowledge of all aspects of the biology of Australia's butterflies. Much of this interest is concentrated around major population centres, with most participants living in or near one of the major eastern capital cities of Melbourne, Sydney, Adelaide, Canberra or Brisbane, so that the butterflies occurring within easy reach of those areas are perhaps the best documented taxa in the country. Collecting trips to country areas or more remote parts of Australia involved (and still involve!) considerable time, effort and resources. Distances are large, and many collectors have historically focused on re-visiting 'traditional' localities (or biotopes, such as 'alpine grassland') for rarer species in the limited time available for their activities in the greater certainty of obtaining specimens, rather than adopt the riskier approach of exploring new terrain. As a consequence, the 'folklore' of butterfly collecting in the south east is bedecked with names of particular 'classic sites' for notable species, in some respects parallel to Britain up to the first half of the twentieth century where particular sites were famous for localised species or even for 'varieties' of lycaenids at the height of their philatelic appeal.

A consequence of this in Australia is that there are still many gaps in knowledge of fine-scale distributions of many taxa. Whereas some butterflies indeed appear to have highly circumscribed and narrow ranges, in some others this pattern may reflect under-collection (or 'under-recording'). The broad distribution maps produced in Braby (2000) indicate the general distribution pattern, and build on those shown earlier by Common and Waterhouse (1981). They indicate 'extent of occurrence' (sensu IUCN 2001), rather than 'area of occupancy' within this.

The latter dimension, necessitating finer scale distribution mapping of butterflies in Australia for any accurate delimitation, is thus limited by (1) small numbers of people participating; (2) those people being motivated largely by hobbyist activities rather than defined scientific investigation, although this is changing rapidly, and having only limited time for their activities; and (3) the large areas involved and costs of travel for survey in remote areas. It is still difficult for many people elsewhere in the world to appreciate the size of Australia. The mainland itself is well over 30 times the area of Great Britain, for example, and not dissimilar to that of the continental United States. The above combination of limitations ensures that distribution recording, and plotting changes in distribution of butterflies in ways now standard in Britain (for instance, as based on well-established protocols and small standardised mapping units) is still largely impracticable. Likewise, strict requirements for permits to collect in national parks and other reserves have been a deterrent to many hobbyists to explore those areas so that, with some exceptions, the values of such areas for butterfly conservation have not been assessed by systematic inventory of the taxa present. 'Traditional' collecting localities fall into two main categories: (1) those that harbour particular species prized by collectors, and (2) those that support particularly high richness of species. Concentration on either may bias sampling effort, as Kitching and Dunn (1999) noted, to extend further the reputation of focal species sites, or to extend the 'species lists' for higher diversity areas by additional collecting effort. In general, attenuation of butterfly species richness occurs with increased latitude and elevation, both gradients of considerable relevance in considering likely impacts of climate changes, and toward the arid centre of the continent. The reduced number of taxa toward the centre of Australia in part reflects the strong aridity gradient.

The fundamental problems of fine scale insect recording in even the best-known and most accessible parts of the country were revealed forcefully in an exercise initiated in the early 1980s by the Entomological Society of Victoria under their then innovative Entomological Records ('ENTRECS', full title Insect Distribution Data Collection and Recording Scheme) programme through which the Society attempted to accumulate and organise records of insect species incidence in Victoria, and to map these on a locality grid based on the 1: 250,000 Series R 502 maps already employed for recording distributions of Victorian plants, so that plant and insect records would be compatible. The grid units were 10 × 10 min, or approximately 15 × 18 km. However, the records of butterflies, as the primary group for which data were likely to be available, yielded a survey map (Entomological Society of Victoria 1986) revealing that many such areas in the state had *no* butterflies formally reported. Other trends indicated on the map (Fig. 1.6) were positions of some major highways, concentration of collecting near Melbourne and some other cities and, in general, the distribution of collectors rather than of butterflies! At that time, 16 butterfly species were recorded from only one grid unit in the state. Six of these were casual vagrants, but others demonstrate the lack of information then available. The larger museum collections, as noted above, are major sources of historical distributional information, but some aspects of relying on this information may cause confusion. The introduced cabbage white, *Pieris rapae*, for example is widespread in Victoria but rarely collected or reported. By April 1985, the cut-off date for the published ENTRECS maps, *P. rapae* had

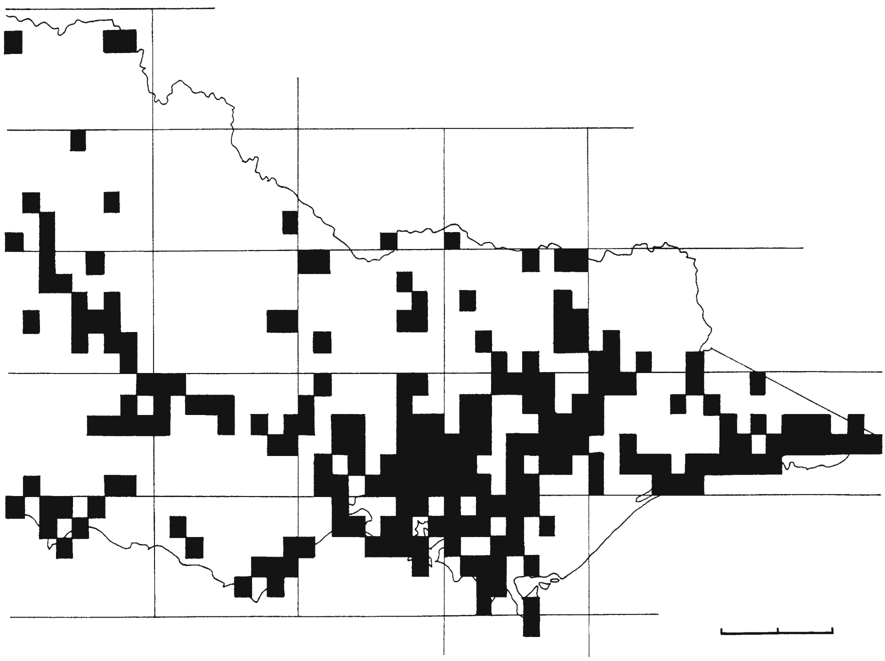

Fig. 1.6 Early attempts to record distributions of butterflies in Victoria: the summary map includes all records available up to April 1983, plotted on a 10 × 10 km grid under the ENTRECS scheme (see text) (Entomological Society of Victoria 1986, scale line 50–100 km)

been reported for only one recording unit to the west of Melbourne. In common with some other common butterflies, it is substantially under-represented in collections, in contrast to those rarer taxa sought more conscientiously and likely to be recorded wherever found. Most collectors have traditionally not recorded incidences (or absences) of more common species of little interest to them.

Emulating older-established European recording schemes, provision was made in ENTRECS for finer scale recording, separation of historical and recent records, and evidence of migratory or other unusual taxa. ENTRECS clearly proved to be more useful for rare and notable species than for the common ones not usually accumulated or reported by collectors on all occasions they are seen; from the maps alone, many such species seem 'rare' from such records, although they are abundant and widespread. Nevertheless, depite the limitations the booklet was a valuable first step in expressing the formal distribution of butterflies in southern Australia, and the scheme was largely the outcome of the vision of two distinguished hobbyists in Melbourne, W. N. B. Quick and D. F. Crosby.

The task was taken up, and expanded Australia-wide, by two other enthusiasts, the son and father team of K. L. and L. E. Dunn, whose industry led to development of what is now known as the 'Dunn and Dunn database', from 1983 onward, and accompanied by a four volume privately-produced account of Australian butterflies (Dunn and Dunn 1991, reissued as an annotated CD-Rom by Dunn and Dunn in 2006). The continued development of the database was discussed by Dunn (2008), by which time the database contained more than 130,500 records. However, Dunn (2008) emphasised the bias in available information toward the eastern half of the continent, reiterated that the distributions of even the most common butterfly species are very incompletely known, and urged accumulation of records of all taxa from under-represented areas to help provide a sound baseline against which future changes may be assessed. The accuracy of distribution records is, of course, of primary importance, and Dunn (2009) also emphasised the transition in culture from early widespread tendency by some collectors to confuse others by deliberately producing inexact or misleading data labels to thwart attempts by other collectors to re-trace the sites, to much greater transparency and accuracy in recording becoming the normal practice. The large ENTRECS recording units, above, for example, although accompanied by a finer grid for detail, do not easily facilitate tracking small individual localities within areas of 270km^2!

An independently produced CD-Rom (Crosby and Quick 1996, under Viridans Databases) was an innovative educational tool on Victoria's butterflies, including distributional and life history data available on all 129 species then recorded from the state. Its features were summarised by Dunn (1997), who noted that it included records available up to the end of 1995.

As additional information accumulates, it is clear that many butterflies in the south east appear to have genuinely small distributions, with various subspecies and others reported from only very small areas, or small proportions of the wider range of the parental species. Some are narrow range endemics, several of them known only from single sites, and so being amongst the prime foci for conservation interest (p. 119). Fortuitously, a few taxa are known only from single National Parks, possibly as remnants of formerly wider distributions, but with the possibility of continuing protection of their habitats in such already protected areas in which management may be practicable. Others are known from groups of apparently isolated populations within a restricted area of occurrence and, unlike the more advanced perspective available for many European butterflies, their population structure is unknown. Some, indeed, may manifest a metapopulation structure but this is generally unproven, and the dispersal capability of most species is unknown. The region also supports many of the most taxonomically-confusing butterfly taxa, with – as noted earlier – some subspecies needing further objective assessment to determine their true relationships. Thus, Tasmania supports a number of putative endemic subspecies not occurring on the Australian mainland.

Without knowledge of population structure, an observed simple concentrated or narrow range may not reflect whether the butterfly occurs as an interlinked metapopulation or a series of isolated populations. Braby (2008b) defined the terms ‘sites’ (as ‘point locations > 1 km apart’) and ‘locations’ (as ‘areas > 10 km apart’). Locations may then be within the same general region or be more widely dispersed across the landscape. On this basis, distance may be a general guide to likelihood of population continuity and range, so that a butterfly occupying several sites but only one location may be an apparent narrow endemic, or occupy a single remaining part of a formerly more extensive range. One of Braby’s (2008b) illustrative examples is the lycaenid subspecies *Candalides absimilis edwardsi* (Fig. 1.7), known from eight sites across five locations in three disjunct areas, as shown. This subspecies is then separated from its close relative *C. a. absimilis* in its southernmost part of the range on the New South Wales coast by more than 120 km, so that *C. a. edwardsi* constitutes a locally endemic subspecies to the west of the great divide.

The above subspecies of *C. absimilis* can be compared with the distribution of the endemic high elevation satyrine *Oreixenica ptunarra* in upland Tasmanian grasslands. Two major distribution blocks occur (p. 108), with an uninhabited intermediate zone of around 100 km including the deep valley of the Mersey River, but both blocks are reasonably extensive and each contains a number of populations of the butterfly. The taxonomy of *O. ptunarra* has historically been complex, with three subspecies widely recognized. However, based on extensive evidence showing a longitudinal cline in size and wing markings and colour, McQuillan and Ek (1997) believed that the pattern of variation would be represented more realistically by synonymising the three named subspecies occurring within the eastern range area, and recognizing a new subspecies to incorporate the western range populations. Much of the variation on which the three named subspecies were designated is clearly clinal in nature, with gradients in phenotype related to environmental variables. As McQuillan and Ek commented, this is a remarkable finding in a species whose entire distribution is over only about one degree of latitude and two degrees of longitude.

A further example of a taxonomically complex satyrine is *Heteronympha cordace*, with three subspecies endemic to Tasmania and another two on the mainland (Fig. 1.8). One of the latter, *H. c. wilsoni* (p. 30), is amongst the most threatened butterflies in the region.

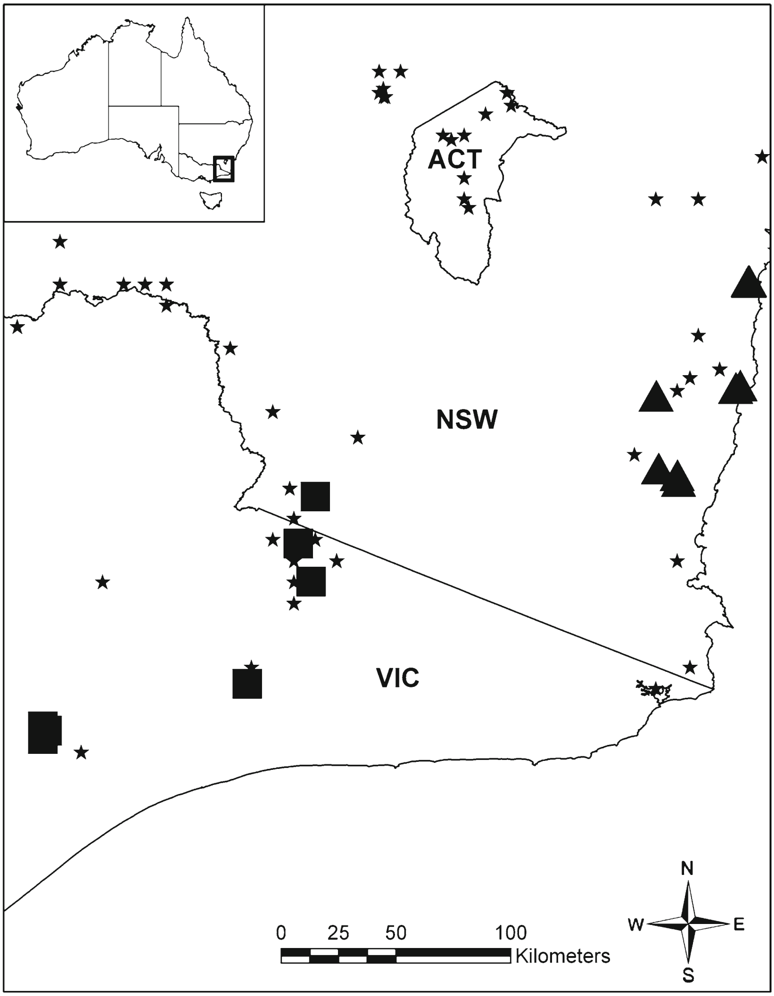

Fig. 1.7 *Candalides absimilis*: distribution of subspecies in south eastern Australia. Triangles, *C. a. absimilis*; *squares*, *C. a. edwardsi*; *stars* are records of the larval foodplant of both subspecies, *Brachychiton populneus* (From Braby 2008b)

The numbers of butterfly species and subspecies reported from the region (up to December 2008) are summarised in Table 1.2, in which some aspects of distribution are noted also, broadly as those which are restricted to the region and those which are more widespread in Australia. Many are locally endemic taxa, and the relative numbers in the table demonstrate clearly the predominance of the radiations noted previously. Several subfamilies of Hesperiidae and Nymphalidae, for example, are much more poorly represented in the south than in the Torresian region, and numerous taxa are reported in the region only on its northern fringe in New South Wales: some, with future climate change, may colonise more extensively as conditions

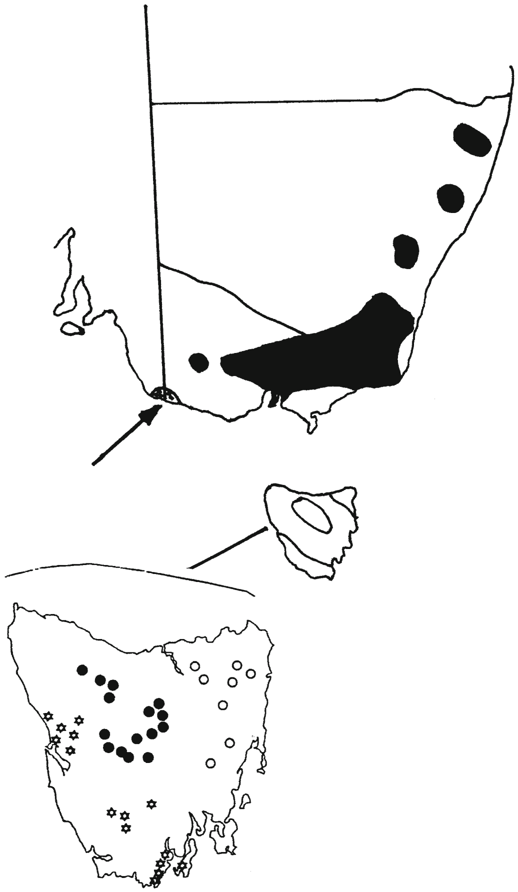

Fig. 1.8 Distribution of subspecies of *Heteronympha cordace* in south eastern Australia with enlarged depiction of ranges of endemic subspecies in Tasmania: *black*, *H. c. cordace*; *arrow* shows narrow coastal range of *H. c. wilsoni*; *solid circles*, *H. c. kurena*; open circles, *H. c. legana*; *asterisks*, *H. c. comptena* (Based on Braby 2000 and for Tasmania, Couchman and Couchman 1977)

warm, and their possible spread is a tool for examining impacts of a warming climate. Clear delineation of the current range is fundamental baseline information for any such applications involving detecting and evaluating distributional changes.

1.5 Distribution and Conservation Status

Because the East Bassian is the most intensively surveyed part of Australia for butterflies, it is possible to comment on conservation status and needs of the various taxa with some confidence, despite the many gaps in detailed knowledge. As foundation

Table 1.2 Butterfly diversity in the east Bassian region: the numbers of species and 'all taxa' (species and subspecies) of butterflies recorded from the range states of the east Bassian. Numbers of species is given as 'total (no. restricted to region/no. in region but also more widespread)'; the majority of the latter are either very widespread or reported in the region only from northern New South Wales, as southward incursives from the Torresian region; the number of subspecies included in 'all taxa' should be taken as indicative, because of ambiguities in acceptance of status of many of these

Taxon	No. species	No. 'all taxa'
Hesperiidae		
Coeliadinae	5 (1/4)	5
Pyrginae	3 (1/2)	3
Trapezitinae	41 (25/16)	77
Hesperiinae	11 (2/9)	18
Papilionidae	9 (1/8)	11
Pieridae		
Coliadinae	8 (0/8)	8
Pierinae	12 (0/12)	12
Nymphalidae		
Acraeinae	1 (0/1)	1
Amathusiinae	0	0
Apaturinae	0	0
Argynninae	2 (0/2)	2
Charaxinae	1 (0/1)	1
Danainae	6 (0/6)	6
Heliconiinae	0	0
Lipteninae	0	0
Limenitinae	1 (0/1)	1
Nymphalinae	9 (0/9)	9
Satyrinae	26 (17/9)	64
Tellervinae	0	0
Lycaenidae		
Liphyrinae	0	0
Polyommatinae	42 (5/37)	48
Theclinae	39 (12/27)	57
Riodininae	0	0

for this, most taxa are recognisable and named, and the life histories of most are known (at least in outline), so that their critical resource needs can be appraised against threats that occur and sound plans for threat abatement made.

Knowledge of these butterflies has been documented mainly by separate endeavours in each political region (State or Territory), so that particular resources for each key area are available. Thus, Museum Victoria, Melbourne, maintains a website that summarises most available information on biology and distribution of Victoria's butterflies. Distributions of the taxa are mapped for several time intervals (no date, 1890–1939, 1940–1969, 1970 on), allowing some inferences of historical change – although, as these records are based on collection data and other records, those changes may need verification. They are not based on any strictly comparative endeavour across these intervals, and simply represent the limited available record of collector activity. As one example, the small ant-blue (*Acrodipsas myrmecophila*) is at present known formally from only one site in Victoria (p. 119) and has apparently disappeared from others from which it was reported earlier in the last century. In that case, the current distribution reflects losses from some historical sites, and the reality of site loss can be confirmed by simple inspection to reveal urban development or other substantial change. The converse situation, of recent discovery suggesting recent arrival, might also occur. Until recently the skipper *Netrocoryne repanda repanda* was known from only one specimen from Victoria, but is now known to breed in a reserve in the east of the State (New et al. 2007).

The only currently recognized endemic full species of butterfly in Victoria belongs to the Lycaenidae: *Candalides noelkeri* was initially known only from two small areas of the interior of the state, but has very recently been reported from others. However, although numerous subspecies attest to variety in the main butterfly radiations noted earlier, throughout the region the current status and, even, existence of some taxa remains highly uncertain. In part, this reflects possible rarity. One recently-documented case illustrates the interpretative problems that arise, and that may need detailed investigation to resolve. The lycaenid *Ogyris halmaturia* (known also as *O. waterhouseri*, see p. 103) is known from South Australia and Victoria, with a historical total of slightly more than 20 sites since it was discovered. Braby and Douglas (2008) estimated that its range has contracted by about 88–98%, reflecting habitat loss, and found that it is now known to occur only at two localities, both in South Australia (Fig. 7.4, p. 104). Nevertheless, it may still occur in the Grampians region of Victoria, possibly within the Grampians National Park, although a number of careful searches over recent decades have so far failed to reveal it. Braby and Douglas considered it extinct there, but noted that 'exhaustive surveys in the known habitat and at the appropriate time of the year are needed to confirm this'. A number of other Victorian localities were recommended for priority searches for additional populations. This butterfly was widely regarded previously as a subspecies, *Ogyris idmo halmaturia*, but recent studies on this complex have led to substantial reappraisal of species limits and distributions (p. 103). Nevertheless, *O. halmaturia* illustrates the perhaps more widespread scenario of species that are already rare, and that may have long been so, having declined substantially but with the real extent of the decline underestimated through lack of comprehensive historical data.

The butterflies of Tasmania (McQuillan 1994, following from an earlier but less accessible account by Couchman and Couchman 1977) and South Australia (Fisher 1978) have been the subjects of monographic handbooks that provide sound bases for students in those states, and summarise most information available up to times of publication. South Australian butterflies are also treated in a website maintained through Butterfly Conservation South Australia (p. 36). All taxa are treated in wider Australian perspective by Braby (2000).

As might be expected from its southerly position and origin, Tasmania has a very limited butterfly fauna of only 39 species, with Hesperiidae and Satyrinae the predominant groups and, with Lycaenidae, those of greatest evolutionary and conservation interest, sometimes exhibiting extensive variation that (as exemplified above) has given rise to naming of endemic island subspecies clearly differing in appearance from mainland forms. McQuillan noted that many of the species are very restricted in distribution within Tasmania, some being upland or alpine species and some others confined to lowland areas where the warmer conditions allow them to persist, some on the southernmost fringe of a predominantly mainland distribution. Most Tasmanian species are elsewhere restricted to the East Bassian Province, and some of the alpine taxa are (or are closely related to) highland forms on the mainland. Tasmanian butterfly distributions have also been plotted on a 10 × 10 km grid. Three species, all Satyrinae, are endemic: *Argynnina hobartia*, *Neoxenica leprea*, *Oreixenica ptunarra*, with *Neoxenica* being an endemic genus. However, one purportedly endemic subspecies in Tasmania poses another, rather different, problem of interpretation. In general, the distributions of butterflies suggested here, and later, are presumed to be natural, so that interpreting distributional anomalies without clear evidence of their causes may be difficult. A single specimen of the skipper *Hesperilla mastersi*, named as a new subspecies, *H. m. marakupa*, was reared from a pupa collected in northern coastal Tasmania in 1963 (Couchman 1965). The butterfly has not been seen again since then, so that no Tasmanian population has ever been found. Within a few years, the capture site had been converted from a *Gahnia* swampland to improved pasture (Neyland 1994). *H. m. mastersi*, the mainland subspecies found mostly in parts of Victoria and New South Wales occurs in wet forests and swampy areas supporting *Gahnia melanocarpa*, a sedge which does not occur in Tasmania. Additional searches by Neyland (1994) failed to rediscover the butterfly, and Braby (2000, who did not recognize the subspecies as distinct) considered it extinct in Tasmania. The individual might have been bred from a vagrant colonist, but McQuillan (1994) noted the possibility of an error in reporting, with Neyland later remarking that exchange of butterfly pupae with mainland collectors was considerable in the 1960s. This can not be confirmed, and the status of the skipper in Tasmania remains intriguing.

Fisher (1978) recorded 64 species from South Australia, most of them from the south and south eastern parts of the state that are 'truly Bassian' with much of the remainder of South Australia much more arid and inhospitable. The 'Lower South east' is of particular significance in marking the westernmost parts of the range of some butterflies found in Victoria, with some of them putatively distinct from their most similar designated subspecies in adjacent southern Victoria. Until recently, the most intensively investigated region of South Australia was the Mount Lofty Ranges and nearby countryside, from which Fisher (1978) reported 49 species (some three–quarters of the state fauna), and which he considered likely to yield very few further butterflies because of the high collecting intensity so close to Adelaide. A checklist (Grund 2009) and individual data sheets compiled by Grund for South Australian butterflies are available on the world wide web: several are cited specifically in the references to this book.

The skipper *Herimosa albovenata albovenata*, rare in parts of eastern South Australia but known also further west in the state, has not yet been recorded from Victoria. *A. cynone gracilis* is also endemic to the state. The lycaenid *Jalmenus lithochroa* is also endemic, but is now found only outside the true Bassian region, in the central north of the state, and has become extinct from former sites near Adelaide. Grund (2002a) referred to the two former distribution centres of this butterfly as 'megapopulations', possibly formerly continuous and now divided through extensive agricultural conversion. The last southern individuals were seen about 1959, and only a few small colonies of the northerly megapopulation are known. The Adelaide region populations utilised *Acacia pycnantha* as a larval food, whilst a second acacia, *A. victoriae,* is the food of the northerly butterflies. *A. victoriae* is itself subject to clearing, as a perceived woody weed on pasture, and its seeds are in demand for harvesting for the increasingly popular 'bush tucker' industry, so that active management to sustain recruitment of the food plant is needed to conserve the butterfly. The status of *Theclinesthes albocincta* beyond South Australia was uncertain at the time of Fisher's account. However, that pioneering book stimulated formation (in 1998) of a specialist organization 'Butterfly Conservation South Australia Inc.' linking a group of enthusiastic hobbyists with the resources of the South Australian Museum, Adelaide, 'to increase awareness of the significant disappearances of South Australian butterflies'. Their web-site, together with that of the South Australian Museum, continues to provide much information on the fauna, with each taxon given a separate data sheet that incorporates photographs and details of biology, distribution, and conservation status and needs. A checklist of butterflies in the state includes details of conservation status, and separate lists for each geographical region are provided.

Chapter 2
Environments for Butterflies in South Eastern Australia

2.1 Introduction

The East Bassian Province is among the most varied parts of Australia and is also that most changed by intensive human activities. It contains the restricted alpine/subalpine regions as the southernmost parts of the Great Dividing Range, forests dominated by sclerophyll eucalypts, southern temperate rainforests with *Nothofagus*, formerly extensive lowland grasslands, upland grasslands above the treeline, a diversity of sedgelands and coastal dune systems, and a generally rich and varied vegetation. Each of the above biotopes, and others, supports butterfly taxa largely dependent on, and limited to, it. Each also gives conservation concerns due to anthropogenic changes, many of them severe, over the last century or so. The climate is 'cool temperate' with evident seasonality, and a trend to being warmer and dryer inland than near the coast. Three major thermal zones are sometimes recognized; warm temperate, such as along the coastal plains; cool temperate, the highlands; and cold temperate, the alpine areas. The region includes Australia's largest cities (Sydney, Melbourne), the nation's capital (Canberra), other state capitals (Adelaide, Hobart) and a number of substantial regional centres, and well over half of Australia's rapidly increasing human population live within this area. Catering for the needs of increasing urbanisation and residential land use, together with recreation, industry and agriculture has led to substantial and rapid changes, and the entire region falls into Graetz et al.'s (1995) broad category of 'intensive land use'.

2.2 Environmental Change

Anthropogenic changes, many of them known or suspected threats to native biota, are the major cause of conservation concerns in the region, as elsewhere. The nine broad threats to butterflies listed by Sands and New (2002, Table 2.1) are each exemplified in the cases discussed later, but these commonly occur (in many unpredictable combinations) in concert, with the different primary disturbances later confounding to cause unanticipated synergistic effects. Aspects of land management, vegetation

T.R. New, *Butterfly Conservation in South-Eastern Australia: Progress and Prospects*,
DOI 10.1007/978-90-481-9926-6_2, © Springer Science+Business Media B.V. 2011

Table 2.1 The major broad categories of threats listed for Australian butterflies by Sands and New (2002)

Habitat destruction
Impacts of land management
Agricultural and forestry practices
Clearing/leveling of hilltops
Pesticides
Weeds
Exotic arthropods
Climate change
Over-collecting

removal, agricultural and forestry practices, weed control and climate change, for example, may all also involve fire in some planned capacity as well as this being a potential threat when not planned. As discussed later, there is sometimes a very fine (and usually unknown) line between 'beneficial management' and 'damaging threat' to butterflies from practices such as burning or grazing, and much of their use in conservation programmes is still untrialed and experimental. Vegetation clearing and wetland draining for the above purposes constitute the major threat to native biota, and results in direct and 'cascade' losses and changes to natural habitats, often augmented and confounded by effects of alien species whose entry may be facilitated by the primary changes. They are the paramount cause of butterfly decline in the region, and changes to habitats are the major basis for conservation concerns.

Many of the key specialised habitats for butterflies appear always to have been rather limited in extent, but rapid and intensifying degradation over the last century or so has (1) led to loss and marked decrease in quality of most key biomes, with some disappearing completely, and (2) fragmentation of those habitats so that remaining populations of many butterflies are increasingly isolated within a presumed formerly much broader range. As for other specialised insect herbivores, specific larval foodplants may occur only in particular vegetation associations and microclimates, and the single main threat additional to habitat loss is progressive invasion by alien species, such as aggressively competitive weeds. Evaluating threats to species requires careful thought to optimise the criteria used, and the possible outcomes that may be informative if monitored (Table 2.2). Whatever the primary cause, many formerly extensive vegetation types now occur only as small remnants. Lowland native grasslands in the south east, for example, have been described as 'Australia's most endangered ecosystem' (Kirkpatrick et al. 1995), with well over 99% of this having been lost to development and pasture improvement. Many of the remnants are small, and most are inadequately protected. Many of these are now valued as refuges, such as for grassland species now extirpated from the wider landscapes. Other important refuges, in demand for formal protection through being declared reserves, include small pioneer cemeteries, road and railside reserves, and some lightly grazed areas. Many of these areas, and others such as the 'roughs' of country golf courses (New 2005) have been preserved fortuitously rather than by conservation design, and are very small – indeed,

Table 2.2 Significant impact criteria for evaluating threats to species. An action is likely to have a significant impact (and, so, be a threat) if there is a real chance or probability that it will cause one or more of the following outcomes (After DEH 2006) (IUCN categories for species are given as EW (Extinct in the Wild), CR (Critically Endangered), E (Endangered), V (Vulnerable))

Lead to a long-term decrease in the size of a population (CR, E) or important population (V)
Reduce the area of occupancy of a species (CR, E) or important population (V)
Fragment an existing population (CR, E) or important population (V) into two or more populations
Adversely affect habitat critical to the survival of the species (CR, E, V)
Disrupt the breeding cycle of a population (CR, ER) or important population (V)
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline (CR, E, V)
Result in invasive species that are harmful through becoming established in the species' habitat (CR, E, V)
Introduce disease that may cause the species to decline (CR, E, V)
Interfere (CR, E) or interfere substantially (V) with the recovery of a species
Interfere with a reintroduction into the wild (EW)
Adversely affect a captive or propagated population or one recently introduced/reintroduced to the wild (EW)

commonly too small to be considered significant for conservation of many threatened vertebrates and thus disregarded by land managers, although perhaps of critical value for insects. Clearance of native forests for plantations, either of eucalypts or alien softwood (mainly *Pinus radiata*) has also been a major influence. Despoliation of alpine systems, including upland grassland, for recreational developments has also been extensive, paralleling resort development along the coast with losses of mangroves and other coastal vegetation. Many similar examples can be cited, and particular cases recur in this book.

Vegetation associations in Australia are complex. Broad categories of habitat based in vegetation types (as in the five adopted by Kitching et al. 1978 for butterflies of the Australian Capital Territory – Table 2.3) may each include numerous distinct plant alliances, but remain useful broad descriptors that may help to characterise resident butterfly assemblages. Often, separation of vagrants from scarce resident species may be difficult, with the latter the major possible targets for conservation.

For the lowland grasslands mentioned above, Kirkpatrick et al. (1995) succinctly commented 'Ecologically complex and species-rich natural systems dominated by local grasses and herbs have been replaced by simple and species-poor systems dominated by a few species of grass, mostly from the northern hemisphere'. Butterflies are certainly not the only, even the predominant, native taxa to suffer, but the above quotation mirrors processes widely evident across numerous Australian biomes. The demise of grasslands, however, is particularly significant in that treeless 'plains' and open grassy woodlands were understandably attractive for growing crops and grazing stock, and were the earliest terrestrial biomes to be transformed extensively by European settlement. The latter facilitated introduction and spread of European weeds in feed and faeces, and the hard-hooved stock compact soils and lead to losses of deep-rooted native herbs.

These trends are brought into more specific focus by examples below.

Table 2.3 Major habitats of butterflies in the Australian Capital Territory, with number of species recorded in each (Kitching et al. 1978)

Habitat	Characteristics	No. of species
Lowland savanna	Original grasslands, now much disturbed by development	20
Savanna woodland	Two eucalypt alliances at different altitudes	37
Dry sclerophyll forest	Predominant forest below 610m, mainly eucalypts	30
Wet sclerophyll forest	Predominant forest at higher altitudes	40
Alpine zone	Subalpine/alpine woodland With grassland/herbfields, etc.	20

2.3 Threats and Butterfly Declines

Concern for butterflies in southern Australia has arisen both from perceived declines of taxa, and losses of sites that previously supported species sought by hobbyists. No full species has been documented as extinct so, as far as is known, no species of butterfly in the region has become extinct in the last century or so. Local extirpations, however, are frequent. Most conservation concerns have come from losses or increased vulnerability of subspecies, particularly those close to expanding urban areas – initially Sydney and Melbourne, but now encompassing other capital cities and regional centres. One of the earliest reports of such local loss was for the satyrine species *Heteronympha banksii*, which Waterhouse (1897) noted as formerly common at Mosman's Bay (Sydney) but '… now, owing to the progress of settlement, is rarely seen there.' The small patches (fragments, remnants) of native vegetation left in urban areas include some recognised as vital reservoirs of butterflies that have disappeared from the wider landscape in the region; several cases are discussed later. More generally, the importance of urban remnants for butterfly diversity has been emphasised by surveys around Adelaide (Collier et al. 2006) and in Western Australia (Williams 2009). Following Koh and Sodhi (2004), Williams distinguished two categories of butterflies on remnants: (1) resident species or urban avoiders, resident on remnant native vegetation and restricted to natural bushland areas, and (2) non-resident species or urban adaptors which breed primarily on introduced plants and sometimes visit more natural bushland areas. In some features, these categories parallel the division noted by Pollard and Eversham (1995) for British butterflies, and reflecting ecological amplitude, but with the added implications of the effects of landscape connectivity. Those categories ('habitat specialists', 'wider countryside specialists') are broad, but a useful partitioning, whereby the former includes most of the taxa of conservation interest.

However, habitat remnants are by no means confined to the urban environment. The large scale of clearing native vegetation in Australia has led, for example, to largely agricultural landscapes in which small patches of native vegetation remain, sometimes purposefully but commonly because the ground is unsuitable for cultivation by being too steep or rocky, or adjacent to watercourses. In general only small proportions of such landscapes are preserved predominantly for conservation. The example of the Griffith region of western New South Wales (Braby and Edwards 2006) is not unusual. There, extensive clearing occurred following establishment of soldier settlements after the First World War, so that the present fragmented landscape is predominantly a product of changes over about 80–90 years. Nineteen of the 33 butterfly species reported are breeding residents and several ecologically specialised species (mainly Lycaenidae) are restricted to small natural remnants – with the assumption that they may previously have been more widespread on the region. As one example discussed by Braby and Edwards (2006), *Candalides hyacinthinus simplex* is threatened locally. It was found only in one locality near Griffith, breeding in a small roadside remnant of degraded mallee shrubland. This vegetation type was formerly widespread, but was largely cleared in the middle decades of the twentieth century so that only small roadside strips now remain. Elsewhere in the East Bassian, roadside reserves are important remnant habitats for butterflies and other wildlife, and many are valued as botanical enclaves – together with linear railside reserves in which, at least for the time being, native vegetation persists largely unchanged.

The scale of vegetation clearance in Australia is high: Sattler and Creighton (2002) estimated that more than half a million hectares were cleared a year and, despite progressive concerns over this, the process is continuing and has probably led to massive losses of native biodiversity – although much of this has not been documented in detail. Vegetation clearing on this scale has effects on butterflies well beyond increasing the vulnerability of already localised or rare taxa. Braby and Edwards (2006) noted the importance of remnant cypress pine woodland supporting the larval food plant of the migratory pierid *Belenois java teutonia*. This butterfly, the caper white, undertakes long migrations from north to south, and the foodplants in the Binya State Forest of New South Wales are heavily colonised when the butterflies arrive in spring. Should these remnants be lost, it is likely that important migratory pathways of the butterfly may be disrupted, as has apparently already occurred from similar causes in Queensland for the migratory skipper *Badamia exclamationis* (Valentine 2004).

An allied concern is loss of small areas of key vegetation associations through succession. One of the most localised butterflies in Victoria, *Candalides noelkeri* (noted above), is known predominantly from two small sites bordering inland salt lakes, and about 3 km apart (Braby & Douglas 2004). In those flood plains, it is restricted to sunny areas supporting the sole larval food plant, *Myoporum parvifolium*, itself subject to loss through invasion by the shrub *Melaleuca halmaturorum*. This susceptibility to succession by loss of larval food is enhanced by the shading decreasing the attractiveness of the remaining *Myoporum*, and the butterfly is regarded as Endangered. The breeding areas cover only 2–3 ha, and extensive searches have not revealed further colonies nearby. Although possibly more widely distributed in the past, Braby and Douglas (2004) suggested that it may always have had a very restricted range in western Victoria and, possibly, in adjacent southern South Australia (where Grund 2004, advocated further searches), reflected in its very specialised ecological needs. Flood plains bordering natural salt lakes are a threatened ecosystem in the region, and for which agricultural conversion has been a driver of loss, with domestic stock probably also instrumental in conserving remnants of *M. parvifolium* by restricting establishment and spread of the

Melaleuca (Braby and Douglas 2004). Habitat restoration involving replanting of *Myoporum* may be a practical conservation option for this butterfly.

Wetland despoliation and drainage in the region has had severe effects also on other butterflies. One of the taxa of greatest concern is the satyrine *Heteronympha cordace wilsoni* (the westernmost of the five named subspecies of the Bright-eyed brown, found in sedgelands, and three of them endemic to Tasmania: p. 17) which, despite targeted searches in far south western Victoria and adjacent parts of South Australia had not until recently been viewed for more than 20 years. Indeed the first confirmed sightings from South Australia occurred only in 2004 (Haywood and Natt 2006). Although the specimens appeared freshly emerged, the major foodplant was not seen at that site. Adults appear to disperse little from the swampy areas supporting the main larval food plant – the sedge *Carex appressa*. Decline has followed drainage of the habitat for agricultural changes. Following failures to find the butterfly in South Australia (Grund and Hunt 2000), a small colony was discovered there in 2004–2005 (Grund 2006). Described as 'precarious', this was followed by finding in Victoria in 2005, but with numbers declining substantially in 2007–2008. In the small area where the butterfly has been recorded, *Carex* sites have been extensively cleared and degraded, with existing remnants highly fragmented across the Glenelg River area; many such swamps abut timber plantations and are subject to pesticide drift from measures to protect the trees. Survival of *H. c. wilsoni* is likely to depend on protection and restoration of *Carex* wetlands within the areas that the butterflies can colonise. It seems certain that surviving populations may be very isolated, and fostering connectivity may be a key conservation need, in addition to protecting and enhancing all existing colonies together with establishing adequate buffer zones around them.

However, with the exception of such ecologically restricted taxa, many butterflies are not so clearly restricted to particular vegetation-based habitats and range more widely over the landscape. Topographic features, such as those used for hill-topping may be important also. A number of scarce Australian Lycaenidae, and others, are rarely observed other than on the summits of particular hills, which have become 'classic' localities for collectors seeking specimens. For many of those species, biological knowledge remains fragmentary, and a number of examples are discussed later

2.4 Urbanisation

'Urbanisation is widely recognised as having the most intense and concentrated of human impacts on the natural environment' (Bridgman et al. 1995) and, as these authors emphasised, the process of urbanisation in Australia differed considerably from that in Europe, because it was primary rather than a consequence of migration from rural areas to towns or cities to attain improved lifestyles. Australia's major cities were founded *de novo* by settlers, initially convicts and their guards, and the workforce later augmented by free immigrants. Their foundation sites were selected on practical criteria to be able to accommodate arrivals from Britain. Hofmeister (1988) listed five major prerequisites for favourable settlement sites in Australia as:

1. A good anchorage to facilitate trade from overseas
2. Safety from flooding, so not the most low-lying or flood-prone areas
3. Availability of a sufficient fresh water supply
4. Presence of clay for brick manufacture
5. Fertile soil for farming

All early capital cities were thereby coastal settlements, with the inland federal capital, Canberra, a much later development.

These major settlements have increased vastly in population and extent, and a high proportion of Australia's almost 22 million people (as at early 2009) live in major cities or regional urban centres. This concentration is reflected in (1) intensified development of the older inner urban areas, with increasing pressures on open space and conversion of many single-domicile plots to multiple occupancy through the construction of apartments or townhouses on large blocks (so that formerly extensive home gardens are lost), and (2) expansion around perimeters to incorporate additional land for housing and related industrial uses (New and Sands 2003a). Closely linked with this, expansion of recreational needs for an increasing population has led to massively increased coastal development (including new suburbs and extensive landscaping) in accessible areas. These changes variously incorporate:

1. Increased incidence of alien species, including many nursery-grown plants for domestic and amenity plantings, some associated with establishment of open areas attractive to house purchasers
2. Loss of more natural environments, and increasingly impenetrable barriers between remaining fragments, so that many remnants are increasingly isolated and, in many instances, vulnerable to edge effects, resulting in
3. need for site specific management for conservation of resident species that are deemed threatened

Threats related to urbanisation are important in declines of almost 40 Australian butterflies, many of them in the south east (Table 2.4, New and Sands 2003a), with conservation of some of these taxa a major local focus, together with the constraints imposed by small isolated sites. However, in addition to these, the incidence of other ecologically specialised butterflies on urban or periurban sites has led to pre-emptive measures to safeguard them before substantial declines have occurred.

Some populations of the Victorian subspecies of the swordgrass brown, *Tisiphone abeona albifascia* (Fig. 2.1) are threatened by urban development, whereby supply of the larval foodplant, the sedge *Gahnia sieberiana*, has been reduced. Restoration plantings of sedges have been important in providing for the butterfly's future (Belvedere et al. 1998), and countering such local vulnerability has been an important 'rallying point' for conservation interest in some outer Melbourne sites.

The 'Sword-grass Brown Butterfly Project' was initiated by a concerned local group, the Knox Environment Society in 1993, and led to support for the butterfly from many community sectors. Concerns arose from the loss of habitat supporting *Gahnia sieberiana* in this municipal region of eastern Melbourne, and conservation measures were formulated to enrich and extend habitat by plantings. The four sites

Table 2.4 Butterflies believed to be threatened by urban development and related processes in south east Australia (From New and Sands 2003). States where threatened noted in parentheses as: NSW (New South Wales), VIC (Victoria), SA (South Australia), TAS (Tasmania)

Hesperiidae (Australian taxa threatened by urbanisation: 18)
Regional: 16
Anisynta cynone cynone (SA); *Antipodia chaostola chares* (VIC); *A. c. leucophaea* (TAS); *Herimosa albovenata albovenata* (SA); *Hesperilla chrysotricha leucosia* (SA, VIC); *H. c. nana* (SA); *H. donnysa delos* (SA, VIC); *H. d. diluta* (SA); *H. flavescens flavescens* (VIC); *H. f. flavia* (SA); *H. idothea clara* (SA); *Ocybadistes knightorum* (NSW); *Oreisplanus munionga larana* (TAS); *Telicota anisodesma* (NSW); *T. eurychlora* (NSW, VIC); *Trapezites luteus luteus* (NSW, SA, VIC)
Papilionidae (Australian taxa threatened by urbanisation : 2)
Regional: 0
Pieridae (Australian taxa threatened by urbanisation: 0)
Nymphalidae (Australian taxa threatened by urbanisation: 2)
Regional: 1
Tisiphone abeona joanna (NSW)
Lycaenidae (Australian taxa threatened by urbanisation: 17)
Regional: 10
Acrodipsas brisbanensis brisbanensis (NSW, VIC); *A. b. cyrilus* (VIC); *Hypochrysops apelles apelles* (NSW); *H. digglesii* (NSW); *H. epicurus* (NSW); *H. ignitus ignitus* (SA, VIC); *Jalmenus lithochroa* (SA); *Paralucia pyrodiscus lucida* (VIC); *Pseudalmenus chlorinda zephyrus* (TAS); *Pseudodipsas cephenes* (NSW)

Fig. 2.1 *Tisiphone abeona albifascia* (Photo: I.M. Coupar)

occupied by the brown were all small and isolated, and promoting connectivity through additional plantings between them was also an anticipated outcome. Seeds of *Gahnia* were propagated through the Society's community nursery, with smoke and acid treatments facilitating germination. Local schools aided by involving children in plantings in school yards, and home garden plantings were also fostered. Signage and ornamental bollards, carved with motifs of the adult butterfly, its early stages and *Gahnia*, were especially produced for publicity and have been deployed at five restoration sites (Knox Environment Society 2006) (Figs 2.2 and 2.3).Those

Fig. 2.2 *Tisiphone abeona albifascia*: replanted sedge and attendant signage at one of the sites restored through Knox Environment Society project (see text)

Fig. 2.3 One of the ornamental carved bollards placed at sedge-planted sites to advertise the *Tisiphone abeona* project (see text)

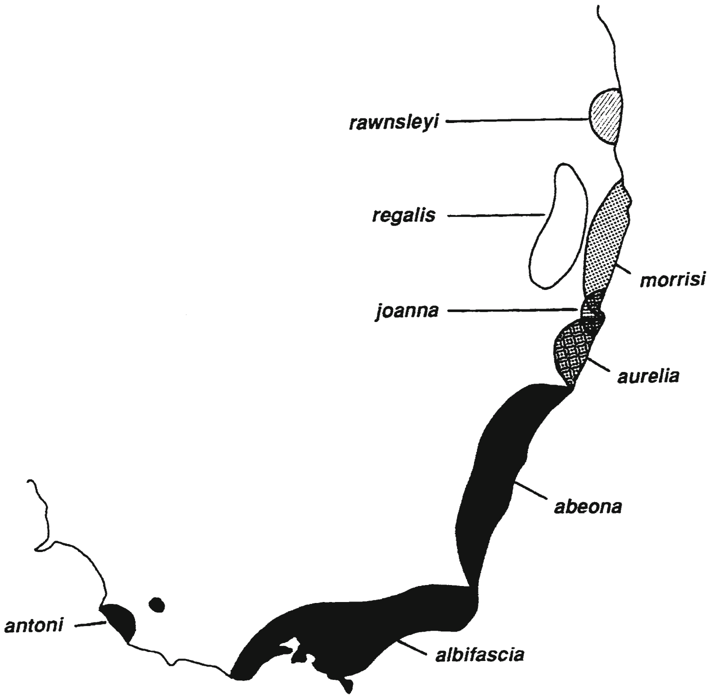

Fig. 2.4 *Tisiphone abeona*: distribution of the various named subspecies in eastern Australia. Note the narrow zone of hybridisation resulting in *T. joanna* (see text)

sites, all of them small, were selected to facilitate connectivity between two known *Tisiphone* populations almost 3 km apart.

Early trial translocations of caterpillars apparently failed, but monitoring continued to assess the values of habitat enrichment for the butterfly. The group's newsletter ('Gahnia') reported progress and also helped to foster wider awareness of butterflies in the area. *T. abeona* is a complex and variable species in eastern Australia, with several of the named subspecies very local in incidence (Fig. 2.4), and one notable form (*T. a. joanna*) is a natural hybrid between two parental subspecies (*T. a. aurelia*, *T. a. morrisi*) near Port Macquarie, New South Wales. Areas bordering the narrow hybrid zone have been degraded substantially, and the prime conservation need is to help counter alienation of the very limited area in which the parental forms come into contact. This case is unusual in representing need to conserve a hybrid form. To the north, *T. a. morrisi* has apparently been reduced by habitat losses from coastal developments, and the practical restoration techniques pioneered for *T. a. albifascia* near Melbourne may have much wider application to other forms of the swordgrass brown.

Practical conservation measures for butterflies near urban areas have considerable potential to increase public awareness of wider needs for conservation, and to involve people in the continuing programmes. Several notable examples in Australia are outlined in some of the case histories which follow.

Chapter 3
Butterflies in Australian Conservation Legislation

3.1 Introduction: History, Development and Reception

As elsewhere in the world, much of the impetus for butterfly conservation in Australia has arisen through particular species being signaled as 'threatened' in some way and, progressively, through the inclusion of such taxa in formal advisory or legislative schedules of 'protected species', a step which may oblige further attention and, if needed, practical conservation management. In general, such listings have been an important part of conservation advocacy, but may cause strong reactions and have not always led to adequate practical management. Australia's conservation legislation caters widely for threatened species, and operates at the twin levels of Commonwealth and individual State or Territory. The latter vary considerably in the provisions and coverage of the acts, and the contexts and implications for butterflies are discussed below.

Each of the six States and two Territories of Australia has its own conservation legislation, mostly providing for 'listing' of threatened species as 'protected' or in some way of conservation significance, and in some cases according these listed taxa priority for allocation of conservation resources. In addition, the federal Environment Protection and Biodiversity Conservation Act 1999 (EPBC) provides wider Commonwealth perspective. Details of the listing process and criteria, and of the consequences of such formal recognition, differ across the various acts, so that the same taxon may occasionally receive similar status in different parts of its range, but on somewhat different criteria, or be ranked differently to reflect more local circumstances and needs. Thus, for nominations for listing under EPBC, a taxon is assessed under five criteria: reduction in numbers, restricted geographical distribution, decline in adult population size in number or distribution, adult population size, and probability of extinction in the wild. Conversely, a taxon may occasionally be allocated to different categories under overlapping acts on the same body of evidence. Allocations for butterflies, fortunately, have so far been reasonably consistent in intent, but the case of a wingless stonefly endemic to a small area of Victoria and listed under Victoria's state act but rejected for listing under the Commonwealth act, illustrates the possible dilemmas that may arise (New 2008a). In practice this is little hindrance because few butterflies are listed, and most of

T.R. New, *Butterfly Conservation in South-Eastern Australia: Progress and Prospects*,
DOI 10.1007/978-90-481-9926-6_3,

these under only the one act pertaining to a single state, and commonly reflecting endemism. Only one Bassian butterfly taxon is listed under EPBC. This, *Paralucia spinifera* (p. 88), is a New South Wales endemic species listed also under the State act. Other state endemics are listed under New South Wales, Tasmania and Victoria acts (Table 3.1), and, although these are not recognized under EPBC this does not lessen their national importance. One New South Wales listed butterfly (the Australian fritillary, *Argyreus hyperbius inconstans*) is listed also in Queensland, and has proved difficult to evaluate (p. 41). The South Australian National Parks and Wildlife Act 1972 has not included any invertebrates amongst its listing of protected animals, so that the best available estimates of butterfly conservation status are advisory, rather than legal decisions. The advisory checklist from Butterfly Conservation South Australia Inc. (Grund 2004) suggests that four taxa in the state are 'Endangered' and 13 are 'Vulnerable' (seven of these within the state but secure elsewhere) (Table 3.2). A further 26 taxa are noted as 'Rare', including vagrants (two) and an introduced butterfly. By far the longest regional list of legally acknowledged 'threatened' butterflies is for Victoria, for which 19 taxa, most of them Bassian endemics, were listed under the Flora and Fauna Guarantee Act 1988 by February 2010. Objective criteria for nominating individual taxa to such formal lists are difficult to define, and judicious use of the 'precautionary principle' is not uncommon.

Protective legislation for butterflies in Australia has invoked strong reactions both for and against its use (Yen and Butcher 1997; Greenslade 1999; Sands and New 2002), with both the act and consequences of 'listing' butterflies on formal legally binding schedules controversial. As elsewhere in the world, the practice has strong proponents and equally vociferous opponents. Much of this dilemma arises because the formal act of listing is accompanied by some legal prohibition or restriction of 'take'. This is generally a well-intentioned protective measure but one that can also be seen as vexatious, as it is based on the usually unproven premise that removal of individuals from the population(s) by collectors is harmful. The outcomes have wide ramifications for butterfly conservation in Australia, which draws largely on the interest and cooperation of hobbyists in providing the foundation knowledge on which conservation need and management is based. The activities needed, and which are likely to be pursued only by hobbyists, include considerable further survey to clarify taxon distributions and ranges, and accumulation of voucher specimens to verify identifications: without such vouchers for close examination, many skippers and blues, in particular, cannot be identified unambiguously – particularly in some species complexes in which taxa are superficially very similar in appearance and amongst which confusion of delimitation persists. Any restriction of those hobbyist activities can (1) erode the level of interest and information accumulation and communication, so knowledge never flows to the general pool of information available for conservation, and (2) lead to a climate of suspicion and persecution so that activities become clandestine for fear of prosecution or retribution for 'disobeying the law'. Despite accusations to the contrary, Sands and New (2002) found it difficult to demonstrate in Australia that responsible hobbyist activities involving capture of specimens for their collections have caused

Table 3.1 Butterflies listed for protection under Australia's Commonwealth and State/Territory legislations covering the east Bassian region at August 2009 (status given as Endangered EN, Vulnerable V where differentiated; not given in some acts)

Act	Butterflies listed
Commonwealth	
Environment Protection and Biodiversity Conservation Act 1999	
	Croitana aestiva (Northern Territory) EN
	Euploea alcathoe (Northern Territory) EN
	Paralucia spinifera (east Bassian) V
State/Territory	
Queensland: Nature Conservation Act 1992	
	Argyreus hyperbius inconstans EN
	Hypochrysops piceatus EN
	Ornithoptera richmondia V
	Acrodipsas illidgei V
	Hypochrysops apollo apollo V
	Jalmenus eubulus V
	Nacaduba pactolus cela V
New South Wales: Threatened Species Conservation Act 1995	
	Argyreus hyperbius inconstans EN
	Ocybadistes knightorum EN
	Paralucia spinifera EN
Australian Capital Territory: Nature Conservation Act 1980	
	(No butterflies listed)
Victoria: Flora and Fauna Guarantee Act1988	
	Antipodia atralba
	Hesperilla flavescens flavescens
	Telicota eurychlora
	Trapezites luteus luteus
	Heteronympha cordace wilsoni
	Hypocysta adiante
	Oreixenica latialis theddora
	Acrodipsas brisbanensis
	A. myrmecophila
	[a]*Candalides noelkeri*
	Hypochrysops ignitus ignitus
	Jalmenus icilius
	Pseudalmenus chlorinda fisheri
	Ogyris genoveva araxes
	O. otanes
	O. subterrestris subterrestris
	[a]*O. halmaturia*
	Paralucia pyrodiscus lucida
	Theclinesthes albocincta
South Australia: National Parks and Wildlife Act 1972	
	(Invertebrates not listed: no more specific legislation)
	Tasmania: Threatened Species Protection Act 1995

(continued)

Table 3.1 (continued)

Act	Butterflies listed
	Antipodia chaostola EN
	Oreixenica ptunarra V

[a] Nomenclature updated from published list

Table 3.2 Butterflies considered to be endangered and vulnerable in South Australia, by Butterfly Conservation South Australia (Grund 2004)

Endangered	Vulnerable
[a]*Hesperilla flavescens flavia*	*Anisynta cynone cynone*
	Trapezites eliena
	T. luteus luteus
	T. phigalia
	T. symmomus soma
	Herimosa albovenata albovenata
	Hesperilla chrysotricha cyclospila
	H. idothea clara
Heteronympha cordace wilsoni	*Oreixenica kershawi kanunda*
	O. lathoniella herceus
Ogyris halmaturia	*Hypochrysops ignitus ignitus*
[b]*O. otanes otanes*	*Ogyris subterrestris subterrestris*
	Jalmenus lithochroa

[a]Listed as *Hesperilla donnysa donnysa* form *flavescens*
[b] Mainland only

any loss or harm to taxa or populations. Such activities are almost invariably non-threatening, particularly in relation to the more devastating impacts of major threats such as wetland drainage or vegetation clearance. The issues of 'overcollecting and species listing' were those advanced and discussed most strenuously in wider debate on progress in butterfly conservation activities. Sands and New (2002) suggested measures to help practical conservation by cooperative activities between conservation agency personnel and hobbyists, and so to replace an atmosphere of suspicion and mistrust by more positive and constructive sentiments (Table 3.3). Despite occasional reports of commercial collecting of rare butterflies for export to collectors elsewhere, these have proved very difficult to confirm, and levels of any such activity in the south east appear to be low.

Many of the problems were canvassed in a survey by Greenslade (1999), who received 57 responses from the 169 potential contributors asked to complete a questionnaire on listing butterflies for legal protection in Australia. The substantive questions posed are noted in Table 3.4, and encompass three major themes (1) the advantages and disadvantages of listing (questions 1,2,5,6,8), (2) the 'permit system' whereby opportunity to take a small number of specimens may be granted (question 7), and (3) which species, if any, should be listed (questions 3,4). A 'state of residency' question (question 9) was pertinent because different States then had markedly different 'rules' and attitudes toward listed butterflies, and the final question simply sought interest in respondents wishing to receive a copy of

Table 3.3 Elements of moving toward greater cooperation between butterfly hobbyists/collectors and conservation managers: illustrative points of a code for conservation benefit suggested by Sands and New (2002)

General

1. Recognition of the value of collecting and related activities as foundation knowledge otherwise not available for conservation assessment.
2. Recognition that listing must be a transparent and responsible action, and can alienate hobbyist interests.
3. Recognition that cooperation, based on non-legal protocols, might foster constructive progress.
4. Recognition that different priorities may be harmonised responsibly by increased understanding and that benefits to conservation may result.

Hobbyists

1. Recognition of need for responsible restraint on numbers of specimens captured, and occasional need for total bans on take. Unwanted and surplus specimens should be released unharmed in site of capture. Particular restraints may be needed on capture of females. Consideration of breeding rather than capture of large numbers.
2. Recognition that specimens of listed species should be collected only minimally, but that voucher specimens from outside the documented range may be critically important, and relevant agencies informed of such incidences.
3. Recognition that disturbance to habitats should be kept to a minimum, and practices such as bark removal and disturbance of ant nests to seek early stages of butterflies restrained.
4. Recognition of property rights and need for permissions to enter and work on any lands, together with not causing damage or discarding litter.
5. Recognition that collected material is a valuable resource, and must be preserved and eventually archived responsibly.

Conservation authorities, agencies and managers

1. Recognition that information from hobbyists is the predominant source of information on Australian butterflies and their conservation status and needs.
2. Recognition that collecting is rarely a significant threat to butterfly populations and that, in most cases, limited collecting will not cause any harm.
3. Recognition that including experienced hobbyists/lepidopterists on management/recovery teams, and their participation in management programmes, can bring benefits not easily available from elsewhere.
4. Recognition that incorporating hobbyist interest into conservation management may bring substantial benefit, and that impeding such interests may impede progress.

Topics for consideration for increased mutual benefit

1. Permits for access to restricted areas or to collect listed taxa issued through interest groups to their members, with condition of return of information and records, and conditions for realistic bag limits or other restraints specified.
2. Possibility of restricting collecting of specimens to any particularly 'safe' sites with secure populations, and avoiding more sensitive populations.
3. Organisation of 'open days' on safe sites for exchange of information between all interested participants
4. Eliminate needs for permits that now may prevent hobbyists taking voucher specimens from outside the documented range of taxa, and encourage exploration in any 'new areas'.
5. Enable clear contact between hobbyists and agency personnel, with designated contact person for enquiries. Likewise, the contact point for interest groups should be clear to an agency or manager seeking expert advice.
6. Active encouragement by agencies of butterfly surveys of national parks and other protected areas, with deposition of data.

Table 3.4 Substantive questions posed in survey of attitudes to 'listing species' in Australia and sent to people interested in butterflies (Greenslade 1999)

1. What benefits do you think that listing rare or endangered butterfly species conveys for the conservation of that species?
2. What disadvantages do you think that listing any rare or endangered butterfly species conveys for the conservation of that species?
3. Are there any species in the attached list of protected species that should not have been listed? If so, please name them and give reasons for delisting them.
4. Are there any species in the list of protected species attached that should be listed? If so please name them and give reasons for listing them.
5. Has the listing of any species caused you to reduce or change the field or other work you might carry out on butterflies? If the answer is yes, please state how and why.
6. Has the listing of any species caused you to reduce or change the way you curate or enlarge your collection of butterflies? If the answer is yes, please state how and why.
7. As permits are required to collect and study listed species, please say how you think the permit system could and should be operated in order to suit amateur lepidopterists.
8. Have you any other comments on mechanisms for protecting endangered species?

the outcome: almost all did so. Thirty six respondents saw some benefits from listing, whereas 54 responses listed some disadvantages to the process. The most frequently noted benefit was increased publicity (15 replies) and the most frequently noted disadvantage was reduction of amateur contributions to research (28).Twenty-nine of Greenslade's respondents to question 5 noted that they had changed their field work habits and were no longer collecting information on listed butterflies, because permits either were not available to amateurs or were too difficult or expensive to obtain.

Twenty six respondents commented that they no longer collected listed species (with several expressing regret that their collections would remain incomplete). Particularly in Queensland, where an annual fee was charged for holding specimens of listed species in collections, the listing of butterflies generated considerable resentment and controversy. Polarised viewpoints, ranging from listing as many taxa as possible, to listing none or only very few genuinely deserving cases, have led to heated debate on the theme. Referring to dragonflies, perhaps generally second only to butterflies as a charismatic insect group sought by collectors but in which voucher material is still needed to confirm identity of some taxa even in the well-documented British fauna, Corbet and Brooks (2008) urged 'civilised dialogue based on mutual understanding and respect for differing points-of-view'. A collector taking voucher specimens for identification may assume duty of care for the responsible use and deposition of that material. Where voucher material is needed for listed butterfly species, this may need explanation to the relevant authority by a credible lepidopterist, who should be able to explain clearly why vouchers are needed. In general, there is little or no evidence that hobbyist taking of specimens (as distinct from exploitative commercial collecting) will harm a population, but it is not always possible to plan in advance to collect vouchers, as the taxon may be encountered unexpectedly outside its documented range. Opportunistic or unplanned sighting of listed or possibly listed (where identity is uncertain from sighting alone) should be viewed as important opportunities to expand knowledge, and acceptance of that information depends on examination of voucher specimens or series. All too commonly it may, rather, lead to a 'witch hunt' and condemnation of the collector, as well as the profile of the taxon involved being incomplete and, in some cases, lowered in credibility.

Although they are confounded in much legislation, 'listing' and 'prohibiting take' should ideally not be confused. A valid listing conveys need for conservation on some defined grounds. Prohibiting take of individuals implies that removal of individuals is a threat, and that cessation of this would decrease chances of decline or extinction. In reality, it almost always flows from the precautionary principle rather than individual taxon knowledge. For butterflies known only from single populations or single sites which are adjudged vulnerable to human activities, controls or prohibition on take may indeed be warranted as a definable threat abatement measure. In most instances appraised, this is not the case. The Entomological Society of Victoria, then largely composed of butterfly enthusiasts, in 1973 listed several butterflies for 'Limited Voluntary Protection', stipulating that no more than two adult specimens should be taken (netted) by any collector per year, and that no larvae or pupae should be taken at any time; this had no legal force but was significant in increasing conservation awareness and the need for responsibility amongst the membership.

In general, the obligations that flow from 'listing' a butterfly (or other invertebrate) must often be interpreted and followed through by non-entomologists. Even before this, however, ambiguities may arise in assessing nominations for listing. Obtaining sound independent peer review of nominations may be very difficult. In many cases, the only people who have studied first-hand a rare butterfly in the field and who may understand its biology and needs are those who have prepared the nomination for consideration, and any other invited reviewer may lack that personal experience. In Australia, the nomination and reviews are considered by a national or locally-based advisory committee charged with recommending an outcome, where necessary seeking any additional advice or opinion that may be available. That committee is likely to include, at most, a single member with primary interests in 'invertebrates', and whose word may be critical in deciding the fate of organisms well outside his/her personal interests or experience. Individual credibility, at all stages, may be an important influence on the outcome of a listing nomination for taxa for which scientific information is sparse and unlikely to be augmented other than by additional research. Such nominations are likely to include information that may be supported or dismissed, even by 'experts', who may express polarised views over how particular 'facts' or observations may be translated.

One example of such a dilemma is for the Australian fritillary butterfly, *Argyreus hyperbius inconstans* (p. 36), now found only in small coastal areas of northern New South Wales and southern Queensland, and for which strongly held opinions for and against conservation need have been advanced. The major problem for this butterfly devolves on interpreting large fluctuations in numbers, such that it usually occurs at very low densities or is apparently absent from any given site, but on occasions - even at intervals of several years - becomes very abundant. It is listed as ‘Endangered’ in both range states, but a workshop in New South Wales (for BAP, below) considered it ‘Data Deficient’ in New South Wales, because of lack of ecological understanding. The predominantly, and presumed natural, low density of the butterflies in most years has hampered informed assessment of whether it is indeed threatened. In BAP it was assessed as ‘Vulnerable’ for Queensland where, however, there is still serious lack of reliable biological information. Later, Sands and New (2008) pondered whether an irregular larval diapause might influence adult apparency in leading to the ‘boom and bust’ scenario suggested by variations in abundance of *Argyreus*. Although this is speculative, the butterfly demonstrates well the difficulties of interpreting the dynamics of even highly irregular abundance. In the absence of clear understanding, designing a recovery plan or similar scheme is impossible other than for protecting sites at which the butterfly has been recorded and, possibly, augmenting the supply of critical resources – in this case of the larval foodplant, *Viola betonicifolia*.

Presence of low numbers of any butterfly, in itself likely to arouse conservation interest through implied rarity, is almost always very difficult to interpret – unless declines are obviously linked with defined loss of habitat/resource extent or quality, most commonly through direct habitat loss. In the case of Illidge’s ant-blue, *Acrodipsas illidgei* (below), which is usually observed only in very small numbers, this may be an artifact due to the adults flying rather little and so being ‘cryptic’ as they remain stationary on mangroves. Alternatively, of course, they may represent a case for genuine concern. Without biological understanding, such numbers may be due to either or both of (1) sampling limitation or inadequacy (for example by not catering for behavioural idiosyncrasies or phenological variations by repeated visits, or butterfly activity being influenced by weather) and (2) a temporary trough in normal population dynamics. There is no information for Australian butterflies on how a census population size may relate to effective population size, but it seems that the latter may sometimes become very small. Most of the taxa of current concern occur in small (census) populations, with those that have been censused likely to contain no more than a few hundred individuals, in some cases far fewer, and confined to small sites isolated from other populations, should these even exist. In most cases any such additional populations remain elusive, and most have been found fortuitously.

The prevailing conservation practices are undertaken also with little or no knowledge of population structure, but some general assumption that many small or putatively isolated populations are closed. Whether many species parallel European cases in manifesting a metapopulation structure across the wider landscape is almost wholly unknown. For some taxa, however, it is indeed clear that substantial reductions in formerly more extensive habitat have occurred, with fragmentation implying that dispersal or interchange of individuals between the remaining patches is (1) less than might have occurred previously or (2) is prevented by inhospitable regions between habitat patches and/or the greater distance between them, so that putative barriers to dispersal have now been imposed. The population on each patch may thereby become enforcedly closed and, perhaps, increasingly vulnerable. Some butterfly species appear to be rather sedentary, and not likely to expand their range dramatically even when the opportunity to do so occurs. However, the reasons for such restrictions are usually unknown.

Whatever the biological justification for 'listing', several butterflies accorded this status have become the most important 'flagships' or 'icons' for insect conservation in Australia, as a consequence of the notoriety flowing from this status. Their study has augmented understanding of invertebrate importance and conservation, and how this may be fostered, as well as inducing considerable local interest and pride. Several of these taxa are discussed in detail in later chapters, in which the avenues by which knowledge and experience accumulate emphasise the symbioses between professional conservation managers and 'people who understand butterflies'. For most of these taxa, alienation of hobbyist interest and support would effectively halt informed conservation activities and progress.

From another perspective, listing a taxon may be a passport to eligibility for funding or other resources needed to support conservation, or gain the taxon priority for these. It is thereby a responsible action, irrespective of the grounds involved, but there is still some danger that listing will itself be perceived as conservation activity rather than as a facilitating step. The wisdom of drawing attention to 'rarity' or conservation threat by listing a taxon may need to be considered carefully because, as well as benefits for conservation, the wider problems that can arise may be substantial (Beale 1997). Beale's concerns arose from the earlier designation of Illidge's ant-blue, *Acrodipsas illidgei* (a locally endemic myrmecophagous species which occurs in restricted mangrove swampy areas in south eastern coastal Queensland, in association with *Crematogaste*r ants in broken 'stubs' on mangrove bushes) as 'Permanently Protected Fauna' in 1990, under Queensland's Fauna Conservation Act 1974–1979, and later changed to Endangered under the more recent replacement legislation. That designation implied very strict restrictions that, in Beale's opinion, would hamper conservation by inhibiting observations and communication on the butterfly's distribution and abundance. The legal protection required all specimens collected to be registered, and rendered any non-approved collecting illegal. Restrictions were imposed on keeping specimens, even those collected before the legislation became effective, in collections, and Beale noted that people might even be reluctant to share information, because of fears of unguarded comment leading to investigation and possible prosecution (see also Beale and Zalucki 1995). In essence, the implications of this law could reduce likelihood of communication and lead to possibility of habitat destruction in areas unknown to agencies but well-known by collectors to support the species, simply because people did not make the information known. Possible parallels occur elsewhere.

3.2 The Butterfly Action Plan

Following from an earlier account on conservation status of Australian butterflies by Dunn et al. (1994), Sands and New (2002) compiled a broad national Action Plan for Australian Butterflies (henceforth Butterfly Action Plan, BAP), based on all available information, including that from a series of eight weekend workshops across the country, attended by a high proportion of Australia's hobbyists and lepidopterists, and interested conservation agency personnel. These workshops were invaluable in exchanging and questioning information that had previously not been available for conservation assessment, and in drawing on the knowledge and experience of people with, sometimes lengthy, field experience and unpublished knowledge of most of Australia's butterflies. Opinions on the conservation status and need of some taxa varied considerably but, at each workshop, all taxa of possible conservation interest occurring within the relevant State or Territory were discussed individually and as fully as knowledge and experiences allowed, together with those taxa elsewhere in the country. Wide-ranging discussions emphasised the importance of direct evidence of losses, declines and threats or, conversely, of range expansions and greater security, with concentration also on distinguishing between 'rarity' (as a term evocative to collectors) and 'vulnerability' as reflected in definable threats and trends (as direct evidence of need for conservation). Sands and New sought advice also from people who were unable to attend a workshop, and circulated drafts of various taxon synopses to relevant experienced workers for comment and, in some cases, revision. BAP remains the only such synoptic action plan for a whole taxonomic group of Australian invertebrates.

The major topics on which information was sought for each taxon were:

1. Number of localities at which each was personally observed or collected, and over what period the observations were accumulated.
2. Estimates of contraction of distribution (on a four point scale of 0, 20, 50, >80%) over the past (stated number) of years.
3. Estimates of increase of known distribution over this period – reflecting that this may commonly reflect increased search effort rather than range expansion.
4. Estimates of the number of populations that have become extinct at (x) localities over (y) years.
5. Estimates for decline based on personal experience, rather than on hearsay.
6. Knowledge of breeding populations in high quality reserves such as national parks, on the basis that management there may be easier to promote than on other lands.
7. Listing of threats affecting the taxon, with continuing anthropogenic threats to habitat and critical resources particularly important.

These discussions did much to clarify genuine conservation concerns, and the reasons for them, with several trends particularly relevant as a guide to allocating threat status:

1. Fewer localities of greater concern than many localities: taxa from single localities (sites) particularly significant.
2. Larger and faster contractions more serious than smaller and slower ones, although any contraction may need serious appraisal.
3. Higher number (proportion) of populations lost more serious than lower number (proportion); overall number of populations also important.

4. Definition of threats provides rational basis for management through threat abatement, and assessing difficulty of effective conservation.

Status evaluations emphasised threat evaluation in relation also to any evidence (or, in some cases, strong inference) of accelerated losses or declines from human activities. Sands and New (2002) noted nine broad categories of threat to butterflies (Table 2.1, p. 26), based on workshop discussions. Most of these involve loss of habitat extent or quality, either by direct anthropogenic change or as the outcomes of the impacts of alien organisms or climate change. However, the immediate impacts (visible) may be accompanied by much more extensive and intangible implications for species, which extend over much longer periods. Evaluating environmental changes as threats to a species may need careful and site-specific (or population-focused) monitoring to determine their real impacts (New 2009), with some of the themes noted in Table 2.1 a possible guide to priority considerations.

Individual synopses of 220 taxa of Australian butterflies were prepared for BAP. They encompassed all those noted historically or recently as of conservation concern, leading to the recognition of those taxa listed in Table 3.5 as 'Threatened'. Many are predominantly East Bassian and most of them occur only in this region. Others were categorized as 'Data Deficient' or 'Lower Risk'. The first of these categories is important in showing levels of ignorance, with a number of taxa very poorly known – some from few individuals, and with little or nothing known of their ecology or susceptibility to change. Indeed, as Clarke and Spier (2003) showed for a series of other Australian invertebrates, the distinction between 'Data Deficient' and 'Critically Endangered' is often obscure, as the latter extreme status has been allocated commonly on rather flimsy information or inference. A number of the above assessments differed from those attributed earlier for the same taxa, as an outcome of (1) new knowledge and (2) use of different criteria, together with recognition that allocation of a conservation status is not a permanent fate but open to revision at intervals as a function of the taxon's dynamics and as knowledge accumulates. Many of the taxa treated as Data Deficient may be realistic candidates for much higher conservation concern. Alternatively, they may be secure at present. At this stage we simply cannot tell, and the precautionary principle dictates that they should remain of concern until proven otherwise.

Nevertheless, any such allocation of conservation status must be made clearly and on criteria that are acknowledged as valid and understandable. A number of commentators have suggested that the widely advocated 'red listing' criteria promoted by IUCN (2001, from earlier versions) and selected from within these for the most suitable approaches for poorly documented invertebrates, may be a sound foundation. The lack of quantitative population information for butterflies, and ambiguities in separating threat-induced numerical trends from normal 'background fluctuations' necessitate emphasis on distributional and incidence data rather than risk of extinction flowing from population viability estimates. New and Sands (2004) recapitulated concerns over uncritical application of the IUCN criteria to Australian butterflies, but adopted fully the spirit of a hierarchy of categories, encompassing Extinct; Critically Endangered, Endangered, Vulnerable (as three categories of 'Threatened' invoking

Table 3.5 The butterfly taxa regarded as threatened (Critically Endangered -CR, Endangered- EN, Vulnerable- V) nationally or within range states by Sands and New (2002), some nomenclature updated

	Status		
Taxon	National	State	Range states
Hesperiidae			
Anisynta cynone cynone	VU	VU	SA
Herimosa albovenata albovenata	VU	VU	SA
Hesperilla flavescens flavescens	LR	VU	VIC
H. flavescens flavia	VU	VU	SA
H. idothea clara	NCS	VU(SA)	VIC, SA
Ocybadistes knightorum	VU	VU	NSW
Telicota eurychlora	LR	VU (Q)	Q, NSW, VIC
Trapezites phigalia phigalia	NCS	VU (SA)	NSW. VIC, ACT
Nymphalidae			
Argyreus hyperbius inconstans	DD	VU (Q)	Q, NSW
Heteronympha cordace wilsoni	CR	CR (VIC, SA)	VIC, SA
Oreixenica kershawi kanunda	LR	VU (SA)	VIC, SA
O. ptunarra roonina	VU	VU	TAS
Tisiphone abeona morrisi	NCS	CR (Q)	Q, NSW
Lycaenidae			
Acrodipsas brisnbanensis cyrilus	VU	VU (VIC, SA)	VIC, SA
A. myrmecophila	NCS	EN (VIC)	NT, Q, NSW, VIC
Candalides noelkeri	EN	EN	VIC
Hypochrysops piceatus	EN	EN	Q
Jalmenus aridus	VU	VU	WA
J. eubulus	LR	VU (NSW)	Q, NSW
J. lithochroa	LR	CR (SA)	NT, SA
Ogyris halmaturia	EN	EN (VIC, SA)	VIC, SA
O. otanes	DD	EN (VIC)	NSW, VIC, SA, WA
O. subterrestris petrina	CR	CR	WA
O. s. subterrestris	VU	VU (VIC, SA) DD (NSW)	NSW, VIC, SA
Paralucia pyrodiscus lucida	VU	VU	VIC
Pseudalmenus chlorinda myrsilus	VU	VU	TAS

conservation concern); Lower Risk; Data Deficient (as a collective priority for further investigation to augment basic knowledge); Conservation Significance (taxa apparently not threatened but which cannot be separated clearly between Lower Risk and Data Deficient) and No Conservation Significance (taxa sufficiently well known to be able to exclude them from any of the above categories, as secure but recognising that circumstances may change rapidly).

These categories were separated by a key, referring to a number of criteria (Table 3.6).

Priority for allocation of resources follows the urgency of conservation need to prevent extinction, with 'Critically Endangered' more needy than 'Endangered',

Table 3.6 The key devised to help designate conservation status (categories of threat) for Australian butterflies (Sands and New 2002), to avoid problems of strict quantitative thresholds of population sizes. 'Listed conditions' for threat categories include whether populations are known in protected areas, such as national parks, historical evidence for declines in abundance and/or range, knowledge of management potential for threats known

1. (a) Information on biology, distribution and resident/vagrant status sufficient to make an informed evaluation of conservation status	2
(b) Information insufficient to make an informed evaluation; with little or no information in any of the above topics	Data deficient
2. (a) Threats defined for the species: threats to major populations or population segregates likely to lead to species extinction	3
(b) No threats defined for the species: threats to major populations or population segregates are not likely to lead to species extinction	No Conservation Significance
3. (a) Threats identified for all known populations and considered to pose a risk of extinction within 5 years (one or more listed conditions implicit), usually no more than five populations or major population segregates known	Critically Endangered
(b) Threats identified for all or most known populations, normally including those of greatest significance (size, distribution), and considered to pose a risk of extinction within 5–10 years (one or more listed conditions implicit)	Endangered
(c) Threats identified for some populations and considered sufficiently important to pose a risk of extinction within 10–20 years (one or more listed conditions implicit)	Vulnerable
(d) Threats identified but not considered to pose a risk of extinction within 20 years (one or more listed conditions implicit)	Lower risk

and Endangered followed by 'Vulnerable'. National concerns were accorded precedence over state or more local ('municipal') priorities in BAP. However, in practice these more local issues may become very important because of legal requirements flowing from listing the taxon under State/Territory legislation giving them priority – even though they may not be nationally threatened. In Victoria, the small ant-blue, *Acrodipsas myrmecophila*, as noted earlier, is at present recorded from one small population, with clear evidence that several other populations have become extinct. Within the State it is therefore ranked as 'Endangered', but because of its wider Australian distribution (Northern Territory, Queensland, New South Wales: Fig. 3.1), it is not accorded national conservation significance.

However, imposition of political barriers on a taxon range can in this way elevate the importance of outliers in two distinct ways: (1) a species may extend narrowly across that divide as part of a continuous range, so that it is simply on the edge of a wide continuous range and accorded conservation significance simply by political happenstance and far beyond its overall threat level assessed across the full range, or (2) it can be a disjunct outlier far from other populations of the taxon. The

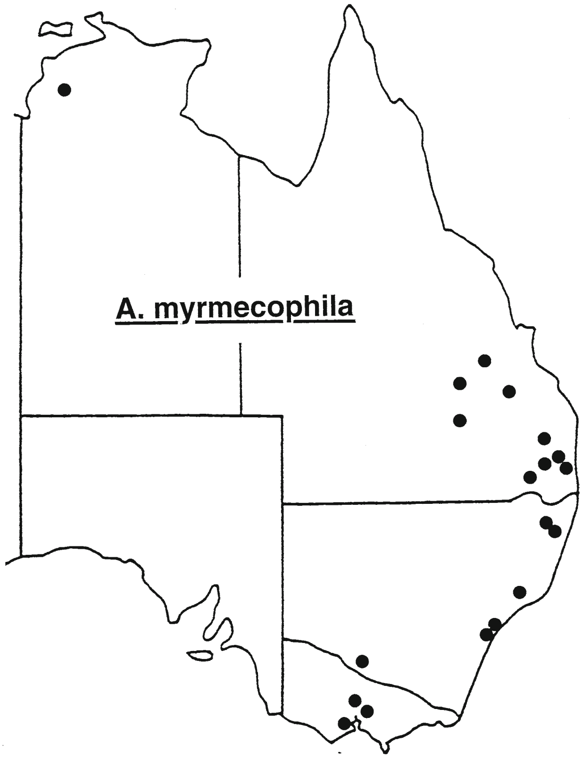

Fig. 3.1 Distribution records for *Acrodipsas myrmecophila* in Australia

Victorian population of *A. myrmecophila* is not simply a political outlier as in the first of these categories, but apparently separated by a considerable distance from the nearest other known populations. It may thus be of evolutionary or ecological significance, although no genetic information is yet available. This possibility is acknowledged under BAP and by the butterfly being listed under the State act. *A. myrmecophila* exemplifies that national and more local rankings for the same taxon may differ considerably, and that the location of outlying populations may be a factor to consider in allocating a status and ranking. For the many taxa that are indeed endemic to a single State, such ambiguities should not arise, although different status may be allocated under different legislations because of differing criteria for assessment or, more rarely, different taxonomic interpretations.

The chaostola skipper, *Antipodia chaostola*, is listed as 'Endangered' under Tasmania's Threatened Species Protection Act 1995. It occurs now in only five localities there, although its larval food plant (the sedge *Gahnia radula*) is widespread in the eastern parts of the state (Neyland 1994, Neyland and Bell 2000). It is associated also with *Gahnia microstachya*, mainly in near-coastal lowland loclalities, including part of the Freycinet National Park (TSS 2006). Unusually, it has a 2-year life cycle, so that the caterpillars are present for about 20 months, rendering population estimation through counts of larval shelters a viable approach. All populations are isolated on small, fragmented sites, and continued habitat loss is the major threat. *A. chaostola* occurs also in Victoria and New South Wales, with a different subspecies recognised in each of the three range states. Sands and New (2002) assessed the Tasmanian *A. c. leucophlaea* as 'Data Deficient', suggesting that (despite loss of some colonies through urbanisation and agricultural conversion) the lack of ecological knowledge at present hampered focused management other than by safeguarding key habitats (as implied also by Bryant and Jackson 1999). Neither mainland subspecies was considered threatened despite earlier implications that they might be Endangered (*A. c. chaostola*, New South Wales) or Vulnerable (*A. c. chares*, Victoria). However, *A. chaostola* is known from only three localities in Victoria, despite considerable exploration of other possibly suitable sites (Wainer and Yen 2009), and appears to be very scarce, with the small populations found only in restricted areas of heathy woodland. In this skipper, both taxonomic validity of the subspecies and confusions between rarity and threat have influenced allocation of conservation status.

3.3 Consequences of Recognition for Conservation Need

Recognition of a threatened status leading to legal 'listing' of a butterfly for conservation significance may confer obligation to appraise it further, perhaps through preparation of a 'management plan' or similar document. These requirements differ under the different acts (Table 3.7), so that such documents can be very diverse in formal requirements and scope (New 2009), and range from brief statements to much more comprehensive appraisals. To be useful in practice, rather than

Table 3.7 Obligations and likely outcomes arising from formally listing taxa under the various Acts noted in Table 7

Act and Obligation
Environment Protection and Biodiversity Conservation Act 1999
National conservation plan for all listed species, and this must remain in force once published. Wide consultation with range states/territories, for joint planning where needed.
Queensland: Nature Conservation Act 1992
Can promote recovery planning under regulation for 'Proposed Management Intent'
New South Wales: Threatened Species Conservation Act 1995
Preparation of a Priority Action Statement, replacing earlier requirement for a Recovery Plan, and detailing needs for recovery and threat abatement. Wide consideration of listed taxa in planning land management and development.
Australian Capital Territory: Nature Conservation Act 1980
Facilitates preparation of an Action Plan
Victoria: Flora and Fauna Guarantee Act 1988
Preparation of an Action Statement, 'as soon as possible after listing', as an outline of evaluation and management needs; progressive central recording of all 'Actions for biodiversity conservation' as cumulative dossier.
Tasmania: Threatened Species Protection Act 1995
May lead to declaration of critical habitat, options for preparation of a Recovery Plan or Threat Abatement Plan

simply fulfilling an administrative obligation, they should be based on the best available ecological information and in Australia must inevitably include substantial focused research components to underpin effective management.

One call from BAP, not yet wholly fulfilled, was for an invertebrate specialist to be appointed to each state/territory conservation agency. In part this is so that documents of this nature might be prepared or overseen by someone with sound understanding of the problems involved, rather than predominantly by people trained mainly in vertebrate biology or that of vascular plants. One major advantage of listing butterflies is that they can effectively 'spearhead' wider advocacy for invertebrates, because they are understood more widely than most other insect groups, and others. Nevertheless, preparation of far-reaching conservation documents for butterflies may be an activity far beyond the comfort zone of many of the people charged with doing so. Insect population structure and dynamics, the subtlety of critical resource supply, life histories and phenological vagaries may all convey themes and idiosyncrasies that bewilder non-initiates, and that even experienced insect ecologists find difficult to interpret.

A central aspect of planning conservation is evaluation of threats, as the basis for designing key activities to remove them or reduce their impacts. Activities in one of three major option categories can then be pursued, perhaps with longer term attention to others as a lower priority:

1. Protection and enhancement of populations on existing sites.
2. Increase the number of occupied sites by artificial means, perhaps involving restoration leading to translocation or facilitating natural dispersal from nearby populations.
3. Increase connectivity between sites, such as by establishing stepping stones or corridors to facilitate natural movement of butterflies between them.

Most butterfly conservation in Australia has until now been site-based, with the presumption that a site occupied at present is suitable (defined as such simply by presence of the butterfly) and that, with proper management, it can remain so indefinitely and perhaps, be improved. Without full knowledge of optimal conditions, we commonly lack any scientific or otherwise justifiable definition of an 'optimal site' but, notwithstanding this aspect, this approach is essentially short to medium term if pursued in isolation, because it ignores some of the important implications of climate change within the region. The site-based examples discussed indicate possible limitations of this strategy for longer term conservation, should those sites become untenable. Several of the taxa show distributions that suggest classic features of vulnerability to warming (Peters and Darling 1985), but data on range changes are not available to demonstrate any trends in distribution paralleling those now well-documented for Europe. Exploring the current climate ranges occupied by 77 endemic Australian butterflies, and modeling scenarios of distributional change with several different projected temperature regimes (Beaumont and Hughes 2002) implied that even species with currently wide climatic ranges may be vulnerable to change, and that several more narrowly distributed taxa may be particularly vulnerable

Table 3.8 The seven endemic butterfly species identified by Beaumont and Hughes (2002) as likely to be at particular risk from climate change

Taxon	Distribution	
Hesperiidae		
Exometoeca nycteris	WA	?relictual species, low dispersal ability
Trapezites heteromacula	Northern Qld	Large range contraction implied by models
Lycaenidae		
Hypochrysops halyaetus	WA	Obligate myrmecophile, large range contraction implied by models
H. piceatus	Qld	Obligate myrmecophile
Jalmenus clementi	WA	Obligate myrmecophile
[a]*J. lithochroa*	SA	Obligate myrmecophile
Nesolycaena urumelia	Q, NT	

[a] The only Bassian species considered at risk

(Table 3.8). The latter included four myrmecophilous Lycaenidae, with these and two Hesperiidae all regarded as poor dispersers, and a further lycaenid (*Neolycaena urumelia*) which is ecologically specialised and geographically restricted. Only one of these seven falls geographically into the scope of this book: *Jalmenus lithochroa* (p. 22), a South Australian endemic species, has become extinct in the southern parts of its range around Adelaide. *Hypochrysops piceatus* is the closest other candidate. It occurs in southern central Queensland as a notable local endemic species of considerable conservation concern. Three of the other five taxa noted are confined to Western Australia, and the other two are tropical northern species not found close to any Bassian region.

Several south eastern butterflies, nevertheless, have distributions that imply strongly that they may be lost with climate changes. Alpine endemics, such as *Oreixenica ptunarra* in Tasmania, and *O. latialis theddora*, found only on the upland plateau of Mount Buffalo, Victoria, already occupy the highest terrain available and are absent from lower areas adjacent to these (Chapter 8). If their distributions are indeed restricted by temperature (either directly or by influencing key resources) they would appear to have 'nowhere to go' if they cannot tolerate warmer regimes in the future. Evidence is not yet to hand to determine whether temperature is indeed the limiting factor for their distribution, but this supposition is held widely, and parallels concerns elsewhere in the world for high altitude taxa. Butterfly ranges are not permanent, and shifting distributions (such as northward expansion in Britain) have been attributed with reasonable confidence to climate warming, at a time when loss of natural habitats has never been greater – so that opportunities to track critical resources across landscapes are progressively reduced (Hill et al. 2002). Practical conservation for the longer term cannot ignore the likelihood of such changes and, where possible, may need to include plans for site suitability that anticipate changes decades into the future (New 2008b). This complex scenario is discussed further later (p. 107).

More generally, increased surveys are often stimulated or facilitated by designation of taxa through listing or other recognition that gives them priority, often as an initial step to gain more basic information. In some cases, more intensive searching fails to reveal additional populations or sites, and confirms the conservation need. In others, further populations are found, and the threat supposed earlier may thus not be as severe as originally thought. Before Neyland's (Neyland 2001) targeted surveys for the skipper *Oreisplanus munionga larana* in Tasmania, it was known from only two localities (Neyland 2001; Bell 2002). In addition to confirming its presence at these, Neyland found five further localities in north western Tasmania, all associated with presence of the sedge *Carex appressa* in swampy lowland areas, and all less than 50 m above sea level. It was later discovered on a north coast site (at Penguin), some 70 km east of any previously-known site (Bell and Miller 2005). Although some of the sites, on private land, were vulnerable to damage from agricultural clearance and cattle grazing, this survey did much to increase perspective of the conservation needs and status of this skipper.

An important general qualification (or caveat) flowing from this must be emphasised here – that any 'conservation status' category allocated to an Australian butterfly is often open to severe revision, and that status must be considered dynamic, rather than a permanently allocated condition as sometimes presumed. Perspective for any putatively endangered or vulnerable taxon can change rapidly in response to chance discovery (or planned survey) of additional populations, often far from any site on which the taxon has been recorded earlier. Several taxa currently ranked highly on the basis of only single populations, or very few sites, known in the region may thus perhaps be demonstrated to be less threatened. As emphasised earlier, surveys even for many notable butterfly taxa are still highly incomplete: the perspective in this book is based on information in the public arena at October 2009.

Part II
Cases: Subspecies to Communities

Chapter 4
A Wetland Skipper on Sedges: *Hesperilla flavescens*

4.1 Introduction

Two genera of trapezitine skippers are particularly diverse in eastern Australia, and the taxonomic limits of some species within both *Trapezites* and *Hesperilla* are by no means clear. The particularly anomalous skipper *Hesperilla flavescens* was noted earlier to demonstrate the taxonomic complexity within the radiation to which it belongs. Disjunct at the western and eastern extremes of the documented range of the complex (Fig. 4.1), putatively distinct subspecies of this skipper have very similar ecology, and also considerable conservation interest. A comparative account of these helps to demonstrate the approaches to conservation management in the two range states and which arise from parallel but independent threats in the two regions, South Australia (for *H. f. flavia*) and Victoria (for *H. f. flavescens*). The major threats to both have involved habitat loss and degradation of restricted near-coastal saline sedgelands, particularly associated with pressures of urban expansion and with consequent reduction of larval food.

Caterpillars of both these skippers feed almost wholly on one species of sedge, *Gahnia filum* (with a series of common names including chaffy sawsedge, smooth cutting grass, thatching grass), that grows in dense tussocks and up to around 2 m tall, so that it is often amongst the tallest vegetation on sites dominated by low vegetation. In freshwater, the tall tussocks serve as 'resting platforms' for water birds and water rats (*Hydromys chrysogaster*) (Savage 2002). Although other species of *Gahnia* have been reported as food plants (*G. radula* for *H. f. flavescens*, *G. deusta* for *H. f. flavia* [Grund 2002b]) feeding records on several other *Gahnia* species all seem to refer to the very closely related skipper, *Hesperilla donnysa*, itself a very variable taxon. Most of these records are from dryer situations than the saltmarsh habitats frequented by *H. flavescens*. Older, senescing tussocks become unpalatable to the caterpillars and are avoided for oviposition, so that the complementary needs for conservation are protection of *G. filum* sites and maintaining a supply of the sedge in suitable condition.

The female skippers lay eggs on *Gahnia* foliage, usually near the ground, and the caterpillars construct characteristic 'shelters' by securing leaves together. They take refuge in these by day and emerge to feed at night, on young tender foliage.

T.R. New, *Butterfly Conservation in South-Eastern Australia: Progress and Prospects*,
DOI 10.1007/978-90-481-9926-6_4, © Springer Science+Business Media B.V. 2011

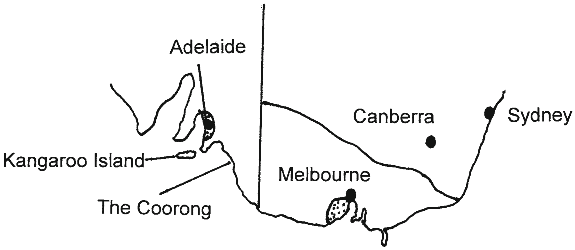

Fig. 4.1 *Hesperilla flavescens*: disjunct distribution of the two subspecies. *Dotted areas* indicate ranges of *H. f. flavia* around Adelaide and *H. f. flavescens* to the southwest of Melbourne; much of the intervening area is occupied by forms of the closely related *H. donnysa*, with some populations in Victoria approaching *H. flavescens* in appearance

Each successive instar constructs a larger retreat, and pupation takes place in the last one, which may be around 7 cm long. The skipper has two major flight periods, in spring (September/October) and late summer (February/March), but it remains unclear whether these represent two generations or a protracted or bimodal emergence from pupae of the same generation. A related skipper, *Hesperilla chrysotricha*, is also found on *G. filum* at some sites in Victoria, but for this species *G. filum* is only one of a range of food plants. This skipper occurs also in dryer areas and the caterpillar shelters are formed by 'twisting' leaves, so that the spiraled shelters are distinguished easily from the parallel leaved shelters of *H. flavescens*. The pupal shelters of *H. chrysotricha* are also closed by a plug of silk, a further way to differentiate the two taxa (Braby 2000).

4.2 *Hesperilla flavescens flavia*

H. f. flavia formerly occurred on the Northern Plains area close to Adelaide, but is now almost certainly extinct there. The formerly quite extensive *G. filum* sedgeland has been almost wholly destroyed in former strongholds for the skipper, for example around St Kilda (an outer northern coastal suburb of Adelaide), by stock grazing, horticulture, and urban and industrial developments (Coleman and Coleman 2000). Only small patches of the sedge remain and, because it is unpalatable to stock, it has been continually removed by farmers slashing and burning it as a component of pasture improvement. However, the Colemans noted that destruction of small remaining patches of *Gahnia* on vulnerable sites such as roadsides has simply been because of ignorance of its importance, so that signage and effective information may help to protect such areas. Elsewhere in South Australia, the butterfly is rather variable and occurs in highly disjunct populations, not all of which may be strictly referable to subspecies *flavia*. They were accepted under this name for conservation assessment by Sands and New (2002). All historical sites for *G. filum* near Adelaide are low-lying – up to only about 9 m above sea level – and are most typically on supratidal floodplains. The major habitats comprise tidal saltmarshes, freshwater tidal wetlands and saltmarsh communities and, as noted earlier, the butterfly is amongst those of high conservation concern in the state. Sands and New accorded it a lower conservation ranking of 'Vulnerable,' based on what was then considered by experts consulted as strong likelihood of it thriving in the extensive apparently suitable areas of the Coorong (Fig. 4.1). However, this has not yet been confirmed and recent persistent drought may have reduced this likelihood considerably: in that eventuality, Sands and New (2002) forecast a higher conservation status. Grund (1997) had earlier signaled the need for surveys in the Coorong as a prime conservation need for *H. f. flavia*. Until now, conservation surveys have been concentrated around Adelaide, in parallel with those for *H. f. flavescens* near Melbourne. However, the latter still exists in the area, whereas efforts for *H. f. flavia* involve primarily assessment of habitat quality and needs for restoration to precede possible re-introduction of the butterfly, either from elsewhere or from any remnant population that is discovered, should it be strong enough to withstand removal of insects for this purpose.

The variety of factors contributing to the decline of *G. filum* in South Australia (Coleman and Coleman 2000) indicate the spectrum relevant in many parallel situations of food plant loss: weed invasions (with features such as grass growing around tussocks hindering oviposition by the butterflies), dust from roads, vehicle use (including recreational vehicles), stock grazing and clearing as above, grazing by rabbits and hares, fire, fragmentation of stands with progressive clearing, collection of *Gahnia* seedheads for dried flower arrangements, drift of various chemicals used nearby for mosquito and weed control and for other agricultural operations, drainage for land reclamation, and damage by possible overcollecting of butterflies. Land drainage and clearing were viewed as likely threats in the Coorong (Grund 1997).

However, despite this wide array of threats, knowledge of the butterfly's biology is sufficient to formulate well-focused recovery planning, centred on *Gahnia* restoration and protection. Notably, Coleman and Coleman (2000) regarded *H. f. flavia* as a taxon for which butterfly collecting might indeed prove problematical. At present this is not the case on the Adelaide Plains, simply because no butterfly populations are known! In common with some other trapezitines, the usual means of collection by hobbyists is to take the larval shelters and rear the caterpillars or pupae through to freshly emerged adults. Collectors may be tempted to remove more shelters than the specimens they need, to compensate for parasitisation and other mortality. Any small newly-discovered population near Adelaide, or any future re-introduced population, could indeed merit total protection from exploitation, at least while its status was being explored properly or the introduced population established.

A companion recommendation was for all potential sites for *H. f. flavia* on the North Adelaide Plains to be monitored annually for the butterfly. Monitoring of populations on Yorke Peninsula was also noted as a means of increasing knowledge, and as a likely source of material for any translocations planned in the future. Unusually in relation to many other butterflies in Australia, neither the butterfly nor its food plant is afforded specific protection under any local state law, so that

Table 4.1 Threatening processes affecting *Hesperilla flavescens flavia* in South Australia (Coleman & Coleman 2000) (compare with Table 4.2)

Habitat loss	Clearing for grazing, horticulture
Habitat modification and disturbance	
Weed invasion	Woody weeds and introduced grasses
Vehicle access	Recreational vehicles on boggy sites
Dust	Roadway dust may reduce palatability of foliage
Fire	Could destroy all available food on a site. *Gahnia* regarded as high fire risk
Grazing and clearing	Young sedges vulnerable; also from hoof damage; clearing often to 'improve' pastures
Feral animals	Uprooting, burrowing and feeding by rabbits and hares
Isolation and fragmentation	Consequences of many of the above processes
Seed and grass collection	Dried flower arrangements; formerly for thatching
Direct threats	
Chemical spraying	Direct sprays for weed control; drift from aerial sprays against mosquitoes and from nearby agriculture/horticulture
Drainage and sea-level change	All sites vulnerable, as low-level
Collecting	Possible over-collecting of larvae for captive rearing

implementation of conservation measures lacks this formal endorsement. *Gahnia filum* sedgeland is regarded as a vulnerable community on the Eyre Peninsula.

The major threat abatement plan (Coleman and Coleman 2000) had 12 objectives (Table 4.1), covered the practical themes in a variety of ways, and recognised also the importance of increased community education and awareness. The social (including acceptance) and economic dimensions and consequences of any such plan are likely to drive its success, and the Colemans considered these in some detail. Central to this is that the community should have the opportunity to be informed fully of the activities proposed and also opportunity to become involved in the project. Implementation of the plan was agreed to by several local legislations and authorities (Cities of Salisbury and Playford, Penrice Soda Products Dry Creek Saltfields, Defence Estate Organisation), all represented on the Butterfly Recovery Team, and part of the land in the Dry Creek Saltfields had been zoned 'conservation.' Plans to regenerate *G. filum* were to be included in the Defence Estate Organisation's Environmental Management Plan.

4.3 *Hesperilla flavescens flavescens*

Conservation measures for *H. f. flavescens* have been concentrated almost wholly on the populations near Altona, an outer western industrial suburb of Melbourne with nearby areas a focus for housing developments to accommodate the city's

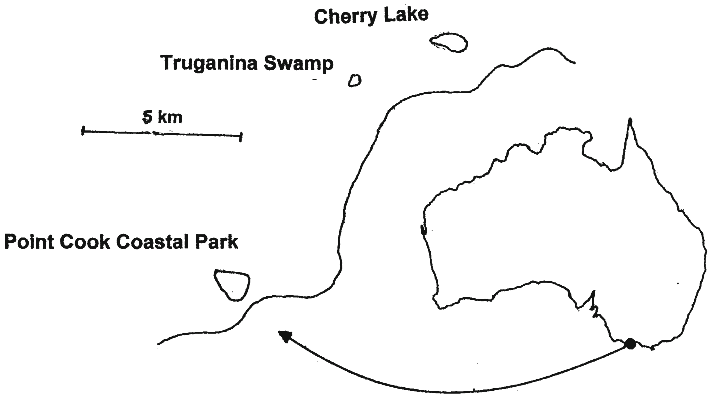

Fig. 4.2 The major population sites for *H. f. flavescens* near Melbourne (after Relf & New 2009)

fast-expanding population. As for *H. f. flavia*, the primary needs have been to increase security of *G. filum* sites and to improve site carrying capacity by restoration. Extensive drainage of the swampland in the region led Crosby (1990a) to estimate that wetland area had been more than halved in the preceding 40 years, so that (also as for *H. f. flavia*) most remaining sites supporting *Gahnia* are small, vulnerable and increasingly isolated from each other. The four major and most important populations of *H. f. flavescens* occur at Point Cook Coastal Park, Cheetham Wetlands, Cherry Lake (Altona) and Truganina Swamp (Altona), with the most distant of these sites separated by only about 10 km (Fig. 4.2). Three of these sites were designated by Crosby (1990a) as 'essential to preserve,' and more recent information on butterfly populations there has confirmed their significance (Savage 2002, Relf and New 2009). Crosby's estimates of population sizes from his 1988 counts of shelters were 250 (Cherry Lake, with a further 100 on adjacent private land), 600 (Truganina Swamp), and around 250 (Point Cook). In addition to these important 'reference sites' supporting the most extreme yellowish phenotype, Crosby advocated conservation of all sites supporting other populations that he attributed to this subspecies, as aids to documenting the evolutionary diversification in this complex. Truganina Swamp covers about 148 ha, and Cherry Lake and nearby sedgeland, some 176 ha – including the lake area of about 60 ha under non-drought conditions. Both areas have been modified by Melbourne Water to prevent drainage problems to nearby properties, and weed and rabbit suppression are ongoing maintenance issues. Cherry Lake is the focus of several school environmental education programmes, related to measurement and importance of water quality and wetland ecology, in which the skipper is a main focus.

The general threats to these populations (Table 4.2) differ considerably, leading Crosby (1990a) to list rather different priorities for management of each site. Thus, Cherry Lake was widely accessible to the public as a council reserve, so that trampling and vehicle use occurred, with horse grazing on the adjacent colony.

Table 4.2 Threatening processes nominated as affecting *Hesperilla flavescens flavescens* in Victoria (Crosby 1990a) (compare with Table 4.1)

Pollution	Both atmospheric and water pollution effects might arise, related to industrial proximity to populations near Melbourne. Pesticides from agricultural activities
Human interference	Trampling, rubbish dumping, dust creation, recreational activities
Animal interference	Horses or stock eating or trampling sedges
Fire	Likelihood increased by human activity
Changed hydrology	Excessive flooding or lack of water. Drainage of swampland a major cause of habitat loss
Weed invasion	Overgrowth, competition
Population dynamics	Predation, parasitism, disease
Overcollecting	

In contrast, Truganina Swamp had not been generally open to people, a restriction that Crosby recommended should continue, particularly to prevent vehicle (including trail bikes) access. However, a number of houses bordering the area had rear gate access. These two sites were under the control of the same management body, now known as Melbourne Water, so that a joint management approach could be contemplated, under supervision of a dedicated ranger. As well as vehicle and people control, measures needed included weed and rubbish removal, and additional fencing to exclude horses. These two sites together were seen as the highest priority for conservation of *H. f. flavescens*, with maintenance of *Gahnia filum* a key need. Point Cook, administered by Parks Victoria, abuts an airfield and is less subject to development pressures, although visited by many people. The main areas of *Gahnia* there are separated from roadways by fencing.

As a result of trials by Savage (2002) and information summarised by Coleman and Coleman (2000), considerable expertise is now available on propagation and enhancement of *G. filum*, and how regeneration may be encouraged. Fire promotes rapid and extensive new growth from burned tussocks, and is an important management component to regenerate senescing tussocks. As Savage noted, the tussocks burn with 'intense heat,' and control burns with wind speed of 6–10 km/h allow fire spread without losing ability to control it by hosing (for example, from pumps mounted on four-wheel-drive vehicles). Fires do not carry well under wholly calm conditions. Using propane torch ignition, 6–10 plants can be burned at any one time. Following summer burns (January–February), burned tussocks often recover rapidly, with fresh foliage suitable for oviposition appearing within a few weeks. The minimum period detected for presence of larval shelters (Fig. 4.3) was only six weeks after burning, so that later summer oviposition can proceed well.

Burning at other times of the year was also successful, with a June burn leading to presence of shelters at the first natural opportunity in the following spring. Shelters were found on nearly half (53) of 120 tussocks accidently burned in late September/early October at Cherry Lake toward the end of the following summer (Relf and New 2009), with a maximum of four caterpillars/tussock. Very high levels of tussock recovery have been reported, both from control burns and arsonist

Fig. 4.3 Larval shelters of *H. f. flavescens* on *Gahnia filum*: (**a**) appearance of entire shelter on foliage; (**b**) shelter opened to show head of resident caterpillar (photos: M. Relf)

activity, but recovery is much slower in the cool parts of the year than in summer. At least a 5 year interval between burns was suggested by Coleman and Coleman (2000), but Savage (2002) believed that the need to burn should be assessed from site assessment and shelter counts, rather than burning at any fixed interval. No more than half of a site should be burned in any year, and the Colemans recommended burning in autumn and early winter (April–August) to allow better control and cooler fires. Under hot dry conditions, burning may kill the tussocks.

The ability to control burns within narrow limits facilitates 'micromosaic management,' whereby individual tussocks – particularly if they lack contiguous foliage with neighbours – can be selected for treatment, with prior inspection ensuring that no caterpillars are present on them. If necessary, occupied shelters can be removed and placed on other suitable tussocks. Occupied tussocks constitute refuges from which adults may move to others as they become suitable through regeneration. Larvae or pupae sequentially occupy tussocks for much of the year, so leaving only a narrow 'window' of non-occupancy for non-selective burns without causing mortality to early stages, namely the first few weeks of the first adult flight season, preceding the bulk of oviposition. However, such burns may risk loss of oviposition sites and food for young larvae unless suitable tussocks are left unharmed as nearby refuges.

Slashing tussocks also allows regeneration, but not as well as achieved by burning. Propagation from seeds is straightforward, but some control of seed harvest may be needed for small *Gahnia* populations. Although reputedly hard to germinate, Savage (2002) noted that seeds collected at any time of the year germinated in 6–7 weeks. Seedlings are also easy to transplant, and several commercial nurseries (in both states) now supply tube stock for planting, in part with a view to encouraging sympathetic land-owners to replace *Phragmites* reeds in wetlands and *Pandanus* as a garden ornamental with *G. filum*.

Both numbers and distribution of larval shelters may be useful indices of *H. flavescens* population size and dispersion and, hence, of conservation status. They are much more easily counted than the fast-flying adults in which their strong flight allows for butterfly movement over at least several hundred metres. Whereas there may be some chances of suicidal dispersal, skipper presences on *Gahnia* translocated to unoccupied areas at Point Cook (Savage 2002) showed colonisation by skippers that must have moved at least 500 m from the nearest population, and such movements suggest a possible metapopulation structure across disjunct patches of *G. filum*. Numbers of shelters were low at one sedge translocation site, possibly because when inspected many of the tussocks were still protected from rabbit grazing by individual plastic sleeves that might have impeded access by butterflies. Colonisation ability has important implications in considering expansion of conservation activities from individual sites to wider landscape scales, directly relevant to a continuing community conservation project at Altona. The Altona Secondary College have fostered use of seed-grown *G. filum* in gardens (Goss 1999), and these have potential to provide 'stepping stones' for the skipper and to increase connectivity between sites. An allied tactic is to explore deliberate translocations of butterflies to sites prepared by planting *Gahnia*. In general, before taking this risky step with genuinely rare species, experimental translocations of related more common taxa may help to guide methodology and reduce the risk of using threatened species initially. In this case, the parallel translocation of *Trapezites symmomus symmomus*, a trapezitine skipper widespread in southern Victoria's wetlands, to a site near Melbourne prepared by planting the larval food plant (*Lomandra longifolia*) might be informative (Braby 1991).

Revegetation of the Altona skipper sites has received considerable community support, with extensive plantings of *G. filum*, as well as other saltmarsh plants as nectar sources. The partnership of Dow Chemicals and the Hobsons Bay City Council has resulted in substantially increased suitable habitat and prevention of pollution to the wetlands. The project received several prestigious environmental awards in the early 2000s. Representative scenes of gahnia tussocks and their condition at the main sites are shown in Figs. 4.4–4.8.

Fig. 4.4 Tussocks of *Gahnia filum*, planted to extend range at Point Cook

Fig. 4.5 Distribution of *Gahnia* tussocks as narrow fringe along lake shore at Point Cook

Fig. 4.6 Dense senescing tussocks of *Gahnia filum*, Cherry Lake, Altona

Fig. 4.7 Replanting tussocks of *Gahnia filum*, Cherry Lake, Altona

Fig. 4.8 Cherry Lake, Altona, view across lake from south west to indicate nearby industrial complexes

Chapter 5
The Australian Hairstreak, *Pseudalmenus chlorinda*

5.1 Introduction

This lycaenid is included here as one of the most spectacular regionally endemic butterflies, which is taxonomically complex, and for which conservation status of the various named subspecies continues to be debated. It is thus one of the taxa of considerable conservation interest, but for which any management (even if this should be needed) can still be couched only in general terms, based on a broad knowledge of distribution and critical resources. *P. chlorinda* exemplifies the many butterflies that at one level are data deficient, but for which broad knowledge is sufficient for 'reasoned inferences' to be made. The hairstreak (Fig. 5.1) represents a monotypic genus, and occurs only in Tasmania and on the southeast mainland, from northern New South Wales to western Victoria (Fig. 1.4, p. 10). It appears almost certain that it reached Tasmania across former land bridges from the mainland. At least six named subspecies are generally acknowledged, with some workers recognising seven, and at least one further, undescribed, subspecies may occur in Tasmania (Prince 1988b, Braby 2000). The complex history of tracing the type locality in Tasmania in order to establish the correct priority name is summarised by Couchman (1962). Although most subspecies, and populations, are highly localised, occasionally the butterfly can be quite abundant where it occurs (Wragg and Elgar 1997). Whereas the species as a whole appears not to be nationally threatened, strong concerns have been expressed for some localised subspecies, particularly in Tasmania where several forms occur in a relatively small area, with some separated by only short distances. Notwithstanding their consistent differences in adult appearance, the life histories of the Tasmanian subspecies are reportedly very similar (Prince 1988b), and are assumed so in comments on needs for conservation management.

5.2 Biology and Conservation

Most populations of *P. chlorinda* are univoltine with adults appearing in October–November, but some mainland populations apparently have a partial second generation (Braby 2000). Larvae of all subspecies are associated with the ant

T.R. New, *Butterfly Conservation in South-Eastern Australia: Progress and Prospects*, 67
DOI 10.1007/978-90-481-9926-6_5, © Springer Science+Business Media B.V. 2011

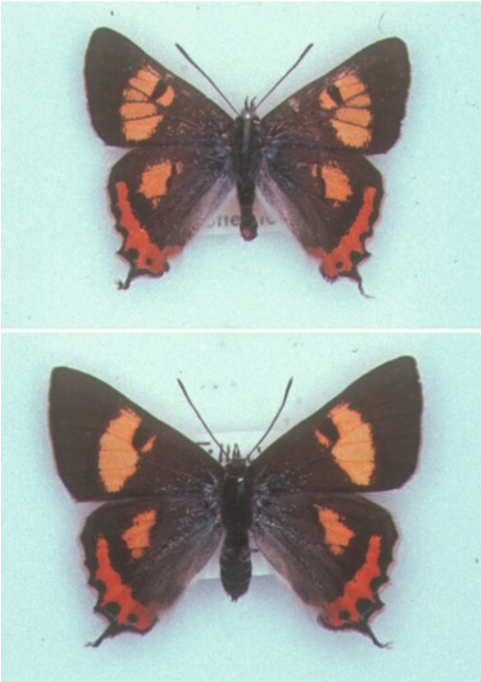

Fig. 5.1 *Pseudalmenus chlorinda zephyrus*, male (*above*) and female

Anonychomyrma biconvexa (cited by some workers as *Iridomyrmex foetans*: Prince 1988b). Caterpillars feed on *Acacia*, with the bipinnate *A. dealbata* the major Tasmanian host, and somewhat greater variety (including phyllodinous species) reported from the mainland. Pupation normally occurs under the bark of nearby eucalypts, in Tasmania mainly being *Eucalyptus viminalis*, so that the critical resources for the butterfly are the coincidence of the ant, acacia and eucalypt, usually in open woodland environments. Fully grown caterpillars are believed to follow ant trails to eucalypts near the acacias in order to pupate. In Tasmania, the availability of this combination of resources has been reduced substantially by land clearing, leading to equivalent losses of *P. chlorinda* (Couchman and Couchman 1977). Indeed, Couchman (1962) then suggested that *P. chlorinda* in Tasmania 'has suffered more than any local species of butterfly'.

Six subspecies of *P. chlorinda* were considered separately in BAP. For most of these, varying opinions on conservation status and need have been expressed, and substantive evidence is rather sparse. Thus, *P. c. conara* in Tasmania has been of concern, following Couchman and Couchman's (1977) suggestion that about 80% of known habitat had been destroyed. Further assessments were 'Threatened' (Hill and Michaelis 1988) or 'Vulnerable' (Prince 1988b). Some specific populations have been reported lost, with land clearing for pasture or woodchip production, and from fires, but Dunn et al. (1994) noted the irregular appearance of this butterfly – so that its apparent absence reflecting a possible irregular diapause regime may be mistaken for extirpation. Advice from entomologists with recent field experience in Tasmania suggested that sufficient good habitat remained to sustain the butterfly and that it is not currently in need of additional management. However, this situation clearly depends on continuity of habitat, and permanent protection may be needed to increase this security. Such differing opinions over extent and quality of remaining habitats for *P. chlorinda* are difficult to resolve, so that any conservation status attributed is inevitably somewhat subjective.

The biology and status of the western Victorian endemic *P. c. fisheri* led Douglas (1995) to assess it as Vulnerable. Within the Grampians National Park, where few recent records exist – it has not been taken since 1978 – historical records are from only five sites. Caterpillars occur on *Acacia melanoxylon* in humid elevated environments and, even if it still exists, the subspecies appears to be very localised. Considerable apparently suitable habitat still occurs in the park and detailed surveys are needed to ascertain its status. The low conservation ranking accorded in BAP reflects opinion that the butterfly is highly likely to still exist, in relatively secure habitat, but also uncertainty over the validity of the subspecies since Braby (2000) referred it to synonymy with *P. c. zephyrus*, by far the most widespread subspecies. *P. c. zephyrus* is somewhat variable in colour intensity and its recognition is confused also in Tasmania, where Prince (1988b) noted a subspecies as 'near *zephyrus*' (below). On the mainland *P. c. zephyrus* is sometimes abundant (Braby 2000) and apparently more secure than the similar Tasmanian entity.

Most of the more direct information on the Tasmanian complex of subspecies was obtained by Prince (1988b), whose overall assessment for the species in Tasmania was 'Vulnerable'. However, the different subspecies were appraised somewhat differently, with *P. c. myrsilus* and tentatively also *P. c.* near *zephyrus* considered 'Endangered' and *P. c. chlorinda* and *P. c. conara* as 'Vulnerable'. From his initial survey of label data from specimens of *P. chlorinda* in all major collections in Tasmania, Prince identified 66 locations where the butterfly had been collected. Fifty two of these were re-visited, together with nine additional sites reported more recently. Most sites were lowland, with 55 at elevations of 25 m or less, and a further 22 between 26 and 75 m. Comparison of a number of parameters at sites occupied by *P. chlorinda* suggested some correlated features that might be desirable in management for the butterfly, and be sought in further surveys as clues to where it might occur. Most occupied sites (80%) were on level ground (47%) or had a northerly aspect (33%). Almost all pupae (a stage that, because of the persistence of pupal remains after adult emergence, is particularly suitable for survey) were on *Eucalyptus viminalis* (92% of occupied trees), with small numbers on *E. amygdalina* and *E. pulchella*, and very occasional occupancy of *Banksia* or *Acacia*. Most eucalypts with pupae were associated with nearby *A. dealbata*, a few with the similar *A. mearnsii*, and occasional individuals with *A. melanoxylon* or *A. sophorae*. The wattles were usually (62%) less than a metre from the eucalypt, with a further 25% only 1–2 m away.

The conjoint components of this resource suite appear to have disappeared from many of the sites historically recorded for *P. chlorinda*, largely from changes in land management. Fire was probably a major contributor to habitat loss on some sites, in removing understorey vegetation and the loose eucalypt bark under which pupation occurs; effects of fire on the host ant are not yet clear. Vegetation clearing is even more pervasive and is a major threat to many of the sites reported by Prince (1988b). In rural areas, complete clearance of woodland and forest for pasture has been widespread and, although small remnants continue to support *P. chlorinda,* it is far less certain that small groups of trees can be colonised or re-colonised. The butterfly is believed to be rather sedentary, despite its fast and active flight, so that populations in such remnants may be relict. However, even single eucalypt trees with understorey and ants can support populations over many years. Sites with many occupied trees (as in Sherbrook Forest, Victoria: Wragg and Elgar 1997) may have special conservation significance.

5.3 Discussion

The major general conservation needs for *P. chlorinda* in Tasmania, and paralleled on the mainland, are habitat protection and restoration. The latter includes plantings of *A. dealbata* close to suitable eucalypts, and wider maintenance of *Acacia* understorey vegetation. In some places, slashing of acacias around eucalypts has rendered sites untenable, and protection of any occupied sites may be needed. Sites close to towns are under pressure from urban expansion, and resultant high land values hamper land purchase for reservation. Prince (1988b) considered raising community awareness an important component of conservation, and a variety of other tactics – such as translocations – may also merit consideration. Trial translocations noted by Prince have already led to established populations persisting for several years.

However, *P. chlorinda* demonstrates well the confusions that arise in many butterfly conservation programmes in Australia, namely (1) taxonomic uncertainty over the status of several apparently distinctive and geographically restricted forms treated at present as subspecies, and (2) uncertainties over the causes of irregular appearance and abundance. Irregular diapause has been reported (and more frequently inferred) in several Australian butterflies, but most of these reported cases have not been examined experimentally. Evaluating conservation status generally depends on counts of adults, so that any biological irregularities that affect apparency may (unless detected!) hamper interpretation of trends, and determination of management needs. Irregular development has been reported (and diapauses inferred) in egg and pupal stages of several lycaenids (Sands and New 2008). Pupae of *P. chlorinda* may hatch within about a month or remain dormant until the following season. The causes of this difference in development pattern are not yet clear.

Chapter 6
Tales of Two Coppers, *Paralucia* spp.

6.1 Introduction

The Australian endemic lycaenid genus *Paralucia* comprises three species of 'coppers', two of which have gained special recognition in understanding and promoting butterfly conservation in different parts of the south east. Each has led in the development of the discipline in its State, been accorded a patronymic common name that fosters local pride and involvement, and is an important flagship species. Conservation management for both is continuing, and the accounts below indicate the similarities and differences between two closely related taxa, both in their biology, and in progress of practical conservation under different legislative requirements. They demonstrate the common elements in approach possible for different species linked with similar resources, and also the peculiarities that each may show.

6.2 The Eltham Copper, *Paralucia pyrodiscus lucida*

No butterfly has been more important in increasing the profile of butterfly conservation in Victoria than the lycaenid subspecies known as the Eltham copper, after the outer north east suburb of Melbourne where it was rediscovered in 1987 (Braby 1987, 1990; Braby et al. 1992, 1999). It has become an important flagship species, both alone and as one of the trio of Victorian invertebrates (the others being the Hemiphlebia damselfly, *Hemiphlebia mirabilis*, and the Giant Gippsland Earthworm, *Megascolex australis*) instrumental in demonstrating the ecological variety of invertebrates around the time of the state's Flora and Fauna Guarantee Act 1988 starting to become effective (Yen et al. 1990). Because of the wider importance of this case, it is discussed in some detail to illustrate increased awareness of butterfly conservation in the region.

This subspecies was described only in 1951 (Crosby 1951), having been collected from a number of sites around Eltham and nearby Greensborough from about 1923–1936, but with the subsequent lack of records over the ensuing 30 or so years

T.R. New, *Butterfly Conservation in South-Eastern Australia: Progress and Prospects*,
DOI 10.1007/978-90-481-9926-6_6,

suggesting that it might even have become extinct over that period, as urban Melbourne expanded to encompass much of the region. Although a small population on private land persisted (Endersby 1996), widespread belief in its extinction was alleviated by the discovery in January 1987 of a population on land scheduled for imminent housing development. The local Eltham community, long recognised for its environmental and artistic sympathies, embraced the butterfly as a local symbol, and the focus of a substantial conservation campaign. Fortuitously, the rediscovery was made during the development of Victoria's Flora and Fauna Guarantee Act, and the imminent loss of the site was rapidly brought to the attention of the then Minister for Conservation in a climate of some sympathy and awareness of importance of threatened taxa, and developing political sympathies. A second nearby colony, likewise scheduled for housing development, was also found. A briefing paper on the prospects for the butterfly on both sites was prepared for the then Department of Conservation, Forests and Lands, and followed by a commissioned survey of the butterfly's biology and conservation needs (Crosby 1987) as the prelude to a management plan (Vaughan 1987, 1988).

Crosby (1987) noted that the copper had been known in Victoria for around a century, and had apparently disappeared long ago from many of its historical sites close to Melbourne. The history of discovery in outer Melbourne emphasised the importance of the butterfly both alone and also for establishing 'the principles of conservation'. Crosby surveyed 50 sites in April 1987, predominantly to detect the host ant with the larval food plant, and the resulting additional discoveries raised the total in the Eltham area to seven occupied sites, some of them very small and with correspondingly tiny butterfly populations. In addition, a colony reported from nearby Yarrambat in 1983 was confirmed lost with the food plant overgrazed by stock. A number of conservation recommendations included establishment of a butterfly sanctuary by either revoking the entire housing estate development or protecting the parts inhabited by the butterfly colonies. The two separate areas affected were then designated the 'western colony' and the 'eastern colony', which names are still in use (Fig. 6.1), together with the nearby Pauline Toner Reserve. Crosby's investigations were made possible only with the cooperation of the developer (Esanda) and a moratorium on building pending its outcome and review. The ensuing options paper from the Department (Saunders 1987) emphasised the importance of transferring the land areas into public ownership in order to manage them for the butterfly. With the Minister's cooperation, and strong support from the State and Shire Governments, a major public appeal was launched to raise funds for land purchase. The Eltham Council also negotiated a land swap for part of the site. Major funding raised included Au $250,000 from the State Government, Au $125,000 from Eltham Shire, and Au $56,000 from public efforts involving a considerable variety of activities.

Crosby's (1987) report was also the foundation for construction of a management plan, in which Vaughan (1987, 1988) recognised the need for an embracing conservation strategy in addition to individual site-based management actions for each main population. By 1988, the number of populations known in the Eltham/Greensborough area had increased, and the butterfly had been confirmed to occur

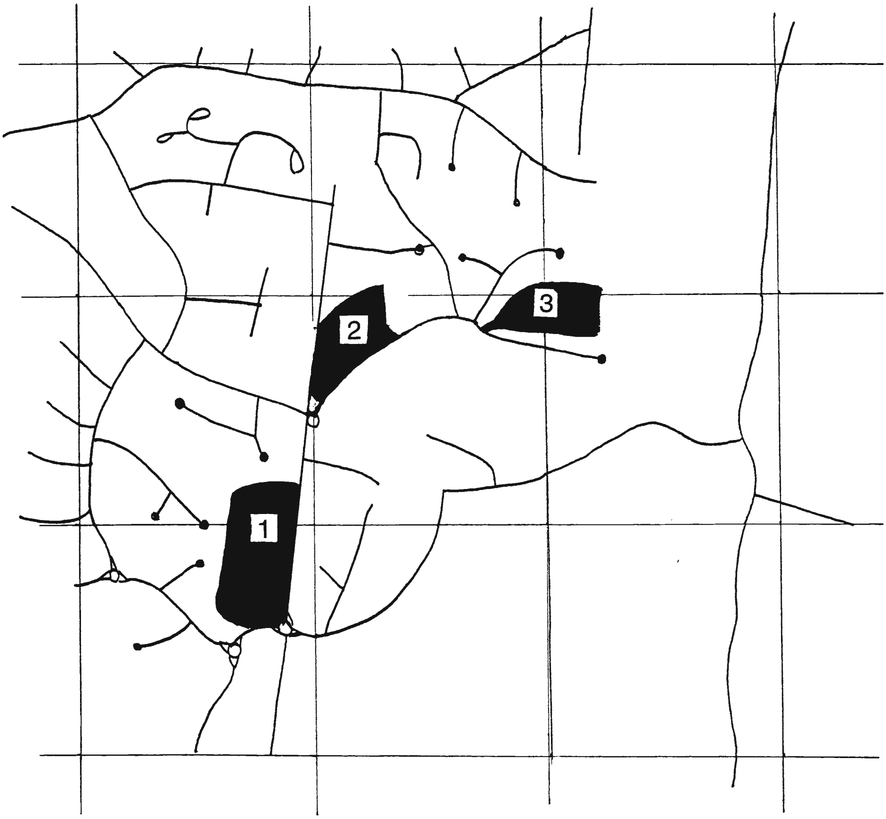

Fig. 6.1 Isolation of sites supporting *Paralucia pyrodiscus lucida* in Eltham by urban development

also at two widely separated historical localities, at Kiata/Salisbury and Castlemaine (Fig. 6.2). Altogether, Vaughan checked about 189 sites for the butterfly's presence, with these varying widely in apparent suitability.

The modified conservation plan accommodated needs for the two potential butterfly reserves in Eltham. A third major focus in the area, only a few hundred metres away from the western colony, was on land then owned by the Education Department but due for sale. *Paralucia* was distributed widely on that site, which was used by the public for recreation, and had a network of pathways. The other Eltham sites were small, apparently with very small butterfly populations, and by the time of Vaughan's (1988) plan 10 inhabited sites were known from the Eltham/Greensborough area. Several of these appeared vulnerable because of their small size and urban threats. The outcome of this public support campaign was protection

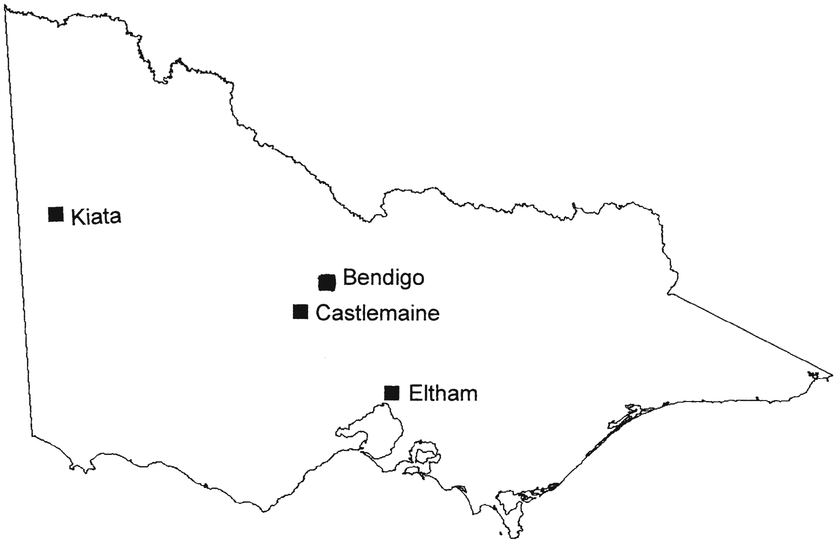

Fig. 6.2 Distribution of the major populations of Eltham copper, *Paralucia pyrodiscus lucida*, in Victoria

of the key areas for the butterfly near Melbourne. The former Education Department land was secured and designated the Pauline Toner reserve, named for the late local State government representative whose enthusiasm and support was of critical importance over this period. The important parts of the western colony (1.6 ha) and eastern colony (1.4 ha) were protected and, with the Pauline Toner Reserve, declared dedicated reserves for the Eltham Copper, with the butterfly's significance in increasing the importance of other reserves supporting populations (Andrew Yandell Reserve, Greensborough; Eltham Lower Park) also recognized. Although the number of building blocks previously planned for sale was thus reduced considerably (Fig. 6.3), their sacrifice for Victoria's first dedicated butterfly reserves apparently increased the commercial values of surrounding blocks. The Real Estate Institute of Victoria noted that flora and fauna conservation on a property is 'often relied upon as a positive benefit, adding value to the property asset' (quoted by Ahern 2002, from DCE 1991). A contemporary socioeconomic study (Grace 1988) argued that a 10% increase in market value of properties near the butterfly reserves within 11 months reflected 'proximity to areas of tranquility and environmental significance', flowing from the local community ethic. Local resident satisfaction also includes components of the retention of 'nature' in the local environment, and reducing future pollution and congestion. School education programmes included references to the Eltham Copper in many lessons, with its intricate biology and the importance of its conservation providing opportunities in many subject areas. The local community support group 'Friends of the Eltham Copper' was founded in 1989, and its members continue to provide invaluable support with monitoring and site maintenance activities in the region.

Fig. 6.3 Subdivision plans covering the then newly discovered Eltham copper sites in Eltham: (**a**) plan as originally proposed (from Crosby 1987) and (**b**) modified plan to allow conservation of reserves for the butterfly (from Vaughan 1988) (*shaded areas: distribution of butterfly populations*)

As noted above, those early surveys also confirmed the presence of *Paralucia* at two other, distant, localities in Victoria – the Castlemaine Botanic Gardens in central Victoria and the Kiata/Salisbury area of the Wimmera in the west of the state (Fig. 6.2). Historical records from both places, from which the copper had not been reported for many years, prompted new searches. One population at Kiata, for example, was known to have died out around 1956 (Crosby 1987), but Vaughan (1988) found it there on five sites. The major populations were on an area gazetted for a Flora and Fauna Reserve. A single small population was also found at Salisbury, several km further west. Much more recently, a substantial population has been discovered (2002) in Kalimna Park, Castlemaine, several kilometres from the Botanic Gardens site and a fourth major locality has been added with discovery of the copper at Big Hill, Bendigo in 2007 (Canzano and Whitfield 2008) and a second colony in the vicinity more recently. Exploration for further populations continues.

The present known distribution of the copper therefore includes (1) a series of populations on small urban sites isolated from each other by housing and related development; (2) the rural sites at Kiata/Salisbury, lacking pressures of urbanisation and with apparent potential for expansion across wider areas; and (3) periurban sites, in public reserves at Castlemaine and Big Hill, collectively constituting three rather different conservation scenarios. As Canzano et al. (2007) emphasised, the different site features and extents necessitate regional and site-specific conservation planning within the broader context of a statewide management plan.

The wide geographical range means that conservation responsibility devolves on a number of local and state authorities, with the situation near Melbourne particularly complex. The six major sites there, all within a maximum span of around 5 km, are managed by Parks Victoria (one site), Banyule City Council (one site), Nillumbik Shire Council (three sites) and privately (one site), with two of the Nillumbik sites owned respectively by Trust for Nature and Yarra Valley Water. The two Castlemaine sites are managed by Parks Victoria (Kalimna Park) and Department of Sustainability and Environment (DSE, Botanic Gardens), whilst those at Kiata and Bendigo are overseen by Parks Victoria alone or Parks Victoria with DSE.

In each area, the butterfly's distribution is very patchy and much less extensive than that of either the larval food plant or the associating ant. At each locality the butterfly populations occupy only small proportions (ranging from about 3–26%) of apparently suitable terrain. Broad characterisation of suitable habitat at the site level is thus possible. Near Melbourne, most populations occur in dryer *Eucalyptus* formations with some open grassy understorey including irregular scattered patches of the food plant. The areas are typically well-drained and have a northerly aspect. In contrast, the populations at Kiata are mainly on flat or gently sloping terrain with open cover of *Allocasuarina luehmanii*, but the larval food also very patchy. The initial impression gained is of sedentary, highly discrete and localised populations on each site, with adults appearing not to fly long distances. Small sites may not allow the full repertoire of dispersal behaviour, but flight activity estimated using mark-release-recapture techniques (Canzano pers. comm. 2009) indicated that individual movement within sites and between resources may be quite extensive. At Castlemaine, the entire *Paralucia* population of the Botanic Gardens moved (over several years) the several 100 m from the eastern to the western end.

6.2.1 Biology

Paralucia pyrodiscus lucida (Fig. 6.4) has one or two generations each year, with the adults appearing at different times across the three major distribution centres so far appraised. Around Eltham, the most intensively studied region, there is a clear univoltine pattern with adults present from about November–March. In the past, the late appearance of some adults in March or April has suggested a bivoltine pattern in some years (see Braby et al. 1999), but these individuals are now thought widely simply to be 'late developers', because there has been no conclusive evidence from larval surveys (below) of a whole generation over the summer period. However, there are indeed two distinct generations at Kiata, with first generation adults appearing from mid-October, and the second generation in February. Castlemaine populations

Fig. 6.4 *Paralucia pyrodiscus lucida*: adult (photo: A.A. Canzano)

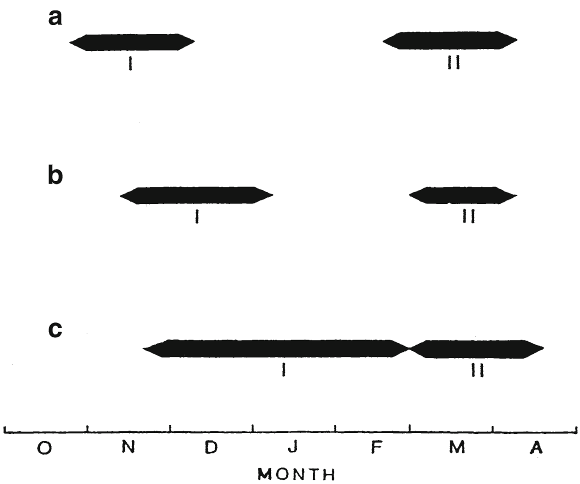

Fig. 6.5 Suggested seasonal patterns of adult appearance of *Paralucia pyrodiscus lucida* at major locations in Victoria (**a**), Kiata; (**b**), Castlemaine; (**c**), Eltham) (modified from Braby et al. 1999)

are similar to those at Eltham, but with some seasonal adjustment reflecting the warmer climate. Fig. 6.5 indicates these differing phenological patterns.

Eggs are laid, singly or in small groups, on the sole larval food plant, sweet bursaria, *Bursaria spinosa* (Pittosporaceae) (Fig. 6.6). This widespread plant varies widely in growth form and appearance. The butterfly is associated almost wholly with small stunted plants up to 30–60 cm high, rather than with the larger luxuriant shrubby individuals that can commonly reach 3–4 m in height and sometimes more. These extreme growth forms have in the past been considered separate 'forms' of *B. spinosa*, but Endersby (1996) suggested that the stunted individuals simply result from over-grazing. Plants selected for oviposition typically have nests of the host ant at their base.

Fig. 6.6 *Paralucia pyrodiscus lucida*; eggs on stem of *Bursaria spinosa* (photo: P. Ingamells)

Fig. 6.7 Caterpillar of *Paralucia pyrodiscus lucida* with *Notoncus* ant on *Bursaria spinosa* (photo: P. Ingamells)

Eggs hatch after about 2 weeks, and caterpillars of all instars are tended by ants from hatching. They feed by night on foliage (Fig. 6.7), and by day remain in the subterranean nest chambers of the ant, a few centimetres within the soil at the plant base (Fig. 6.8). These chambers appear to be 'satellite nests' as they do not contain brood or reproductive ants, and the association between ant and caterpillar appears obligatory. Ants 'shepherd' caterpillars up the plants after dusk, and remain with

Fig. 6.8 Caterpillar of *Paralucia pyrodiscus lucida* with *Notoncus* ant in litter at base of *Bursaria* (photo: P. Ingamells)

them during the feeding period before all retreat to the nests. Two congeneric host ant species are involved. *Notoncus capitatus* is the host species at Eltham and Castlemaine, and *N. ectatommoides* at Kiata. The biology of the two species is very similar. *Notoncus* is a small genus of formicine ants, all predators and nesting in the ground. Six Australian species have been described.

Caterpillars feed until the onset of cooler weather in late autumn (around the end of April–early May) and then mostly remain underground until spring. They do not diapause and may emerge on warm nights over that period, but the major growth phase is from September onward. Pupation takes place within the ant nest chambers, and the adults emerge after about 3–5 weeks, but with suggestions of protracted development related to poor food quality (Endersby 1996).

The butterfly is thereby one member of a tripartite ‘conservation module’ involving the butterfly itself, a specific larval food plant (which is important also as a predominant nectar source for the adult), and specific host ant. However, both *Bursaria* and *Notoncus*, even on occupied sites, are far more widely distributed than *Paralucia*, and also occur together in many other places from where the butterfly is absent. Reasons for this distributional limitation are not at present understood.

6.2.2 Conservation

The small area of the main occupied sites, and the substantial conservation concern and investment around Eltham has led to continuing study and management of all major populations of *P. p. lucida*, with the outcome that these have been monitored more closely and over a longer period than any other Australian lycaenid. Although details of methods, and the personnel involved, have changed somewhat since population estimates commenced in 1987, relative estimates of population sizes on the various sites can be inferred since then. One practical limitation of survey intensity is to avoid undue damage to the very small sites involved.

P. p. lucida is unusual in that the numbers of caterpillars and adult butterflies have both been monitored in various ways, to provide two 'inter-generation' markers of change. The two stages provide rather different, but complementary, information. Presence of caterpillars, for example, denotes unambiguous residency, whereas presence of adults alone may not necessarily do so. The methods have been adapted to allow participation of volunteer inspectors (such as members of the Friends groups at Eltham, Friends of Kalimna Park, Friends of the Kiata Flora Reserve, and the various management agencies listed earlier) in these exercises, with all activities coordinated through a statewide 'Working Group' containing wide representation of interested parties and independent scientists. Recognition of the vulnerability of populations on small sites has led also to preliminary evaluation of captive breeding as a basis for ex situ conservation, and involving the expertise of the Melbourne Zoo.

6.2.2.1 Larval Counts

Since 1996, the most detailed counts have been repeated annually on the western and eastern colonies, on which numbered 10 × 10 m grids have been marked. In selected grid units, all *Bursaria* plants are inspected for caterpillars. Those local samples have been augmented by transect counts to more widely assess distribution across the whole sites (Van Praagh 1996). Commencing about an hour after dusk on fine (calm, no rain, warm) evenings in October/November and, wherever possible duplicated each year, every individual *Bursaria* is inspected by torchlight, and all caterpillars recorded. Every occupied plant has been given an individually numbered metal tag, easily detectable during night inspection, and its height and condition recorded (Fig. 6.9). This approach has allowed estimating (1) plants that are occupied in different years, (2) plants unoccupied, and (3) plants newly occupied each year. In addition to number of caterpillars on each plant, in early years the approximate size of each caterpillar (to the nearest mm) and number of attending ants – often observed in torchlight before the more cryptic caterpillars are found, because they are glossy and move 'frenetically' – were also recorded. Using the same quadrats for survey each year has allowed some interpretation of numerical changes, but the results obtained are extremely difficult to validate, because the counts have also revealed some confounding aspects of caterpillar behaviour. As examples (1) each caterpillar feeds for only a short period before retreating to the ant chambers, so that different individuals may be seen at different times; (2) any physical disturbance (including torchlight, red or other) and many weather changes

Fig. 6.9 Small *Bursaria* plants tagged to indicate presence of *Paralucia pyrodiscus lucida* larvae

such as wind gusts or fall in temperature may accelerate that retreat; and (3) not all individual caterpillars emerge to feed every night, so a single inspection does not furnish a full population sample, and separate nights may provide access to different cohorts of active individuals. Activity is related to temperature, with few caterpillars active at temperatures below about 10°C.

Canzano (pers. comm. 2009) marked well-grown caterpillars with different colours and demonstrated this sporadic activity clearly by inspections on successive evenings. However, she also showed that individual caterpillars are faithful to an individual host plant and rarely move to any other. One individual changing to another plant was only to a neighbour with contiguous foliage.

The behavioural traits noted above very strongly limit the values of these counts for estimating population size and predicting changes, as emphasised by Johnson (2002), but help to provide information on resource usage and phenology.

6.2.2.2 Adult Counts

Flight activity of the coppers is related to temperature, with a predicted lower activity threshold of around 15°C (Braby et al. 1999), and adults fly over most of the day under calm, warm to hot conditions. Counts of adult butterflies have utilised two approaches to sampling, reflecting the different distribution patterns of *Bursaria* on various sites, and based on the observation that Eltham copper adults rarely seem to stray far from these plants, they thereby become an observational focus. Transect counts (based on the protocol of Pollard and Yates 1993) were used at Eltham and Castlemaine. Transect lines (defined and limited by the small areas available) were mainly around 100–150 m, with butterflies seen up to 10 m either side counted by an observer walking slowly along the line and using a stick to lightly tap *Bursaria* to dislodge resting individuals; observers also diverted from the line to inspect *Bursaria* within the 20 m belt of the transect. This unusually wide transect approach is suitable (1) for open country with visibility unimpaired by dense vegetation or topography and (2) where the focal species cannot be confused with any other likely to co-occur there (Braby et al. 1999).

Bursaria occurs in dense clumps rather than widely across the landscape at Kiata, and necessitated a somewhat different inspection method by some recorders, namely use of a 'circle count'. Two observers stand at opposite sides of a patch, within calling range, and count the butterflies active as they are disturbed by moving around the patch and flushing them from vegetation.

Larval and adult counts have proved very difficult to correlate consistently, but both indicate that all *Paralucia* populations are small and each includes, at most, only a few hundred individuals. Some are much smaller; one Eltham colony has only a handful of individuals (at most) noted each year. There is also some general consistency of relative numbers across sites so that, for example, the western colony is consistently the largest population unit in the Eltham area, with the densities of caterpillars and adults largely overlapping on the site. Apparently, only one population has been lost since recording commenced: no representative of the small population at Salisbury, the most westerly known, has been seen since 1994.

6.2.2.3 Threats

Conservation of *P. p. lucida* near Melbourne clearly depends on the continued security and condition of individual small sites, with possible planning for range expansion by translocations to additional sites, not yet designated. Changes to sites are both natural (succession) and from external influences, predominantly weed invasions and the direct threats arising from urbanisation, necessitating site-based management to ameliorate these. Rubbish dumping, run-off from roads and gardens, vandalism, and general recreational activities have all impinged to varying extents, and the natural build up of debris and fallen wood creates community concern as increasing fuel loads for accidental fires with potential to devastate local properties. Elsewhere, the larger areas, clumping of *Bursaria* and diminished urban pressures – replaced by factors such as stock and hare grazing (Kiata) and trailbike riding (Kalimna Park) – provide different management scenarios and needs. At Kiata, important clumps of *Bursaria* have been fenced to exclude grazing mammals. However that wide dispersion also necessitates interchange dispersal by butterflies, so that a possible metapopulation model based on demographic units on each major clump must be fostered through landscape connectivity involving planting of *Bursaria* to constitute links. The small Eltham/Greensborough sites do not allow for any such structure to become clear, but Canzano's (pers. comm. 2009) surveys clearly show butterflies moving around such sites and also that some appear more sedentary, and not recorded far from the point of their initial capture.

Small circumscribed sites are both welcome and frustrating for practical insect conservation. On the one hand, detailed information can be obtained, and management steps be focused very finely, and usually monitored easily in such arenas largely free from many confusing or confounding external influences. On the other hand, the areas may not allow for optimal conservation measures to occur, and there may be considerable experimental risk in novel or intensive intervention, for fear of causing irreversible harm. Space may not be available to reintroduce mosaic successional stages, for example. The management dilemma of such situations was demonstrated by changes on the western colony and eastern colony by the mid-1990s. Build up of woody debris was of increasing concern to local residents as a fire hazard; weed invasions were increasing in extent; and canopy closure was shading out *Bursaria* as parts of the area moved toward a closed woodland (Fig. 6.10).

These factors, together with continuing imposed urban pressures, aroused concerns that, without strong interventionist management rather than continuing low-level maintenance, the sites would indeed become unable to support *Paralucia* within a few years. The needs for such management were thus to 'rejuvenate' the sites, reduce the impacts of invasive weeds and allay fears of accidental fires damaging both the sites and nearby properties (and so help to sustain community support for conservation), whilst protecting the conservation module and some other notable native plant species. The latter, including some rare orchids, found on

Fig. 6.10 The habitat of *Paralucia pyrodiscus lucida* near Melbourne: open eucalypt woodland of the Western Colony, Eltham, prefire

the Yandell Reserve, Greensborough, necessitated site management by hand-removal of individual weeds by experienced botanists able to distinguish weeds from desirable plants. Clearly, this intensive management may not usually be available for any larger area management and can become labour intensive, possible only with considerable botanical knowledge, and expensive. Woody weed removal on some of the larger sites involved removal of alien *Pinus radiata* trees from the southwest margin of the Pauline Toner Reserve, and from Castlemaine Botanic Gardens, necessitating greater intrusion (trampling, heavy machinery, wood removal) on localised areas.

With the need for substantial change on the western colony and eastern colony sites, three major management options were discussed. The first, 'do nothing', can on occasion be the best possible conservation management option, as the perceived risks of 'doing something' can be high. It was discounted here, as no measures to remedy the deteriorating conditions for *Paralucia* would then be imposed. The second option (mechanical change) involved considerable direct physical disturbance by cutting trees and woody weeds, machine and human entry to pile and remove ground debris and wood, and herbicide applications to cut stumps. This intervention is patently 'unnatural', with the impacts on the butterfly difficult to predict. The third option, burning the sites, was eventually adopted for further consideration, in the belief that a fire could be 'designed' to satisfactorily fulfill the most urgent management aims and resemble natural processes to which key biota may be adapted.

Fire is an important structuring force in Australia's terrestrial ecosystems. The south-east has a long history of wild fires, and many species of plants depend on naturally occurring burns for their germination, regeneration and survival. Controlled burning is frequently employed as a management tool in the region, but details of best practice remain highly controversial, with continuing debate over optimal frequency, intensity, extent and spatial mosaic, and seasonality, as well as whether any protocols can be regarded as general in transcending vegetation types or climatic regions. The framework of good experimental studies (with replicated 'before and after' data) to predict outcomes of control burns on invertebrates remains slender, and fire is regarded widely as high risk management for invertebrates, particularly those without defined refuges or 'refuge stages' (p. 86). The decision to investigate the burning option led to a series of other considerations (New et al. 2000) involving public and property safety; how much of the area(s) to be burned and whether to burn both sites at the same time; the time of year to burn; the intensity of burning, with botanical evidence that the hottest possible fire was desirable for weed control and canopy opening, but might possibly provide additional risk to the copper; and responsibility and control of the operation.

The protocol devised had three core pointers: (1) to burn parts of both sites on the same occasion, but seeking to protect the areas on each that supported the highest densities of *Paralucia* as revealed by pre-fire monitoring, as well as boundaries with adjacent residential properties; (2) to make the fire as hot as possible; and (3) to burn as late as possible in the summer, after the adult flight period, eggs had hatched, and caterpillars had partially developed and were close to their winter fasting period. Risks of extirpation were recognised clearly, either by direct burning of caterpillars or the loss of critical above-ground resources, but allayed somewhat by (1) a small colony occurring very close to the western colony as a source for translocation or natural colonisation; (2) that the alternatives might in any case hasten the trajectory toward extirpation; and (3) that the experience gained, even if the outcome was not positive, might benefit other attempts in the future. With all preparations made, including careful marking of all areas to be protected and full cooperation of several Country Fire Authority units to conduct and secure the burn, plans to burn in 1997 were foiled by unsuitable weather, and the exercise was eventually undertaken in April 1998 (Figs. 6.11 and 6.12). The fire maps (such as Fig. 6.13; New et al. 2000) indicated that hot burns, with adequate monitoring and control, could indeed be regulated to within a few metres on such small sites.

Inspections during the week after the fires indicated that many caterpillars survived. Indeed, the record count of 580 caterpillars on the western colony suggested that (1) survival levels were very high, (2) the caterpillars were more easily detected on the charred leafless stems of *Bursaria* than amongst plants with foliage, and (3) a high proportion of caterpillars was present together, seeking food as they became progressively more hungry. Most of the caterpillars appeared at least half grown, and many survived the winter and went on to mature, then feeding on regenerated *Bursaria* growth in spring. Likewise, *Notoncus* appeared not to have been affected markedly. Because *Bursaria spinosa* regenerates directly from old rootstocks, new growth for caterpillars was available without them needing to travel to find it.

Fig. 6.11 Fire management for *Paralucia pyrodiscus lucida*: the Western Colony, Eltham

Fig. 6.12 Fire management for *Paralucia pyrodiscus lucida*: the Western Colony, Eltham, 2 days post-fire

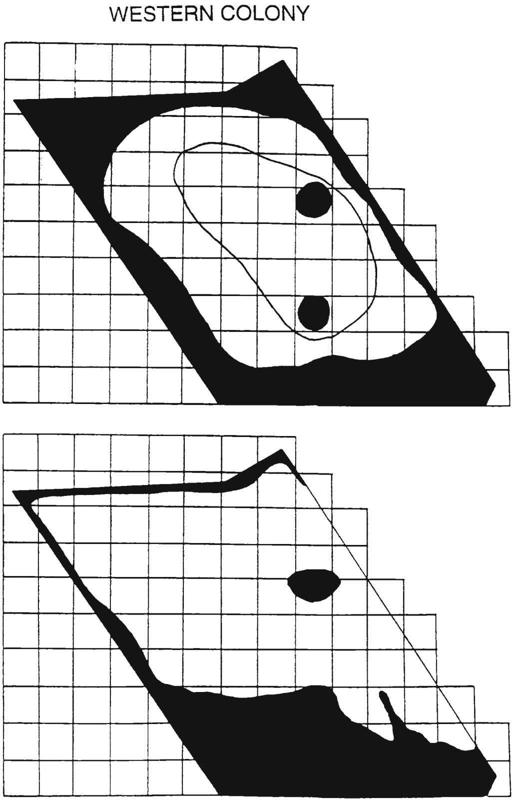

Fig. 6.13 The 'fire plan' for the Western Colony: above, as planned; below as achieved (grid is 10 × 10 m; shaded areas not burned; right of figure is roadside) (after New et al. 2000)

In *P. p. lucida*, the refuges afforded by caterpillars being underground during the day were probably a key factor in their survival, by minimizing direct exposure to flames and high temperatures of radiant heat.

This operation was the first of its kind for an Australian lycaenid, and one of the first anywhere in which the risk of extirpation from novel management was both realistic and accepted. The fortunate outcome could not have been guaranteed, but the detailed planning and careful execution of the burns, building on biological understanding of the butterfly and its requirements demonstrates the detail that should contribute to any similar exercise. The ability to protect concentrations of larvae, literally by damping down those small areas with water and patrolling them during the burns, lends confidence to being able to undertake such management on a fine mosaic scale and on very small sites. There may be a very fine balance between positive management outcome and calamity through an inappropriate fire regime or event, so that in every individual case careful independent risk evaluation is advisable in order to find a 'middle course'. Should burning be inappropriate, such as by being too frequent, too hot, too extensive, or at the 'wrong' time of year, a major threat may eventuate.

In addition to such general approaches to site maintenance, particular weeds or other threat components can need specific measures. Hand-pulling of cape broom at Castlemaine is laborious but, with volunteer help, has been a key element of reducing threat of encroachment on *Bursaria* areas.

The most recent statewide overview of Eltham copper conservation,in the form of a Draft revised Action Statement (Webster 2008) has five main objectives to collectively ensure that populations throughout the butterfly's range remain viable. These are, very broadly, (1) to improve condition of habitat; (2) to increase the extent of habitat; (3) to secure populations or habitat from potentially incompatible land use or catastrophic loss; (4) to increase knowledge of biology, ecology or management requirements; and (5) to increase community awareness and support (Fig. 6.14). The Department of Sustainability and Environment is currently designing an 'Actions for Biodiversity Conservation ("ABC") System' that will hold details of all intended management actions and whether, when, and how they were pursued. Currently very incomplete and not providing for records and methods of monitoring (so that statements of sampling effort are not present), and outcomes and consequent changes, the ABC system may eventually provide a useful historical dossier for any formally recognised threatened species in Victoria.

6.3 The Bathurst Copper, *Paralucia spinifera*

This butterfly is known also as the Lithgow copper, with both the above names based on towns within its limited range in central New South Wales; some workers now refer to it as the purple copper, a more neutral name that avoids inter-town rivalries! *P. spinifera* was discovered only in 1964, at Yetholme (near Bathurst) (Fig. 6.15) and, following collections of additional specimens in the region, was

Fig 6.14 Publicity for conservation of *Paralucia pyrodiscus lucida*: (**a**, **b**) signage at the Pauline Toner Reserve, Eltham; (**c**) track within the reserve; (**d**) signage at Bendigo

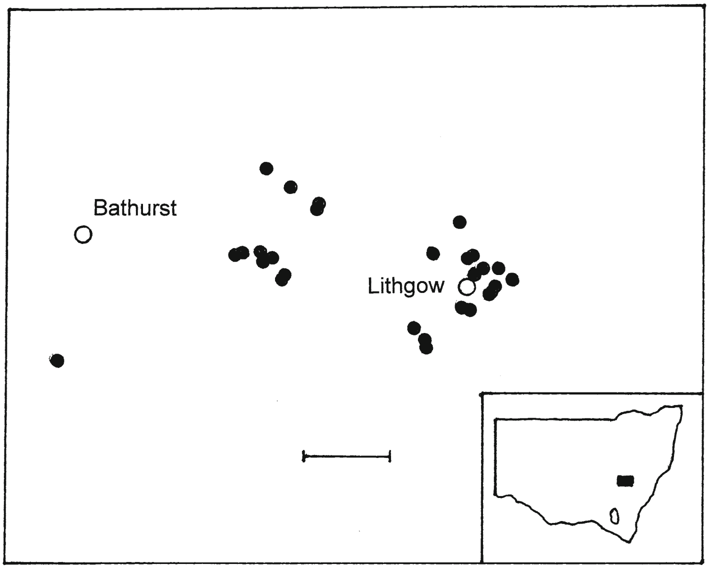

Fig. 6.15 Distribution of *Paralucia spinifera* in the Bathurst-Lithgow area of central New South Wales: sites indicated by black spots; enlarged area indicated in black on inset map (scale line 10 km) (after ARP 2001)

named formally in 1978 (Edwards and Common 1978). At that time it was already recognised as of considerable interest in having a highly circumscribed distribution, and with the sole population occupying a small area in partially cleared sclerophyll forest with *Bursaria* in the understorey; despite many searches following the initial discovery, the butterfly was not found again until October 1977 and, at the time it was described, was known only from a small area to the east of Bathurst.

Subsequent searches have revealed many further populations, so that nearly 40 are now known, all within this single region of the Central Highlands of New South Wales, all above 850–900 m in altitude, and collectively endorsing early opinion that the copper is indeed a narrow range endemic butterfly. All known populations occur on small sites, so that the distribution appears to be highly fragmented. The 29 sites known up to mid-2000, on which most conservation planning devolved, totaled less than 30 ha of habitat, and 14 of those sites were on private land. As for the Eltham copper, a considerable variety of agencies was responsible for management of sites on public land: Lithgow City Council (3 sites), Evans Shire Council (4), Department of Land and Water Conservation (1), State Forests of New South Wales (2), Rural Lands Protection Board (1) and New South Wales National Parks and Wildlife Service (2). The two remaining sites were on Commonwealth land controlled through the Department of Defence. Most sites were not protected formally. Many of the populations were perceived as threatened by fire, weed invasions, clearing of vegetation, grazing stock and, allegedly by overcollecting. Of these, perhaps the most important threat suggested was clearing of native vegetation from private land and roadsides.

The panoply of threats led to federal listing of *P. spinifera* under the forerunner of the Environment Protection and Biodiversity Conservation Act 1999 (p. 35), the Endangered Species Protection Act 1992, and the listing was later automatically transferred to the new act. The reason underpinning its eligibility for listing as 'vulnerable' was that 'Within the next 25 years, the species is likely to become endangered unless the circumstances and factors threatening its abundance, survival and evolutionary development cease to operate'. The butterfly is listed as 'endangered' on Schedule 1 of the New South Wales Threatened Species Conservation Act, requiring preparation of a formal Recovery Plan, with subsequent requirement that a government agency must not undertake actions inconsistent with an approved recovery plan, and land managers must manage sites and habitat in accordance with that plan. Reasons for the State listing included limited distribution, habitat degradation and putative overcollecting.

6.3.1 Biology

The Bathurst copper (Fig. 6.16) appears to occupy a very narrow climatic range, so that the geographical life history variation present in *P. p. lucida* does not exist.

Fig. 6.16 *Paralucia spinifera*, adult on *Bursaria spinosa* (photo: S.C. Nally)

It undergoes one generation each year, with the adults first appearing in August at lower elevations and somewhat later at higher sites. Peak activity occurs in September. Flight may persist up to early December, but typically spans only a few weeks at any site. The sole larval food plant is a named form of *Bursaria spinosa*, *B. s. lasiophylla*, on which eggs are laid. Hatchling larvae are tended by the ant *Anonychomyrma itinerans* (Fig. 6.17), which (as does *Notoncus*, p. 90) forms underground nest chambers at the base of the plant. The taxonomy of *A. itinerans* is confused, and the name probably refers to a complex of species at present. Larval life is about 6–10 weeks. Caterpillars feed nocturnally and are tended by the ants whilst doing so. Pupation (in December–February) takes place within the ant nests. The pupa is therefore the longest life history stage.

B. s. lasiophylla grows at higher elevation sites, and reaches around 2 m in height. It has been cleared extensively, together with its forest overstorey, for agriculture and establishment of pine plantations, so that much of the remaining *Bursaria* now occurs in small remnant patches that restrict the whereabouts of the copper (Fig. 6.18), and dictate its maximum occupancy. The attendant ant also occurs only at high altitudes, so that both these key resource species for *P. spinifera* are probably instrumental in limiting its altitudinal distribution.

Within this mosaic, suggestions have been made that the copper has a metapopulation structure, but this has not been investigated experimentally. Many of the occupied sites are indeed concentrated as groups of 'sub-populations' (Nally 2003). Preliminary genetic studies indicated high diversity within populations, with numbers and gene flow sufficient to maintain variation, so that Clarke and Grosse (2003) suggested that *P. spinifera* comprises a single large population across multiple habitats. The significance of local extirpations is thus difficult to interpret, and the apparent loss of butterflies from six sites, reported by 2000, may be natural – although, clearly, any chances of re-colonisation are diminished with progressive site isolation.

Fig. 6.17 *Paralucia spinifera*, caterpillar with attendant *Anonychomyrma* ants (photo: S.C. Nally)

Fig. 6.18 *Paralucia spinifera*, representative open habitat with small scattered *Bursaria* plants (photo: S.C. Nally)

6.3.2 Conservation

The Recovery Plan for *P. spinifera* embraces most issues involved in its conservation, to the extent that Sands and New (2002) believed that the status of the butterfly would be rendered secure if the various actions proposed were undertaken successfully, and assessed the national conservation status as 'Lower Risk' but Conservation Dependent, rather than severely threatened. The Recovery Plan finally adopted (ARP 2001) aimed 'To stabilize the population through the prevention of threatening processes, then to increase the in situ population through habitat management with the aim of down-listing the species to vulnerable'. All known 'sub-populations' were encompassed, and a primary aim was to protect as many as possible of the occupied sites, including increasing legislative protection of freehold and publicly owned sites. This was one of 20 specified recovery actions (Table 6.1), the others being designed to collectively address three main themes: (1) to identify and prevent the continuation of processes that threaten the butterfly; (2) to inform and educate the community of the significance of the species, and involve the community in recovery actions, so participating in the conservation effort; and (3) to gain a thorough understanding of the distribution, population dynamics and ecology of the butterfly through research and surveys of potential and actual sites. Unusually, all proposed actions were budgeted in the plan, with the considerable variety of actions and agencies involved coordinated through a recovery team including representatives of all major agencies and stakeholder groups.

The community interests and support, as for the Eltham copper, have been a vital component of conservation of *P. spinifera*. Community participation and raised awareness was summarised by Nally (2003), who emphasised that this should involve far more than contributing to a 5-year recovery plan, but also should 'contribute to the evolution of a community's understanding, perceptions and attitudes'. For *P. spinifera*, three main aspects (based on the Lithgow community of around 21,000 people living close to suitable habitats and occupied copper sites) were: (1) understanding the community and identifying opportunities; (2) creating awareness; and (3) involving the community in recovery actions and enhancing awareness. Thus, for the first of these, community sectors recognised at Lithgow were government and organisations, affected landholders, conservation-orientated community groups, other community groups, education institutions, business, and the broader community. Each is likely to have different interests and priorities, motivation, capability and opportunity to participate, and Nally's approach was to contact key individuals in each sector, to ask about their group's activities and objectives, their knowledge of *P. spinifera*, and how they would like to be informed of relevant issues. These approaches revealed the range of environmental interests already present in the community – such as active environmental programmes in schools and groups such as LandCare, the Girl Guides, a cycling club, and others. Nally (2003) also noted that 'there is no set approach for raising community awareness, and it is limited only by the boundaries of imagination'. The initial phase of raising awareness was through distribution of information sheets on *P. spinifera*, encapsulating aspects of its biology and ecology, the identified threatening processes and the recovery actions required – but avoided involving the National Parks and Wildlife Service projected actions involving the community, because this might suggest that the Service was driving community involvement.

For successful community involvement in recovery programmes, it is important (Williams 1996) that (1) the activity is a community initiative rather than one 'directed to be done' by authority; (2) the community can identify personally with

Table 6.1 The management actions projected in the recovery plan for *Paralucia spinifera* (ARP 2001)

Threat abatement
(Objectives: to prevent the continuation of factors that are detrimentally affecting the Bathurst copper butterfly or its habitat, and to prevent the occurrence of activities that may affect the Bathurst copper butterfly or its habitat)
Assessment of threats
Clearing prevention and impact assessment of industrial and other activities
Weed management
Create habitat corridors
Illegal collecting monitoring
Manage vehicular access
Dust management/road maintenance
Fire management
Grazing management
Feral animal management
Dead timber removal/firewood collection
Community education and awareness
(Objectives: to increase awareness of the Bathurst copper butterfly and blackthorn as an endangered species habitat; to encourage involvement of the entomological community in recovery efforts; to guide and assist owners and managers of Bathurst copper butterfly habitat in the recovery efforts on their lands; to ensure that local, State government and Commonwealth agencies make informed decisions on matters that affect the conservation of the Bathurst copper butterfly)
Inform and educate the broader community
Inform and involve affected landowners
Inform and educate local and State government agencies
Inform and involve lepidopterists
Research and monitoring
(Objectives: to create and disseminate records of known sites to relevant persons; monitor populations at each of the sites; identify and assess potential Bathurst copper butterfly habitat and undertake or encourage research into aspects of the ecology of the Bathurst copper butterfly that is likely to provide information valuable to the recovery of the taxon; to understand essential aspects of the ecology of the Bathurst copper butterfly, host blackthorn and attendant ant)
Record extant sites
Monitoring
Identify and assess potential habitat
Research
Reservation/conservation
(Objectives: increase the legislative protection of publicly-owned land Bathurst copper butterfly sites, and increase the security of freehold Bathurst copper butterfly sites)
Increase legislative protection

the site; and (3) that there are perceived direct benefits to the community so that collectively the actions are within their ‘comfort zone’ and seen to be worthwhile. Community initiatives are important also to help prevent loss of interest should a directing agency fail to deliver.

A number of different community participants became involved at Lithgow, initially through separate actions but which in combination (Fig. 6.19) contributed substantially to key recovery actions. The unsolicited offer from a local café (the 'Bellissimo Café') did much to increase community awareness beyond the initial phase. The new café displayed and distributed information on the copper, had copies of documents and the recovery plan available for patrons to browse, identified itself as a sponsor, offering 'butterfly cakes' from which a premium was donated to the recovery effort, and also donating tips to the programme. Their efforts, together with the education kit on the butterfly prepared for school curricula, provided the foundation for the practical measures displayed in Fig. 6.19.

A key consideration of management for *P. spinifera* has been the role of fire, with design of a suitable burning protocol viewed as a potentially valuable tool. Strong suggestion that sporadic fires may stimulate fresh growth of *Bursaria* from underground rhizomes, and observations of large numbers of butterflies on sites two years after burning (following small numbers in the first post-fire season) implied

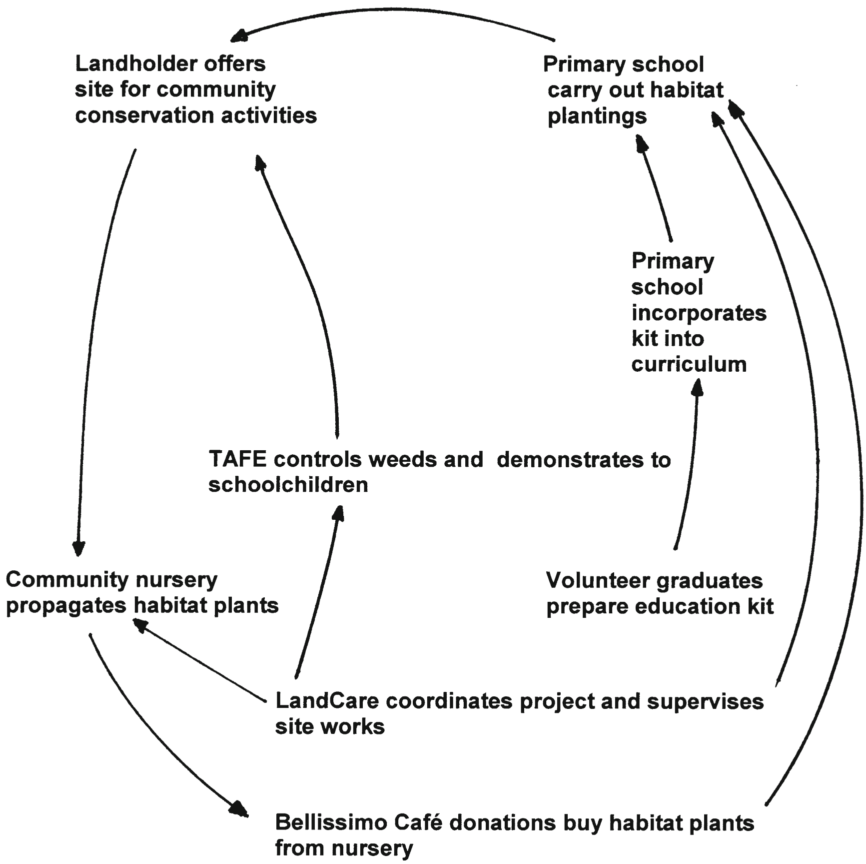

Fig. 6.19 Community interactions for conservation of *Paralucia spinifera* (after Nally 2003)

possible benefits from the practice. The Recovery Plan suggested that fires during the subterranean pupal period (February–August) might be the most suitable for butterfly survival, with fires earlier in this period (March–June) maximising *Bursaria* regeneration as food for the next generation caterpillars. As for the Eltham copper, timing of the fire may thus be critical in determining whether it is positive management or severe threat. Possible impacts are enhanced by the low dispersal of butterflies, which typically do not move more than up to about 15 m from a habitat patch (Mjadwesch and Nally 2008). However, with the presumption of a metapopulation structure, an experimental approach to determining response of *P. spinifera* populations after fires may be possible (Healy and Wassens 2008). As a needed preliminary, the relationships between landscape and local patch features and isolation – and consequent probability of occupancy/colonization by the butterfly and mutualistic *A. itinerans* should be determined. For individual patches for which fire management may be contemplated, Healy and Wassens suggested that this prior assessment should include area of patch, height and condition of *Bursaria* plants, leaf litter, presence and abundance of other vegetation, fire history (if known), distance to nearest other patch, surrounding land use, presence of *A. itinerans*, and presence of *P. spinifera* (adults, larvae). For experimental burns, no more than half of a patch should be burned in any year, and burns should target occupied sites on which *Bursaria* is senescing or weed infestations are already reducing quality. Ideally, burned patches should be sufficiently close to other butterfly populations to enable re-colonisation. These trials remain to be undertaken.

Should natural re-colonisation not be feasible, translocations from other viable populations to the sites may be viable, with a fortuitous exercise reported by Mjadwesch and Nally (2008) clarifying how this might be attempted. A road realignment commenced in 2004 unexpectedly revealed a population of *P. spinifera* in its path, after the project was well advanced. The Roads and Traffic Authority immediately stopped further work in the affected area. In combination with the (now) Department of Conservation and Climate Change a butterfly management plan was devised (Mjadwesch 2004) to revise the roading plan and seek ways to avoid loss of the population. The final plan would retain only about one third of the potentially lost habitat, but earlier construction of an expensive bridge, and associated works, precluded protection of a greater area. However, it appeared feasible to move caterpillars from the area to be lost, and a two-stage plan was designed for this operation: (1) potted *Bursaria* plants were sunk into the ground of the donor site and some were treated with sugar solution (anticipated to attract *Anonychomyrma*) which apparently also fostered increased caterpillar occupation of treated plants; (2) plants that were to be destroyed by development would be searched systematically at night for caterpillars, and those found moved to ‘safe’ plants. One resulting observation parallels that on *P. p. lucida* (p. 80): whilst all observed caterpillars of *P. spinifera* were collected during this exercise, inspection of the same individual *Bursaria* plants on successive nights generally revealed others, and some plants continued to supply caterpillars over the 12 nights of collection. Mjadwesch and Nally (2008) noted that individual plants could harbour upward of 50 caterpillars in accompanying ant chambers. Trials on moving the ants within the site were successful, suggesting that *A. itinerans* might there comprise a 'supercolony' so that ants accompanying relocated caterpillars would easily settle and that resident ants would accept these caterpillars. Suitable recipient plants were identified and caterpillars and ants transferred to these. Over 12 nights to January 2005, 1,260 caterpillars were transferred from 97 plants, and some other occupied plants transferred directly. The potted plants from stage 1 were removed in December 2005 and replanted in the area designated for restoration to which nursery-grown *Bursaria* plants, replacing the 147 lost to roadworks, had also been introduced. Despite some uncertainties in monitoring the outcome of this exercise, Mjadwesch and Nally (2008) indicated a high level of success, and the translocation was a critical step in conserving the population and in using the 'compensatory habitat' or 'habitat offset' approach. The outcome was in part due to community involvement and Roads and Traffic Authority participation, without which the laborious collection of caterpillars and subsequent monitoring could not have been undertaken. Earlier, the Recovery Plan (ARP 2001) considered translocation but considered it an inappropriate strategy at that stage, with protection of occupied habitat a clear priority. The case documented by Mjadwesch and Nally demonstrates the need for enterprise and versatility in a species recovery programme to accommodate any needs brought about by unusual or unexpected circumstances.

6.4 Discussion

The conservation programmes for these two closely-related species, have involved exchanges of information across the two teams, helping to consolidate and explore management based on increasing knowledge of the similarities and differences between the butterflies. Dependence on the same major food plant is a major overlap, and interactions between caterpillars and ants also appear rather similar. *P. spinifera* has been reported, on one occasion only, with a second ant genus (*Crematogaster*, see Mjadwesch and Nally 2008), but both these *Paralucia* species otherwise appear to have very specific mutualisms with different ant genera. The third species of *Paralucia*, *P. aurifer*, associates with another species of *Anonychomyrma*, in the *nitidiceps* species group, and also feeds on *Bursaria spinosa*, so that closely parallel mutualisms are entrenched in different species within the genus. For *P. aurifer* and *A. 'nitidiceps'* both participants benefit from the association (Cushman et al. 1994) and, although the other partnerships within *Paralucia* have not been studied in equivalent detail, they are presumed to be similar. Experimental studies with *P. aurifer* showed that caterpillars reared with ants (1) were substantially (31–76%) heavier than those reared alone; (2) developed considerably (37%) faster; and (3) passed through one or two fewer instars. Ant attendance was associated with heavier pupae, shorter pupal duration, and slightly larger adults. Cushman et al. hypothesised that these 'benefits' resulted because ant-tended caterpillars fed for longer periods than untended larvae. Field observations indicated also that ants colonised *Bursaria* plants, and founded satellite nests at the base, only after lycaenid larvae were already present, with higher ant survival rates when caterpillars were present – presumably because of the nutritious secretions they provide.

Mutualisms between ants and lycaenids are widespread in the Australian fauna, and a recent survey (Eastwood and Fraser 1999) reported *Notoncus* only from *Paralucia* and (*N. capitatus*) *Jalmenus evagoras* (as one of a considerable variety of ants attending this widespread species) and (*N. ectatommoides*) with *Theclinesthes onycha*. *Anonychomyrma* has a wider range of associations, as listed by Eastwood and Fraser, with 14 other lycaenid species reported with it.

Protocols for conserving *P. spinifera* apply to a relatively narrow geographical and climatic range, with all sites reasonably close together, in contrast to the wider tolerances of *P. p. lucida*, for which site-specific differences and phenology may dictate different levels and priorities for management. Both programmes have benefited enormously from community inputs and interest, but sustaining impetus has sometimes proved difficult around Eltham. Many of the people initially involved as 'neighbours' close to the sites have moved away in the ensuing 20 or so years, and some of the newcomers do not have the equivalent high conservation concerns. Urban threats continue to be monitored, but any details of their impacts – for example, of traffic activity – remain unclear. For *P. spinifera*, road traffic was believed to affect two occupied sites by dust deposition on *Bursaria* rendering it unpalatable. Whereas the same broad suite of threats is evident for the two species, impacts may differ greatly. Grazing by rabbits and hares at Kiata has led to management protection of *Bursaria* clumps by exclusion fencing, but grazing by stock in *P. spinifera* areas may be beneficial when at low densities, by selective grazing of other plants to reduce competition with *Bursaria*, but severely damaging at high densities by (1) direct removal of *Bursaria*; (2) trampling affecting *Bursaria* and compacting the ant nests; and (3) being accompanied by pasture improvement measures such as superphosphate applications (that may change soil quality) and manuring (with associated weed spread). However, for both taxa, complete prevention or exclusion of grazing may lead to detrimental habitat changes. A key consideration is that stock or other vertebrate grazing must not be at a level that prevents recruitment of *Bursaria.* Low level grazing has occurred on two *P. spinifera* sites for more than 20 years without apparent lessening of butterfly numbers (Approved Recovery Plan 2001).

Bursaria spinosa is by far the most widespread species of the genus in eastern Australia and is also very variable in form and appearance (Cayzer et al. 1999). Only stunted or juvenile forms appear suitable to *Paralucia*, but *B. spinosa* can attain the stature of large shrubs or small trees up to about 10 m tall. Intriguingly, larger plants usually lack spines above the browsing height of mammalian herbivores (references in Cayzer et al. 1999), lending support to suggestions that spines may be a counter-herbivore measure. Extending that argument it might be suggested (without any evidence beyond correlation of incidence) that the butterflies might even select young plants in part because large native herbivores do not do so.

Chapter 7
Unity in Richness: Azure Blues (*Ogyris* spp.) in Patchy Environments

7.1 Introduction

The genus *Ogyris*, commonly known as the 'Azures' contains some of the most spectacular and ecologically intriguing lycaenids in the region (Fig. 7.1), and most species – some of considerable conservation interest – occur very patchily in the landscape. Even the more common species tend to be highly localised with widely separated populations, but some distribution records are obscured by uncertain taxonomy. Some of the more common species are rather variable, with several named subspecies, and some rarer taxa are also taxonomically complex and their integrity, in some cases, ambiguous. In consequence, some historical records of their incidence are also ambiguous, and differences between some named subspecies are small. As one pertinent example, detailed discussion of the nomenclature of a scarce taxon of conservation interest, *O. halmaturia*, has led to reinstatement of this name (Grund 2010) soon after it was dismissed in favour of *O. waterhouseri* by Braby and Douglas (2008).

Ogyris occurs only in mainland Australia (14 named species) and New Guinea (3 species). Nevertheless, because of the substantial collector interest in these butterflies over a century and more, knowledge of Australian distributions is reasonably complete, but has also led to suggestions that collector attention has been implicated in the declines of some taxa, through the notoriety of classic collecting localities as sources for capture of highly desirable localised forms. Pronounced sexual dimorphism (Fig. 7.1b) further confounds identifications in some species.

Adults are often difficult to capture. Those of some species tend to fly high around the tops of trees supporting their mistletoe caterpillar food plants, and some apparently only rarely descend to more accessible levels. Those of more open country, such as semiarid desert regions, do fly close to the ground and are more accessible, but are very cryptic when at rest. Many specimens in collections have been reared from pupae collected from under loose eucalypt bark, in crevices on tree trunks (Fig. 7.2), or the environs of ant nests, leading to (1) possible depletion of populations and (2) removal or destruction of suitable pupation sites and ant nests. Whereas mistletoes are the most widespread food plants, caterpillars of two species fed on root-parasitic plants (Santalaceae: *Choretrum glomeratum,*

T.R. New, *Butterfly Conservation in South-Eastern Australia: Progress and Prospects*,
DOI 10.1007/978-90-481-9926-6_7,

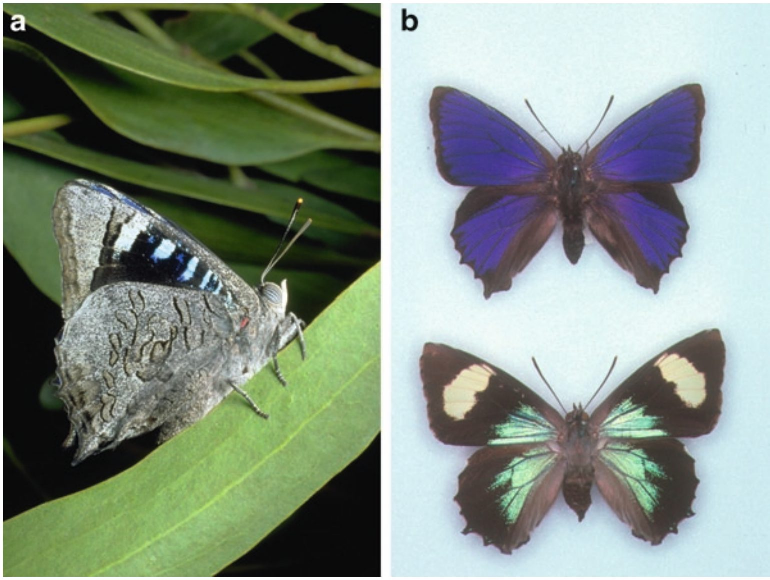

Fig. 7.1 (**a**) *Ogyris genoveva* at rest (photo: I. M. Coupar); (**b**) male and female of *O. genoveva araxes* to illustrate strong sexual dimorphism

Fig. 7.2 Representative base of large eucalypt trunk to indicate wealth of crevices and subcortical retreats suitable for pupation of *Ogyris* species

Table 7.1 Ant associations with Australian *Ogyris* species: records of ant identifications summarised from Eastwood and Fraser (1999). Genera only given, other than for *Camponotus*

Ogyris species	Ant taxa recorded as associates
O. genoveva	*Camponotus* (*consobrinus, nigriceps,intrepidus, eastwoodi, loweryi, terebrans, subnitidus* group), *Rhytidoponera*
O. zosine	*Camponotus* (*claripes, novaehollandiae* group, *maculatus, subnitidus* group, *rufus* group, *nigriceps, extensus* group)
O. idmo	*Camponotus* (*myoporus* group, *nigriceps, terebrans*)
O. subterrestris	*Camponotus* (*myoporus* group, *terebrans*, *novaehollandiae* group)
O. otanes	*Camponotus* (*hartogi, claripes* group, *terebrans, wiederkehri* group)
O. abrota	*Froggattella, Technomyrmex, Crematogaster, Rhytidoponera, Iridomyrmex, Anonychomyrma, Linepithima*
O. ianthis	*Froggattella*
O. iphis	*Froggattella*
O. aenone	*Philidris, Anonychomyrma*
O. amaryllis	*Crematogaster, Iridomyrmex, Anonychomyrma, Podomyrma, Camponotus*
O. oroetes	*Meranoplus, Anonychomyrma, Ochetellus, Podomyrma, Crematogaster, Tetraponera, Iridomyrmex, Froggattella, Pheidole, Camponotus* (*eastwoodi*)
O. olane	*Crematogaster, Monomorium, Iridomyrmex, Anonychomyrma, Ochetellus, Podomyrma, Camponotus* (*terebrans, consobrinus*), *Froggattella*
O. barnardi	*Crematogaster*

Leptomeria priessiana) and further trophic variety occurs with the supposition that *O. idmo* and its allies may be predatory on ant brood (Field 1997). All the species associate with ants to some extent, presumably as symbiotic interactions, but a very wide spectrum of ants have been reported to occur with *Ogyris* species (Table 7.1).

7.2 Biology and Conservation

Several species and subspecies of *Ogyris* have received considerable conservation attention. Although the criteria leading to such concern may not be stated clearly, very few members of the genus are assuredly of little conservation interest, although ambiguities in status interpretation arise also from the varying ways in which different subspecies are viewed by different workers. For western Victoria, only one of 10 such taxa appraised by Douglas (1995) was categorized as 'common' and, at the other extreme *O. otanes* may be extinct in the region and was assessed as 'endangered.' This desert-mallee species, one of those feeding on *Choretrum*, has been reported in Victoria only from the Big Desert, but has not been seen there since 1989 and, before that single observation by Douglas, since 1977. It was collected first in Victoria in 1971 and the nomination for listing under FFG (signed in June 1991) refers to 'known populations … later wiped out by unscrupulous collectors,' so that the spectrum of threats included collecting, destruction of sensitive sand dune habitats by vehicles (with a specific instance of erecting a trigonometrical survey point on a major sand-hill cited as causing damage, as such topography is needed by adults for hill-topping), and fires. *O. otanes* is more secure in South Australia, and perhaps most so on Kangaroo Island (Fisher 1985, Dunn and Dunn 1991, Fisher and Watts 1994a). It occurs also in Western Australia, but butterflies there differ somewhat in appearance from those in the east, and two new subspecies have recently been erected to contain these (Williams and Hay 2001).

Choretrum glomeratum (Santalaceae) is sparse in Victoria's deserts, but can become abundant on Kangaroo Island (Fisher 1985 noted it occurring widely along roadsides and in conservation areas there; Grund 2008), particularly after fires. Both Grund and Douglas have noted the 'scorched' appearance of *Choretrum* on which *Ogyris* caterpillars have fed – with their grazing on bark leading to browning of foliage, as a marked change from the normal yellowish-green colour, and a good indication of the butterfly's presence. However, the possible regeneration sequence for Kangaroo Island suggested by Grund (2007) is as follows: (1) fire destroys the butterfly colony, but also the undergrowth that competes with *Choretrum*, and also opens up the woodland habitat; (2) several years after fire, with proliferation of *Choretrum* from nearby areas on sandy soils and from seeds dispersed by birds (particularly by emus) the butterfly can re-colonise and become abundant; (3) this high density can persist for many years before the woodland again becomes too overgrown and *Choretrum* declines, leading to decline of *O. otanes*.

In contrast to this scenario, extensive fragmentation of native vegetation on the mainland increases chances of permanent destruction of colonies by fires, because reservoir populations for re-colonisation do not exist. Droughts are also implicated as contributors to recent losses, and other concerns on Kangaroo Island include conversion of suitable breeding areas to farmland. However, habitat fragmentation has rendered mainland populations of *O. otanes* vulnerable to an array of influences such as drift of pesticides from aerial spraying of nearby agricultural areas, rabbit burrowing, and damage to *Choretrum* by kangaroos, which may shelter under the bushes during the heat of the day and disrupt host ant nests through their 'scrapes.' Desirable propagation of *Choretrum* to increase resources for the butterfly is problematical for two reasons: (1) that as a root parasite it is often considered undesirable and a target for suppression, and (2) that high proportions of its fruit are attacked by other insects, particularly the caterpillars of a small moth (Grund 2007).

For most other *Ogyris*, removal of mistletoes (Fig. 7.3) is a general threat, as these are perceived widely as pests, and food plants of urticating caterpillars such as those of *Euproctis edwardsii* (Brown-tail moth, Lymantriidae). The latter is particularly significant near urban areas, as even air-borne hairs from caterpillars can cause severe allergic reactions in people. For *O. abrota*, the protection of large eucalypts as shelter for stock in grazing areas has become an important component of saving the *Muellerina* mistletoes needed by its caterpillars. More recent clearing in southeastern South Australia for vineyard establishment has led to extensive losses, because such shelter trees are there not important. Grund (2001) recommended

Fig. 7.3 (**a**, **b**) Representative large eucalypts heavily infested with mistletoes (darker foliage), both near Broadford, Victoria: scale indicated by blue stake, 60 cm tall

establishing a public education programme for people in near urban areas, in which clearing has been particularly severe.

O. otanes is one of a few species of *Ogyris* that associates with the large *Camponotus* ants, in this case with *C. terebrans*, a host shared with several other *Ogyris* of conservation concern. These include members of the formerly-designated '*O. idmo* complex,' namely *O. halmaturia* (formerly known as *O. waterhouseri* or *O. idmo halmaturia*, p. 81) and *O. subterrestris subterrestris* in the southeast. Historical records of these have been confused, with some records of '*halmaturia*' in reality the more recently recognized *subterrestris* (Field 1992, 1999). Both these taxa are also very narrowly distributed, and elusive. As noted earlier, it is widely believed that these taxa (including true *O. idmo*, in its present sense confined to Western Australia) may have arisen from *O. otanes* and adopted the habit of feeding on ant brood. Grund (2003) suggested that this habit might enable them to withstand the effects of periodic food plant losses from fires. The major host ant involved, *C. terebrans*, is a very variable species (McArthur et al. 1997) confined to sandy soils and able to rapidly colonise disturbed habitats. It has differing 'northern' and 'southern' forms, with the variation apparently clinal in nature. Different *Ogyris* species associate with these forms – *O. halmaturia* with the southern form, *O. subterrestris* with the more northerly form. It is widespread, but a rarely-considered threat to it may also apply to the butterflies. In fire prone areas of Victoria, one tactic used (since 1967) to help restrict wild fires is to disperse fire retardant chemicals from aircraft. Effects of the most commonly used retardant (Phos-Chek[R] – containing di-ammonium sulphates and mono- and di-ammonium phosphates) on ants include substantially reduced activity of *C. terebrans*, with possible consequent influence on *Ogyris* caterpillars (Seymour and Collett 2009). Additional clarification of any such effects is needed but, in the meantime, it is prudent to restrict use of retardants on any sites known to support rare *Ogyris* species and, perhaps, also other myrmecophilous butterfly species.

O. halmaturia (mostly under the name *O. idmo halmaturia*) has historically been recorded from several widely separated localities in western Victoria and South Australia (Fig. 7.4), and its continued presence on Kangaroo Island needs confirmation: Grund et al. (2006) suggested that it is 'near extinct' there. It is probable that all these butterflies have always been rare and very localised, but most of the reported populations may now be extinct, predominantly through the effects of land clearing and associated disturbance. The major need for conservation at present is simply to determine whether any extant populations occur in Victoria and parts of its former range (including Kangaroo Island) in South Australia and, if found, to assure their protection.

A list of priority localities for seeking *O. halmaturia* was suggested by Douglas (2003), together with the times of year in which adults were likely to be present. Should any be found, some protection of habitat might be possible through support from local conservation organizations. Similar circumstances apply to *O. s. subterrestris* for which, although extant populations occur in north-western Victoria, historical records again imply a previously wider distribution. In South Australia it is apparently even scarcer, with recent sightings only at two sites along the River

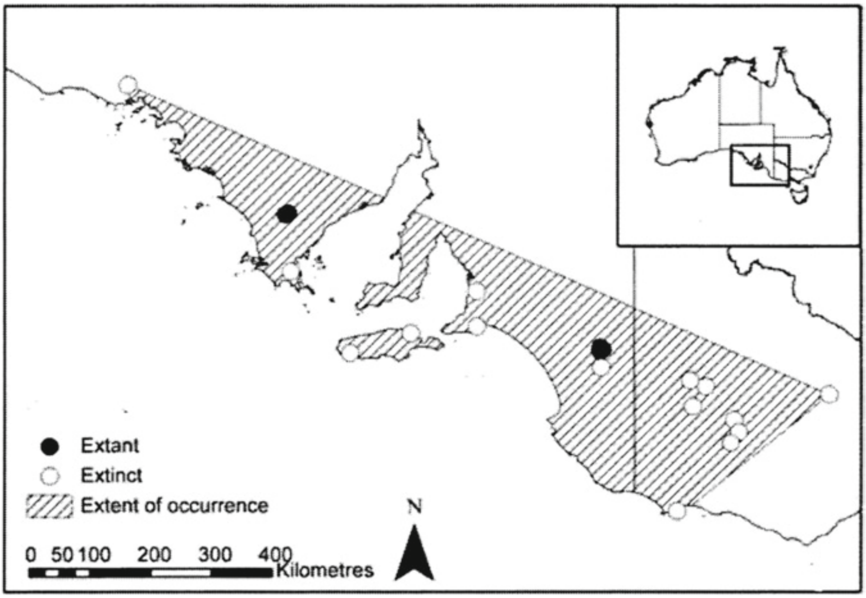

Fig. 7.4 Historical and current distribution of *Ogyris halmaturia* (from Braby and Douglas 2008)

Murray near the northern Victorian border. Butterflies were abundant at both Victorian populations known to Douglas (2003), but a classic collector locality at the more northerly Mildura cemetery (giving *O. s. subterrestris* the widely used common name of 'Mildura ogyris') no longer supports a population since changes to the site have occurred by earthworks and soil removal. In common with many other small 'pioneer cemeteries' in Australia, long fenced and protected from grazing and other despoliation that have severely altered the surrounding landscape, the Mildura cemetery is a haven for local wildlife, and part of it is protected for an endangered plant (*Ptilotus polystachyus polystachyus*, Amaranthaceae). It has been suggested as a possible re-introduction site for the butterfly, but Douglas (2003) suggested that further preparatory research should precede this risky process.

A population in South Australia known to Field (1997) and Douglas (2003) occupies a small roadside strip of mallee vegetation extending over an area of about 500 m long and 10 m wide. The site has been considered vulnerable to pesticide use on adjacent agricultural land (Field 1997), and is within a belt of land sprayed heavily to control locusts as this occasional need arises. To the other side of the roadside fence, sheep grazing has been implicated in butterfly decline. Only one of about 60 mallee eucalypts there supported *C. terebrans*, whereas about half the roadside trees did so (Douglas 2003). *O. s. subterrestris* may also be threatened by recreational activities, including habitat damage resulting from off-road vehicles, including trail bikes. Recovery needs noted in BAP include a recommendation for restricting vegetation clearance around known populations, with provision for buffer zones (suggested tentatively at 1 km) of conserved vegetation. Exclusion fencing may help regulate or remove stock grazing, and conscientious restriction of pesticide use is also needed. At present, further surveys for the butterfly are also needed, particularly to determine whether it still occurs in New South Wales, where its incidence is based on a single specimen captured at Broken Hill (far to the north of all other records) in 1912. The closely related *O. s. petrina* is known only from a small area near Lake Douglas (Western Australia), and is ranked as 'critically endangered' because of potential vulnerability to recreational activities over this small range. It may, indeed, already be extinct, and detailed surveys are needed to determine this.

Conservation concerns for several other *Ogyris* species reflect uncertainties (or polarised viewpoints!) over the integrity of localised subspecies of more widespread and generally more secure species. Thus, *O. amaryllis* is the most widely distributed species in the genus, but the putative subspecies *O. a. amata* is restricted to the Australian Capital Territory. The validity of this subspecies is doubted by some workers, reflecting the occurrence of forms intermediate between it and 'true' *amaryllis* in appearance. Subspecies *amata* has been considered rare (Dunn et al. 1994), with concerns over low recruitment of mistletoes on young trees in its range. Likewise, the gradation in appearance between *O. a. amaryllis* and *O. a. meridionalis* (an inland form) appears very gradual. Problems also occur in interpreting variation of *O. genoveva*. Thus, *O. g. araxes* has not been recognized by some recent authorities (including Dunn and Dunn 1991, Braby 2000) but was distinguished by Douglas (1995) as rare in Victoria and considered vulnerable to threats including fires destroying mistletoe-bearing host trees. The species has also been considered threatened in the Australian Capital Territory. Although the number of populations of *O. genoveva* has declined, some appear to be very secure in reserves so that it may currently not be threatened in its entirety. Nevertheless, it is one of many Australian butterflies for which many of the outlying populations, especially those on private land, could become increasingly vulnerable. Very little information is available on some of these: *O. g. splendida*, from inland South Australia is especially poorly known, and exemplifies the taxa for which conservation status can be inferred only from fragmentary biological information.

Outlying *Ogyris* populations of uncertain taxonomic status fall clearly into any consideration of conservation of 'significant populations' or 'evolutionarily significant units.' Whilst not necessarily vital to conservation of the presumed parent species, these may be important in illustrating the evolution and patterns of variation within it. Even if they prove to be simply clinal outliers, any distribution based on consistent phenotypic or biological difference may remark a unique entity, loss of which would impoverish Australia's biodiversity.

Chapter 8
Butterflies in a Disappearing Ecosystem: Alpine Satyrinae

8.1 Introduction

Australia's alpine and subalpine zones are small, confined to the southeast of the continent and, by European or other standards, not particularly high: the highest peak (Mt Kosciuszko) reaches only 2,228 m high, and much of the so-called 'snow country' lies well below this. The latter term was adopted as a descriptor by Green and Osborne (1994), because a consistently defined snow-line may be absent, particularly in Tasmania. Nevertheless, somewhat over 10,000 km^2 of southeastern Australia receives heavy and usually persistent snow every year, and the region commonly termed the Australian Alps largely comprises rolling plateaux in Victoria, New South Wales and the Australian Capital Territory. The term refers most commonly to these mainland areas, but Tasmania also has substantial, but generally lower elevation snow-covered areas. The mainland areas, in particular, are major foci of winter recreation and substantial resorts, with good accommodation and access roads, have been developed on or near many of the major peaks. The scenic attraction of the mountain areas also increasingly encourages summer tourists. Mainland areas are largely linked by a series of national parks and reserves and collectively cover an area of about 135 km^2, with the largest single area (the Snowy Mountains) about two thirds of this.

The true 'alpine zone', terrain above the treeline, varies considerably in elevation across the region, as a reflection of solar intensity. The snowline lies between 1,800 and 1,900 m in New South Wales, is somewhat lower in Victoria, and ranges as low as 750 m in south western Tasmania. This upper zone is botanically complex, with some 200 plant species in a number of distinctive associations. The lower 'subalpine zone' encompasses the altitudes between the uppermost limit of the treeline and the lower winter snowline, defined as that with continuous snow cover for at least one month a year. A variety of herbfields and grassland associations at higher levels intergrades with open woodland at their lower margins.

The major conservation concerns for the snow country, and for the numerous organisms largely restricted to it, arise from two complementary and complex syndromes, namely (1) acceptance of the reality of climate change, anticipated widely to reduce the areas of snow country substantially over the next few decades and

T. R. New, *Butterfly Conservation in South-Eastern Australia: Progress and Prospects*,
DOI 10.1007/978-90-481-9926-6_8,

(2) concerted efforts by the winter sports industry to capitalise on the recreational potential of the region before this is diminished. As Galloway (1988) noted, by northern hemisphere criteria of links between length of ski season and resort viability, even the main Australian ski resorts were then scarcely viable, with artificial snow-making facilities being used to extend the season. Modelling studies suggested that a rise in mean temperature of only 2°C would seriously threaten the viability of the industry, and reduce the average ski season from about 130 days to about 60 days, with skiing becoming impossible at the lower altitude resorts now popular for cross-country skiing. Coupled with anticipated reduction in precipitation of 20% in Galloway's models, the skiable areas of New South Wales could diminish from around 1,400 km^2 to about 270 km^2. Precise models are, of course, impossible to conjecture, but the 2°C projection above is not too disparate from another suggestion of the 'best' (+0.3°C) and 'worst' (+1.3°C) temperature rises by 2030, quoted by Pickering et al. (2008). However, whilst high profile candidates for conservation in the region include endemic mammals such as the mountain pygmy possum (*Burramys parvus*), many less charismatic organisms also give cause for concern. Many specialised endemic alpine plants are likely to become vulnerable as, in parallel with the butterflies discussed below, they would seem to have 'nowhere to go' should their current range become untenable.

8.2 Alpine Butterflies

The snow country supports many restricted range insects, with several species of Satyrinae amongst its most characteristic butterflies. In particular, several taxa of the Australian endemic genus *Oreixenica* are highly typical denizens of these higher altitudes and absent from nearby lowland areas. All are univoltine, have very characteristic flight seasons during summer, and can be locally abundant on alpine/subalpine herb fields and grasslands, where caterpillars feed on *Poa* tussock grasses. As noted earlier (p. 50) several of these may be threatened by warming climates, and are viewed as possible 'barometers' for climate change, as their current distributions are reasonably well-known. Populations of all tend to be naturally disjunct on the mainland, where the various plateaux are separated by inhospitable lowlands that the butterflies cannot (or, strictly, do not appear to) traverse.

The two taxa of primary conservation interest are both signaled as threatened (or likely to become threatened) by both climate change and more immediate habitat disturbance. *O. ptunarra* (p. 17) in Tasmania has considerable evolutionary interest as a variable local endemic species, and *O. latialis theddora* is a distinctive subspecies known only from Mt Buffalo, Victoria. Somewhat unusually for butterflies of conservation concern, the broader distributions of both taxa are well known and unlikely to be augmented much by additional surveys, but population structure remains unclear, together with the extent of inter-population dispersal and connectivity within the areas they occupy.

8.2.1 *Oreixenica ptunarra*

Despite recent suggestions (McQuillan and Ek 1997, p. 17) that the three named subspecies of *O. ptunarra* (Figs. 8.1 and 8.2) might not remain valid, and represent clinal variations, some conservation assessments to date have recognized these as distinct entities, subject to somewhat different levels of threat. Their broad ‘traditionally accepted’ distributions span the range shown in Fig. 8.3, with this collective range incorporating a net habitat area of about 4,000 ha (Neyland 1993). In addition, McQuillan and Ek suggested that the disjunct populations of especially small and dark butterflies should be named as a new subspecies. All three named subspecies have at some stage been appraised as ‘endangered’ (Dunn et al. 1994; Neyland 1992) or ‘vulnerable’. Discussions preceding status allocation for BAP suggested that none was truly endangered at present, but that *O. p. roonina* might be of the most serious concern because most of its main habitat is on private land and so threatened by changing land uses unlikely to occur on protected lands.

However, the revised taxonomic arrangement suggested by McQuillan and Ek was applied in a revised recovery plan (Bell 1999), in which the two entities recognized are termed ‘*O. p.* north-west’ for the putative new subspecies and ‘*O. p. ptunarra*’ for all other populations. By 1999, additional surveys of likely habitat had been made, and Bell considered that more than 90% of the area of occupancy had been identified. About 120 populations of *O. p. ptunarra* were known, covering about 11,100 ha of habitat, and the 30 populations of *O. p.* ‘north-west’ ranged over about 3,300 ha. Most occupied habitat was on private land, with only about 6% in any formal reserve. The six protected colonies covered about 600 ha in the Central Plateau Protected Area and about 50 ha in the Cradle Mountain/Lake St Clair

Fig. 8.1 *Oreixenica ptunarra*, female (photo: J. Homfray, courtesy M. Neyland)

Fig. 8.2 *Oreixenica ptunarra*, habitat of open *Poa* tussock grassland in Tasmania (photo: M. Neyland)

National Park, within the declared World Heritage Area. A further 18% of occupied habitat is on state-owned land, with the remaining 76% on private land.

O. ptunarra has lost much of its former range to pasture conversion of native grasslands, and Neyland (1993) also suggested that it might have been eliminated from parts of its range in the western Central Plateau of Tasmania by over-burning and over-grazing in the past, as well as by establishment of forestry plantations. Anderson and McQuillan (2003) claimed that it is highly susceptible to such random catastrophes. Whatever the causes of loss, *Poa* tussock grassland and related grassy woodland over much of the former range has been reduced to small isolated fragments of this formerly much more widespread biotope. This habitat fragmentation is associated strongly with parallel isolation of butterfly populations. Neyland's (1993) contention that without intervention the butterfly will continue to decline helped to draw attention to its plight, and the initial recovery plan (Neyland 1992) formed the basis for subsequent study and conservation interest. Assessments have been based on observations during the adult's short autumn flight season, when it is present on any site for only about 2 weeks each year.

Surveys by Neyland (1992, 1993) revealed 150 sites that supported *O. ptunarra*. Most of them are small (less than 10 ha) and only 20 are larger than 20 ha in extent (Fig. 8.4). However, in terms of site condition and the numbers of butterflies observed there, as well as land tenure, few sites were deemed 'secure' (Fig. 8.5). Most were considered 'vulnerable', and a few 'endangered' with the butterfly likely to become extinct in the near future. Indeed, several populations known in 1988

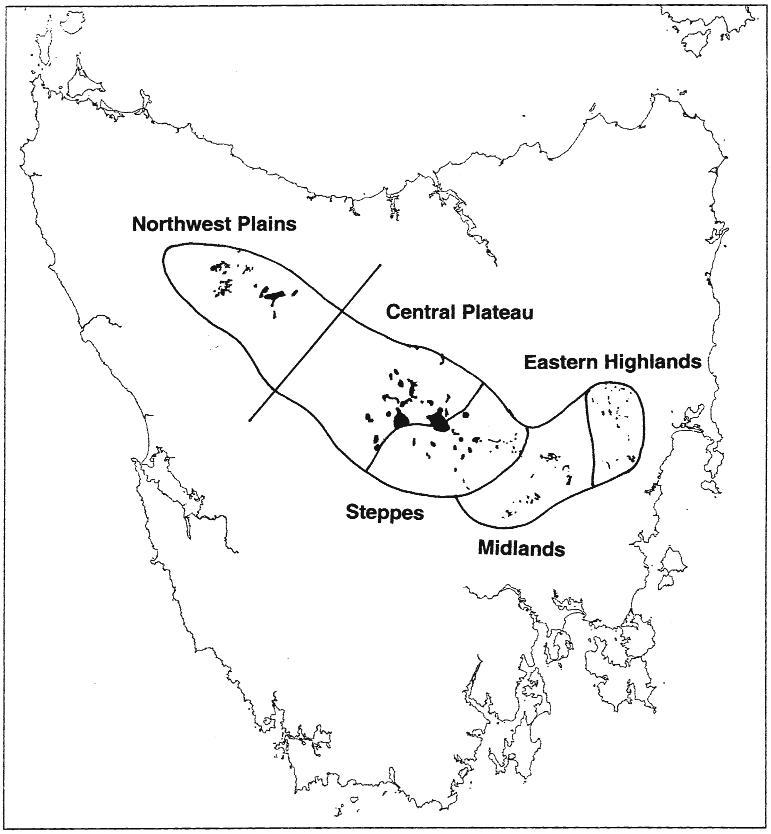

Fig. 8.3 Distribution of *Oreixenica ptunarra*: black and diagonal line shows distribution and division between the two subspecies now recognised (Bell 1999); the five biogeographical regions encompassing this range are shown (Neyland 1992, 1993), and the distribution of the 'traditional 'three subspecies across these is: *O. p. roonina* (Northwest Plains, Steppes, Midlands), *O. p. ptunarra* (Central Plateau), *O. p. angeli* (Eastern Highlands)

(Prince 1988a) had disappeared by the time of Neyland's survey shortly afterward. Areas of less than a hectare were considered unlikely to sustain populations. Most sites surveyed by Neyland were under continuing pressures from stock grazing. Dispersion of populations was also informative. Many populations were on the fringes of larger areas that could earlier have supported large numbers of butterflies but in which pastoralisation had massively reduced the extent of native vegetation. Stock grazing could usefully be reduced on many sites as a practical measure to reduce chances of further losses (Neyland 1993), but some limited grazing may be beneficial in preventing *Poa* from becoming overgrown. On the other hand, *Poa* is notoriously difficult to eliminate completely, even by heavy grazing.

The impacts of site isolation reflect the butterfly's dispersal capability. Flight behaviour of *O. ptunarra* was studied to (1) determine whether either sex exhibits

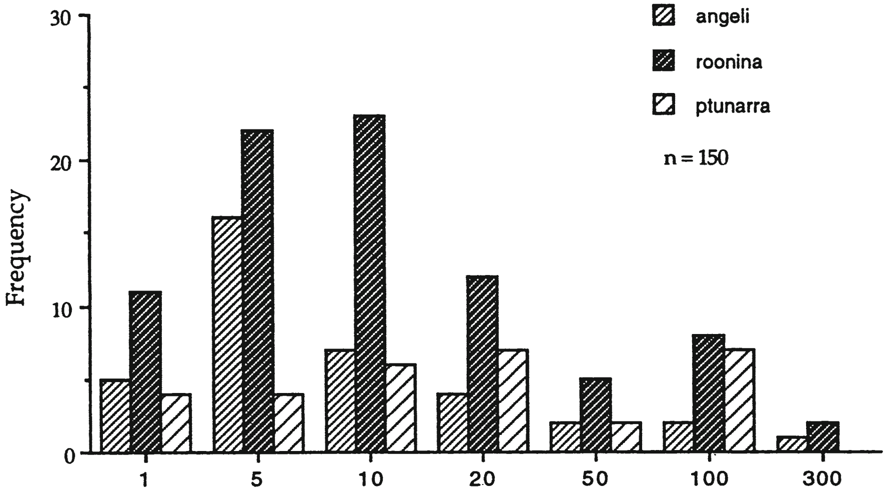

Fig. 8.4 Areas of sites occupied by *Oreixenica ptunarra* in survey by Neyland (1992, 1993)

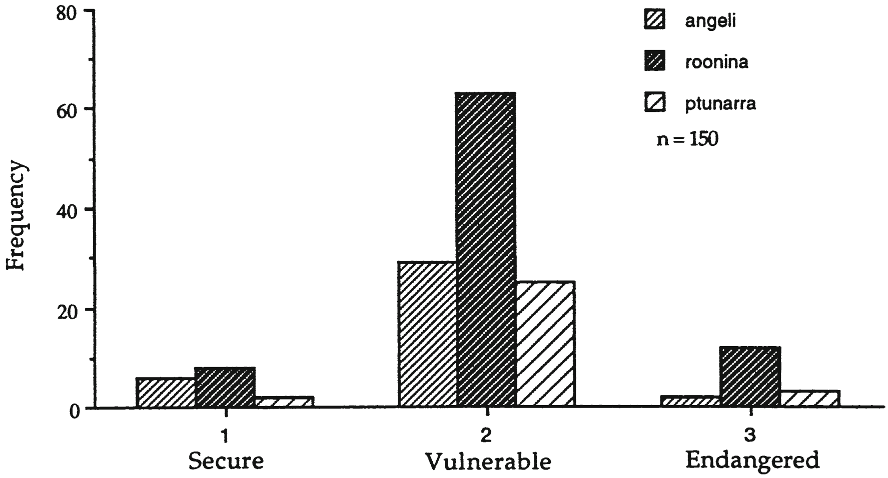

Fig. 8.5 Levels of vulnerability assessed for sites occupied by *Oreixenica ptunarra* in survey by Neyland (1992, 1993)

any form of territorial behaviour that might limit wider dispersal and (2) suggest how landscape features might influence connectivity in conservation management (Anderson and McQuillan 2003). Rather than using mark-release-recapture approaches, inferences were based on direct observations to construct a time budget for individual butterflies, and plotting their movements by dropping numbered flags at 10 s intervals or when the insect landed. This procedure enabled an individual's flight pattern to be assessed as a series of linear movements, and was facilitated by neither sex typically flying far. Males are more dispersive than females and moved a mean distance of 4.75 (±0.37) m each flight event. Their pattern usually constituted a 'closed polygon' to give strong inference of spatial territoriality within a site. Females are more sedentary, moving a mean distance of less than a metre (0.79 ± 0.18 m), without such defined pattern. If disturbed, butterflies fly further, and males engage other individuals in antagonistic encounters. This generally very localized dispersal led Anderson and McQuillan to suggest that restoration to form continuous corridors of *Poa* might best facilitate dispersal. However, the more extensive flight, aided by winds, also implied the value of 'stepping stone' plantings of tussocks in helping *O. ptunarra* to reach other sites. These tussocks could be spaced no more than 250 m apart, and linear corridors were suggested to be 10–15 m wide, and to contain open spaces suitable as territories. Neyland (1993) had earlier noted that a number of sites apparently suitable for *O. ptunarra* were unoccupied, and suggested that the butterfly might have been extirpated by land use changes in the past and later not been able to re-colonise the areas. Some sites might be suitable for re-introduction, or for facilitating re-colonisation, as above.

The outcomes from the initial Neyland recovery plan, guided by a recovery team operating from 1994, were positive, with a number of the proposed actions progressing (Bell 1999). In addition to its protection under the state act, *O. ptunarra* is protected during forestry activities under the Forest Practice Act 1985, with conservation guided by a Code of Practice. This protection is perhaps particularly important for the north-west subspecies, because in the North-West Plains, more than 80% of populations and more than half the habitat area occur on land owned by North Forest Products. Long-term agreement between the Company and the Parks and Wildlife Service are needed for butterfly conservation, together with other cooperative agreements with other landowners in the region.

Collectively, outcomes from the Neyland (1992) plan substantially increased ecological knowledge relevant to site management, so specifically that (1) fencing trials to exclude stock led to some butterfly declines due to increased weed and introduced grass invasions, so that grazed tussock grasslands were favoured by *O. ptunarra* over fenced ungrazed areas; (2) continuing cooperation with landowners led to incorporation of butterfly conservation considerations into ongoing farm management; (3) fire management has improved and is likely to increasingly become part of normal forestry management operations, with clear recognition that fire is important in sustaining habitat quality; (4) methods for monitoring butterfly abundance have improved; and (5) preliminary studies of feasibility for translocations have occurred. Translocation is possibly a useful tool for the future. An education brochure prepared in 1996 has been distributed widely in Tasmania and, together, these advances have enabled a refined programme for conservation based on ensuring protection on private land for specific populations, and continuing to foster land management practices sympathetic to the butterfly throughout its range. Monitoring is projected to assess effects of grazing and fires on butterfly abundance, and it is also important to stabilize the taxonomy of the *O. ptunarra* subspecies, as a consistent working tool for effective communication.

Bell's (1999) plan thereby had six designated Recovery Actions: (1) protect the habitat of specific populations; (2) provide advice and information to land owners and managers; (3) monitor habitat and butterfly population density annually over a series of selected sites; (4) revise the taxonomy of the complex; (5) undertake short distance translocations of butterflies as a feasibility study to determine whether new populations can be established by direct transfer of adults taken from secure populations; and (6) revise conservation status based on results, in anticipation of downgrading the butterfly to a lower category of conservation concern. Other than taxonomy, all these actions are under the control of a single agency, so that feasibility of accomplishing them may be increased by such a clear focus.

8.2.2 *Oreixenica latialis theddora*

O. l. theddora (Fig. 8.6) is highly unusual in that it is one of few taxa for which the entire range is within a designated national park, an area in which guided conservation management should be more likely to succeed than on the less controlled land subject to a variety of threats equivalent to those evident for *O. ptunarra* in Tasmania. Mount Buffalo is an isolated granite island (Fig. 8.7), rising to 1,723 m in central Victoria. Its significance and scenic grandeur were acknowledged by it being created one of Victoria's first national parks, declared in 1898. With more recent expansion, the park now encompasses 31,000 ha and supports more than 550 vascular plant species. The long interest in the area has ensured that much of the plateau is in 'near-natural condition' (Calder & Calder 1998), and the major habitats at higher levels include herb-rich snow grass plains on which the butterfly occurs. *O. l. theddora* is found also around some boggy areas, such as around Lake

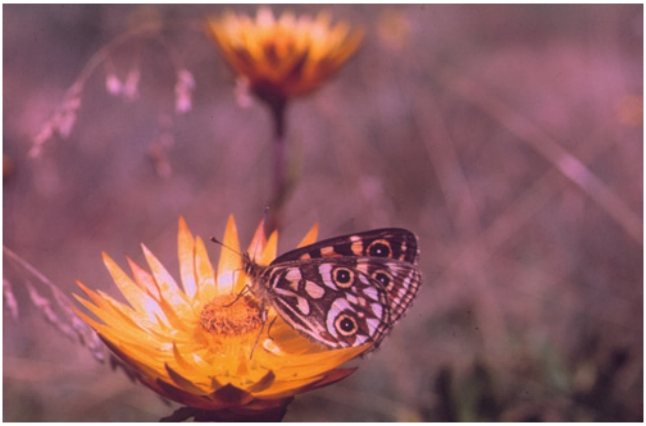

Fig. 8.6 *Oreixenica latialis theddora* on Mount Buffalo, Victoria

Fig. 8.7 Mount Buffalo, Victoria, habitat of *Oreixenica latialis theddora* below The Horn

Catani (Marion 1998), and is probably a relict on the plateau, not having survived at lower altitudes (Crosby 1998). It is widespread on the plateau, but occurs on a number of separated sites and only over the rather shallow altitudinal band above about 1,230 m.

This restricted distribution has signaled conservation interest, with a BAP ranking of 'Lower Risk (Near Threatened)', but no specific conservation recovery actions were proposed. It was listed under the Flora and Fauna Guarantee Act in 2003 on the bases of being 'significantly prone to increased human pressures associated with recreational activities in the alps', noting also that 'It is prone to threats by inappropriate fire'. Susceptibility to climate change was also noted. The major continuing need is to prevent additional losses and fragmentation of the habitat, such as by carefully controlling expansion of recreational activities and associated disturbances and constructions. The butterfly is mentioned amongst the significant fauna of the park in the Mount Buffalo National Park Management Plan (1996), but no additional information is included.

O. l. theddora is already at the highest altitudes at which suitable habitat occurs at present, and clearly has only very limited opportunity to follow the commonly predicted trend of 'moving upward' to track progressively suitable regimes as warming proceeds. Its future thereby seems rather bleak and difficult to predict. The problem is complex on Mount Buffalo, as the main snow grass areas are below the treeline, rather than the more usual condition of comprising a distinct zone above this (Figs. 8.8 and 8.9). The grasslands occur in an 'inverted treeline', as areas between hills that are prone to summer frosts. They are apparently maintained by those frosts inhibiting invasion of these cool areas by snow gums (*Eucalyptus*

Fig. 8.8 *Oreixenica latialis theddora*, typical habitat on Mount Buffalo: near Lake Catani

Fig. 8.9 *Oreixenica latialis theddora*, habitat as inverted tree line, grassy habitat in frost hollow, Mount Buffalo

pauciflora) from adjacent wooded areas; warming might remove this inhibition and facilitate rapid invasion of the habitat by trees.

The mechanism suggested to maintain this 'inverted' condition is that cold air assembles in valleys at night, resulting in much cooler air temperatures than on nearby ridge-tops (Williams and Costin 1994). Many native trees and shrubs are killed off as juveniles in the resulting prolonged cold conditions. Such frost hollows grasslands are a conspicuous feature of the Australian Alps, and occur in areas of cold air drainage at about 1,200–1,650 m altitude. They are typically fringed with full-sized trees, most commonly of *E. pauciflora*, and the dynamics of the boundary maintenance have received considerable recent attention in relation to possible climate change influences, and with implications that boundary dynamics may indeed be changing and tree invasion increasing. On Mt Hotham, where this dynamic boundary has been studied in some detail (Wearne and Morgan 2001), some invasive trees have gained sapling status, but intrusions have occurred only up to 15 m from the boundary edge – still well beyond any protective effects of the existing canopy cover. Causes of this expansion are not yet fully defined, but duration of snow cover and increased temperatures during the growing season are regarded as likely contributors.

The treeless regions of the Australian Alps are those most intensively exploited by people, earlier for stock grazing (and with the non-renewal of grazing licences from 2005 a highly controversial issue undertaken for conservation of the alpine environments) but latterly skiing and tourism amongst major influences on land change. In addition, alien plant invasions are far more varied than widely supposed. McDougall et al. (2005) listed 128 invasive species, most of them uncommonly, from treeless areas. Many of these plants appear unable to establish permanently at low temperatures and in areas with long snow cover. Extensive alpine fires in 2003 were followed by dramatic expansions of some species, and the difficulty of eradicating aggressive invasive plants is already a serious management issue for the region. McDougall et al. (2005) thus endorsed earlier opinions that the alpine areas may be at serious risk from plant invasives.

With climate change predictions close to those modelled by Galloway (1988, p. 107), trees are likely to encroach increasingly on currently treeless high elevation areas in Victoria, with raised temperatures also likely to facilitate colonisation and establishment of further alien plants. In the meantime, and recognising the practical problems of controlling arrivals of 'opportunistic plants' with vehicles or people, greater care over the species used in replanting bare soils and those used in ski resort summer gardens is needed to exclude species not native to the area.

In Tasmania, the forest-grassland boundaries occur at much lower altitudes – from about 500 m upward – and those at different altitudes were compared by Fensham and Kirkpatrick (1992). In all three zones appraised, open areas were colder and had wetter surface soils than forests. Projected low temperature limits to tree establishment would differ substantially with altitude, and no single critical temperature value occurred. In these environments, the primary cause of lack of trees in open areas may be competition for moisture and root space from the dense grass sward. Although stock grazing inhibits seedling growth, it does not appear to be a major cause of seedling exclusion. Frost and waterlogging may contribute at higher altitudes, and fire might also be influential (Fensham and Kirkpatrick 1992). Rapid accumulation of fuel loads in lower altitude *Themeda* grassland rendered frequent fires likely, so that persistence of tree seedlings to reach their sapling stages was considered difficult. This complexity suggests that there may be no simple explanation for the boundary dynamics, and that these are influenced by a wide array of factors in concert. Nevertheless, knowledge of how high altitude grasslands are maintained is a key element of conservation planning for alpine *Oreixenica* and other denizens of these restricted biotopes.

Chapter 9
Butterfly Community No. 1

9.1 Introduction

Victoria's Flora and Fauna Guarantee Act (FFG) recognises three main categories of entities for formal listing, namely species, communities and threatening processes. It was innovative in extending the extent of formal protection beyond the initial species level, and in addressing measures to counter the major causes of conservation concern. The most difficult of these categories to deal with is 'ecological communities', largely because of the difficulties of suitable definition, but is underpinned by the need for the entity to be ecologically defined, rather than simply applying to an individual site defined by place name. 'Butterfly Community No. 1' is the only insect-based community so far listed and has demonstrated (and, in some cases, helped to clarify) the many practical problems in definition that can arise, and in deciding the 'boundaries' of any such entity. It was nominated (23 October 1989), and listed (22 May 1991), on the presence of a number of 'rare' butterflies at Mount Piper, near Broadford in central Victoria (Fig. 9.1), constituting an assemblage that appeared decidedly unusual in both composition and richness.

9.2 Mount Piper

Mount Piper is a conspicuous local landmark, a vegetated conical volcanic plug projecting to 456 m from a largely cleared pastoral plains landscape on the outskirts of the town of Broadford, and its summit has long been known to butterfly collectors as an important hill-topping site in central Victoria, from which a number of locally elusive species may be retrieved. As such, it is an oasis of more natural vegetation in a highly altered landscape dominated by introduced grasses (Jelinek et al. 1994). Prime among the significant butterflies reported there are the two species of 'ant blues' that occur in central Victoria, *Acrodipsas myrmecophila* and *A. brisbanensis*, and for some decades Mount Piper has been the only locality in the state where these two species are known to co-occur. Both species are listed individually for protection under FFG (see Jelinek and White 1996a, b) and they

T.R. New, *Butterfly Conservation in South-Eastern Australia: Progress and Prospects*, 119
DOI 10.1007/978-90-481-9926-6_9, © Springer Science+Business Media B.V. 2011

Fig. 9.1 Mount Piper, view from nearby to indicate local prominence in pastoral landscape

and the wider butterfly community are considered to be 'significantly prone to future threats that are likely to result in their extinction, primarily because of their restricted occurrence and sensitivity to environmental conditions'. In particular, proposals for gold-mining and other mineral exploration (following from earlier explorations in the twentieth century and with interest revived over recent decades and several applications for exploration licences for the area being made) might lead to serious damage to the community, amongst a portfolio of other threats including fire, land clearance, damage by feral (goats) and other grazing mammals (cattle, rabbits), and possible over-collecting of selected butterfly species. At that time, much of Mount Piper (about 56 ha) was included in an Education Reserve for the Study of the Natural Environment, established in 1980. The prominence of Mount Piper had earlier led to development of the summit area for transmission and survey purposes, with associated development including a vehicle track to just below the summit, and tree felling to establish sight lines, as well as communication towers and a radio shed. In the 1940s, the Broadford paper mill was fueled by timber from Mount Piper, and mining for gold and antimony occurred – with intermittent mining and mineral exploration applications occurring up to the present, as extraction techniques continue to improve and render treatment of low grade ores economically viable. With increasing community pride and realisation of the wider conservation interest of the area, most goats had been eradicated by 1990, and the radio shed, mast and associated structures also removed by that time, so that the summit area has gradually been restored to a more natural state.

Consistent local support for conservation of Mount Piper and its environs has been headed by the Broadford Environmental Action Movement (BEAM). The area has been a focus of research and management since 1992 (Jelinek 2005) and is listed on the Register of the National Estate (p. 163), based on its ecological significance, particularly for invertebrates. In addition to a variety of localised butterflies, Mount Piper supports two state-listed mammals, the brush-tailed phascogale (*Phascogale tapoatafa*) and the Common bent-winged bat (*Miniopterus schreibersii oceanensis*). In the 1990s it was also the site on which one of very few populations of the golden sun-moth (*Synemon plana*, Castniidae, p. 170) then known in Victoria occurred. Conservation management thereby focused on the putative needs of the moth (grassland) and the ant blues (woodland, summit), so encompassing concerns for several different biotopes.

The initial Action Statement for the Community (Jelinek 1991) set out a series of desirable actions (Table 9.1) as a basis for increasing knowledge and focusing management, with the recognition that far more detailed information on the biology of the two key ant blue species was needed, together with surveys to enumerate the butterfly species present and to detect any further species of direct conservation interest. Further searches were projected on putatively similar hills in central Victoria, to determine whether a similar suite of butterflies occurred there, and indicate the possible unique features of the Mount Piper assemblage.

Table 9.1 The initial management actions suggested for 'Butterfly Community No 1' in Victoria (Jelinek 1991)

Research and monitoring
Focus on habitat requirements and biology of rare butterflies
Encourage intensive systematic monitoring
Survey to endeavour to locate other sites where community may occur
Identify and document critical habitat of community
Increasing awareness and formal protection
Ensure protective zoning from Shire of Broadford, to prohibit mining, control vegetation clearance, and include sympathetic land use
Gazette regulations for Mt Piper Education Reserve
Implement awareness, information, education programme for local community
Site management and threat abatement
Ensure adequate perimeter fencing, where necessary assisting landholders to fence around community on freehold land
Involve local community in activities such as hand removal of introduced weeds and monitoring butterfly populations
Control and eradicate rabbits and selected weed species
Promote revegetation of all disturbed areas and tracks
Investigate alternative sites for facilities needed by public authorities; relocate remaining facilities outside community
Remove redundant structures from summit
Improve and maintain access road in reserve
Restrict vehicle and horse access; prohibit trail bikes; provide visitor interpretation display and brochure; instigate regular patrols
Initiate appropriate fire management
Landscape context
Conserve and enhance native vegetation corridors to increase connectivity of Mt Piper with other areas of natural vegetation

Surveys of butterflies commenced in 1991–1992 and 1992–1993, when transect counts and hilltop surveys for adults were made throughout the main flight season (November–March) (Britton and New 1993). These surveys increased the number of butterfly species reported from Mount Piper to 37, with others reported later (Table 9.2), but a number were of uncertain residential status and some were clearly stragglers or more regular migrants outside their normal breeding range. The surveys demonstrated the twofold importance of Mount Piper as (1) a habitat for nearly a third of Victoria's resident butterflies and (2) a hill-topping site for additional, non-resident, species, some of which are rarely recorded in the state. However, it remained unclear whether the *Acrodipsas* species, and some others of conservation interest, recorded on the summit bred in the Mount Piper reserve.

The species of greatest interest was the small ant-blue, *A. myrmecophila* (Fig. 9.2) always rare in Victoria but with a wider Australian distribution and, although quite rare throughout its range and most records of hill-topping individuals (Dunn and Dunn 1991), the main conservation concerns are within the state. Its recorded historical distribution in Victoria included three localities: the vicinity of Ringwood (an outer eastern suburb of Melbourne, where it has been lost to urbanisation), Ocean Grove, to the west, and Mount Piper (Fig. 9.3). Most biological knowledge had been accrued in the 1960s from studies on the Ocean Grove population before that, too, became extinct. Most Victorian specimens in collections had been reared from larvae or pupae found there associated with a nest of the so-called 'coconut ant' *Papyrius* (previously *Iridomyrmex*) '*nitidus*', a member of a complex of species and itself rare. Observations at Ocean Grove suggested strongly that this was an obligate association, and that the caterpillars fed on ant brood. The same ant colony was visited in the early 1990s, but the butterfly had apparently long since disappeared, so that Mount Piper was the only known locality for this butterfly in Victoria. It was, however, exceedingly elusive, and three seasons of observation yielded only five hill-topping individuals (New and Britton 1997), so that its very scarcity may result in substantial under-recording of where it actually occurs, and renders documentation of population size almost impossible.

The 'large ant-blue', *A. brisbanensis cyrilus*, is somewhat variable in appearance, and only doubtfully distinct from *A. b. brisbanensis*. However, in the sense in which these names are applied most commonly, and pending thorough taxonomic reappraisal (as advocated by Sands and New 2002) the two do not overlap in Victoria. *A. b. brisbanensis* occurs only in the east of the state, and *A. b. cyrilus* in the central and more western regions. The few known populations occur mainly in forest and woodland remnants, with a population reported by Douglas (1995) from the Little Desert National Park apparently the largest known. In South Australia, it is known from one site and regarded as endangered (Grund 1999). In Victoria, it has apparently been lost from more than half of the limited number of sites from where it has been recorded historically (Fig. 9.4), with most of the remainder – including Mount Piper – being hill-topping sites with no clear evidence of the butterfly breeding in their vicinity. Indeed, many of the initial management needs projected for both species by Jelinek and White (1996a, b) were formulated from experiences there. Details of the life history of *A. brisbanensis* are not yet clear, but

Table 9.2 'Butterfly Community no 1'. The taxa reported from Mount Piper, Victoria to 1998, and their status

Hesperiidae	
Trapezites phigalioides	Resident
T. phigalia phigalia	Resident
Trapezites luteus luteus	Possible resident
Hesperilla donnysa	Vagrant
Dispar compacta	Resident
Signetta flammeata	Possible resident
Taractrocera papyria papyria	Resident
Ocybadistes walkeri sothis	Vagrant
Papilionidae	
Papilio anactus	Non-resident, migrant
P. demoleus sthenelus	Non-resident, migrant
Pieridae	
Delias aganippe	Resident
D. harpalyce	Resident
Belenois java teutonia	Non-resident, migrant
*Pieris rapae ra*pae	Non-resident, migrant
Appias paulina ega	Non-resident, migrant
Eurema smilax	Non-resident, migrant
Nymphalidae	
Geitoneura klugii klugii	Resident
Heteronympha merope merope	Resident
H. penelope sterope	Resident
Vanessa kershawi	Resident
Vanessa itea	Possible resident
Acraea andromacha andromacha	Non-resident, migrant
Danaus chrysippus petilia	Non-resident, migrant
Polyura pyrrhus sempronius	Non-resident, migrant
Lycaenidae	
Acrodipsas brisbanensis cyrilus	Presumed resident
A. myrmecophila	Resident
Hypochrysops delicia delos	Resident
Ogyris olane ocela	Resident
O. genoveva genoveva	Presumed resident
O. abrota	Presumed resident
Neolucia agricola agricola	Possible resident
Theclinesthes miskini miskini	Possible resident
T. serpentata serpentata	Possible resident
Lampides boeticus	Possible resident
Zizina labradus labradus	Resident
Nacaduba biocellata biocellata	Resident
Candalides hyacinthinus hyacinthinus	Possible resident
C. h. simplex	Vagrant
Lucia limbaria	Possible resident
Jalmenus evagoras evagoras	Resident

(continued)

Table 9.2 (continued)

J. icilius	Former resident -? extinct
Noctuidae	
Comocrus behri	Resident
Phalaenoides glycine	Resident
Eutrichopidia latinus	Resident
Castniidae	
Synemon plana	Resident
Arctiidae	
Nyctemera amica	Resident
Asura lydia	Resident
Utetheisa pulchelloides	Resident
Thaumetopeidae	
Epicoma tristis	Resident
Zygaenidae	
Pollanisus viridipulverulenta	Resident

Note: a number of conspicuous diurnal moths are also listed here, as 'honorary butterflies'. Most of these are common and widespread species but the golden sun-moth, *Synemon plana*, is federally ranked as 'critically endangered') (list from New 1998)

Fig. 9.2 *Acrodipsas myrmecophila*: adult emerging from nest of *Papyrius* ants (Ocean Grove, Victoria) (Photo: D.F. Crosby, November 1961)

it is believed strongly to have an obligate association with *Papyrius* ants (oviposition on a stump occupied by *Papyrius* was reported at Kangaroo Ground (p. 134) – a formerly occupied site near Melbourne – by Douglas and Braby 1992), so that this ant genus constitutes a critical resource for both ant-blue species, with strong suggestion that both may form mutualistic relationships with it.

However, *Papyrius 'nitidus'* is also elusive. It nests in dead wood – either standing or fallen, with most reports of its incidence being from open forest areas. The

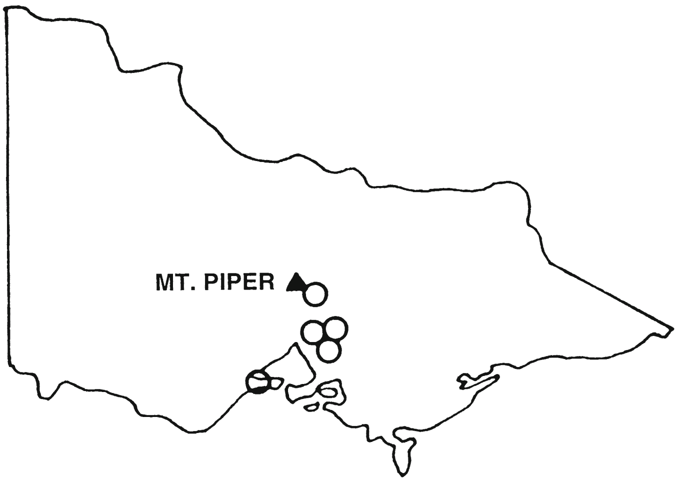

Fig. 9.3 *Acrodipsas myrmecophila*: distribution records for Victoria (Mount Piper indicated by *triangle*, historical records as *open circles*)

Fig. 9.4 *Acrodipsas brisbanensis*: distribution records for Victoria (notation as for Fig. 9.3; extant records as *solid circles*)

ants forage for honeydew produced by Homoptera on eucalypts and acacias, and nests are sometimes close to such desirable food supplies. In addition to the strong coconut scent that gives the ants their common name, carton coverings to byres and trails are also reasonably diagnostic. Apparent nests in stumps or logs may be linked by underground pathways over areas of up to a hectare or more. Surveys of ants at Mount Piper by pitfall trapping and direct searches revealed substantial ant diversity (New et al. 1996), and added to the conservation importance of the site as an area where 'more mesic' and 'more arid' ant faunas meet in Victoria, but failed to reveal *P. nitidus*. Nevertheless, an interim management step was to try to maintain suitable *Papyrius* habitat by prohibiting collecting of roadside fallen wood for fuel, and emphasising the importance of retaining remnant natural vegetation on neighbouring private properties. The ant, however, was known to have been present on farmland about 3 km east of the reserve in the mid-twentieth century (ca 1950–1970), when *A. myrmecophila* was also recorded; that population may have been extirpated by agricultural development (D.F. Crosby pers. comm. 1991).

Further direct searches led to finding a small colony of *P. nitidus* in privately owned land abutting the eastern side of the Mount Piper reserve in late 1994, in which a grid of 20 pitfall traps operated for 6 months to survey ants only some 25 m away had previously failed to reveal its presence (New and Britton 1997). The ants occurred in a small stump, and in several pieces of dead wood, collectively over an area of about 15 × 25 m. Beardsell (pers. comm. 1991; Beardsell 1994) studying a *Papyrius* population near Kinglake, had demonstrated that augmenting the supply of suitable dead wood – as by well-weathered old wooden fence posts with natural crevices and cavities and left on the ground – enabled the ants to move into suitable cavities and incorporate the wood into their occupation. This important principle led Britton (1997) to experiment with artificial wooden 'trap nests' at Mount Piper, and monitoring of an initial series of six trap nests placed near the ant colony in January 1995 showed that all were indeed colonised rapidly (possibly reflecting general scarcity of other dead wood in the colony region) by *Papyrius* and subsequently contained early stages of *A. myrmecophila* (New and Britton 1997), with its identity confirmed by captive rearing. The trap nests (Figs. 9.5–9.7) were designed for easy rapid opening and examination, without disturbing the ants and caterpillars unduly, and repeated inspection of their contents facilitated the first tentative interpretation of the lifecycle of the small ant-blue (Figs. 9.8–9.10). *A. brisbanensis* was not found in these nests, and may be associated with another very similar *Papyrius* found elsewhere more on standing dead timber. Thus, although hill-topping *A. brisbanensis* individuals were apparently more numerous than those of *A. myrmecophila*, the former's conservation needs cannot be specified precisely. Males of *A. brisbanansis* were observed (four in 1991–1992, five in 1992–1993) around the highest eucalypts on the summit; no females were seen, although they have been reported hill-topping elsewhere (Braby pers. comm.1993).

The trap nests revealed some critical features of the life cycle of *A. myrmecophila*, with the seasonal pattern of development summarised in Fig. 9.10. The pattern is predominantly bivoltine, with the two generations differing considerably in developmental time. The early ('spring') adults result from eggs laid in March/April, with the earliest pupae found in September, and adults emerging from early November. Caterpillars from eggs laid from mid-November onward develop over only about 2 months, with pupae found from early February, and some adults emerging soon afterwards. Eggs were found adjacent to the ant nest entrance, most

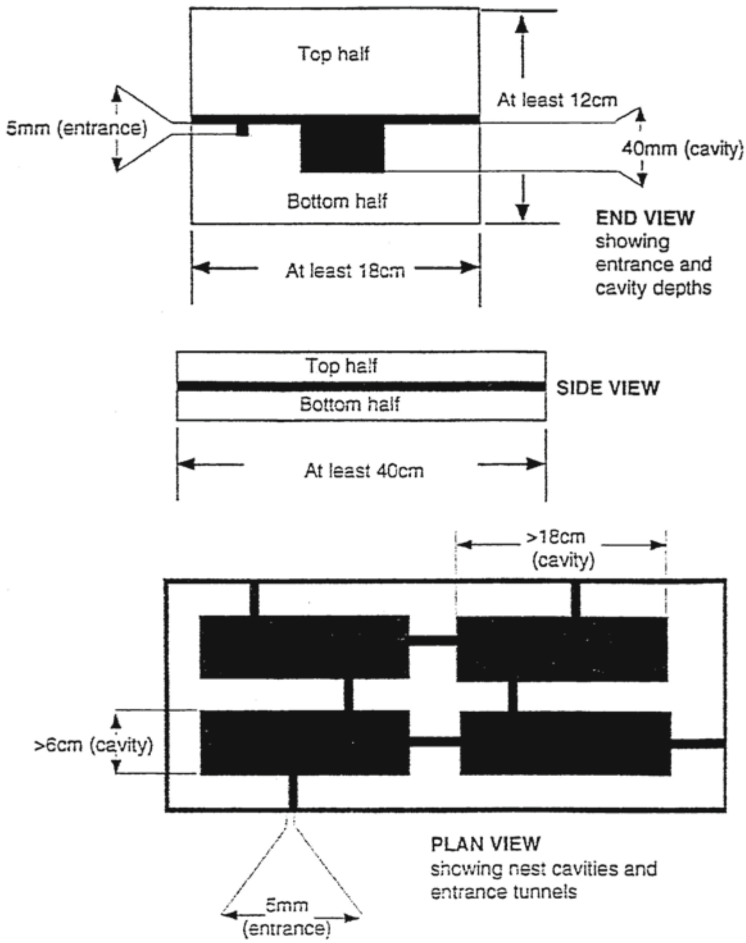

Fig. 9.5 Design of wooden trap nests for *Papyrius* ants as tools in conservation of *Acrodipsas* spp. (from Britton 1997)

of them close to the ground, and are tended by worker ants. First instar caterpillars enter, or are carried by ants into, ant nests and appear to pass the whole of their development there. Caterpillars feed on ant brood, and pupation takes place in or near the nests. The butterfly therefore appears to exhibit obligatory larval myrmecophagy and to have entirely abandoned phytophagy, so that conservation of the ant is a key element of conservation, with supply of dead wood and accessible honeydew needed.

Consideration of translocating ant colonies to expand locally the area over which it occurs followed from the successful adoption of trap nests, as above. If such nests supported independently thriving ant colonies, they would constitute near-perfect translocation units, simply by moving them to new sites (New and Britton 1997): if they also contained caterpillars at the time of moving, the entire community module

Fig. 9.6 Trap nest, as above, as placed in the field

Fig. 9.7 Group of trap nests placed near regenerating small eucalypts as source of honeydew for *Papyrius* ants at Mount Piper

could be included. Long distance translocations have not yet been attempted, but encouraging trials over several hundred metres at Mount Piper indeed suggest independence of *Papyrius* colonies in individual trap nests. The practicalities of using the nests (1) as monitoring devices for such rare butterflies; (2) as a means of augmenting local ant colony size and accessibility; and (3) for translocation purposes each merit exploration for related lycaenid species.

Finding a mate and an uncommon ant appear to be highly risky processes for any butterfly that itself occurs in only low numbers, and the normal behavioural

Fig 9.8 Trap nest opened to show ants and caterpillars/pupae of *Acrodipsas myrmecophila* after several months of field placement at Mount Piper

Fig. 9.9 Group of pupae of *Acrodipsas myrmecophila* on dead wood at Mount Piper

repertoire must accommodate these needs. Hill-topping appears to be an integral part of mate-seeking, and emphasises the importance of maintaining suitable topography in the landscape. Britton et al. (1995) noted the partitioning of 'territory' or perching stations between different butterfly species adopting this behaviour on Mount Piper, so that even individual trees were important for particular species. For conserving 'butterfly communities', it may be necessary to

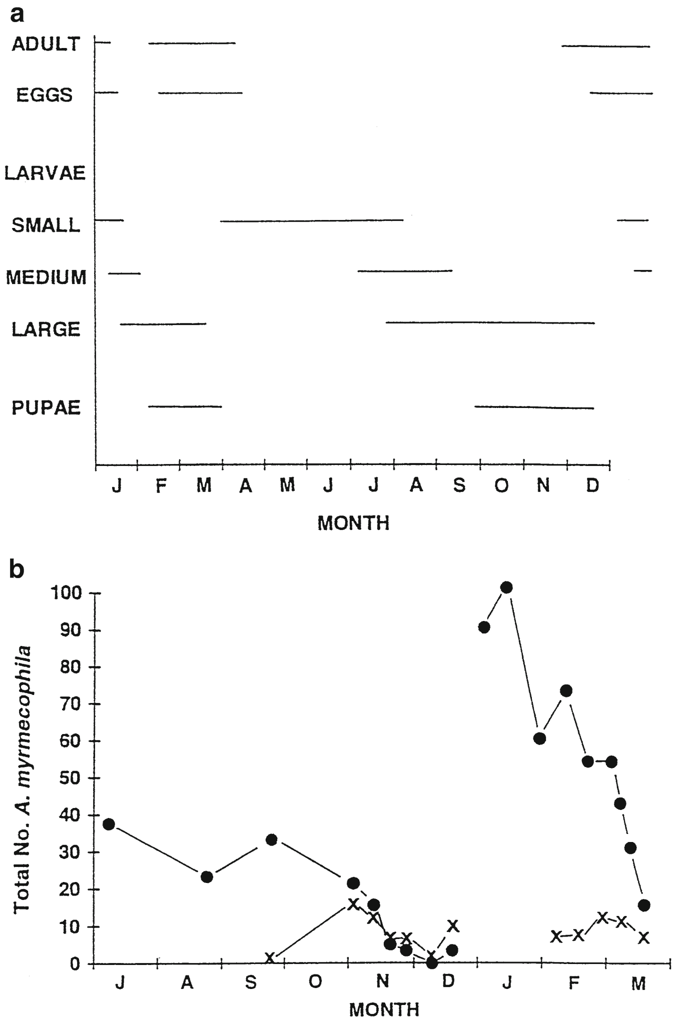

Fig. 9.10 Seasonal development of *Acrodipsas myrmecophila*: (**a**) pattern of seasonal interpretation, based on (**b**) numbers found within trap nests (solid circles, larvae; crosses, pupae; both from New and Britton 1997)

maintain individual isolated hill tops in sufficiently diverse form that an array of territories and flyways supports the needs of the various species of interest (Fig. 9.11).

At Mount Piper, several other significant lycaenids were found on the summit. They included *Ogyris genoveva genoveva* (known from fewer than ten localities in Victoria, and associated with some *Camponotus* ants nesting around trees supporting mistletoes), and the more common *O. olane ocela*, and *Hypochrysops delicia delos*. For the two species of *Acrodipsas*, it is likely that the highly characteristic coconut-like scent emitted by the ant functions as an attractant cue for female

Fig. 9.11 Hilltop area of Mount Piper, indicating variety of territorial perches and patrolling areas

butterflies to locate ant nests for oviposition. It might, therefore, be possible to employ similar cues to monitor for presence of the adults in surveys, but several trials at Mount Piper have not yet confirmed this. The scent produced by *P. 'nitidus'*, as an anal gland secretion, is apparently sufficiently unusual and specific to be used for host-seeking in this way. It is associated with isoiridomyrmecin, and the ant also produces isodihydronepetalactone (Cavill and Clark 1967).

The two species of *Acrodipsas* discussed here are amongst many poorly-understood ant-associated lycaenids in Australia, and any innovative survey protocols, or modes of manipulating the species in conjunction with specific host ants, may have much wider conservation relevance. Although myrmecophagy seems to have evolved many times in the Lycaenidae, it is regarded widely as 'evolutionarily unstable' as it has only rarely persisted: in this regard, *Acrodipsas* is apparently unusual (Eastwood and Hughes 2003). Mitochondrial cytochrome oxidase analysis implied that *A. brisbanensis* and *A. myrmecophila* are closely related, and perhaps basal in the genus because they parasitise the ancestral dolichoderine ants. Most other species of *Acrodipsas* have shifted later to associate with Myrmicinae (*Crematogaster*), but the genus may have originated in eastern Australia. Only one other species of *Acrodipsas*, *A. cuprea*, is found in Victoria and differs substantially from the two of concern here in associating with *Crematogaster*.

9.3 Communities in Legislation and Practice

The specific needs for conserving 'Butterfly Community no. 1' have so far emphasised these selected species, in the context of the main features of a specific site, and as emphasised in a later 'recovery plan' (New 1998), in which the twin aims were to provide broad security of the site, with resources to conserve diversity, and more focused programmes to conserve notable individual species in this context. Both of these demand a combination of research and practical management actions. Each was considered under a hierarchy of specific objectives and actions needed (Table 9.3), following an overall objective of 'To stabilise and maintain the butterfly community … and, through management of the habitat and core focal species of Lepidoptera, to downgrade the community and listed endangered or vulnerable species within 10 years'. This has not been achieved, but in working toward this target the support of the local community, building on the importance of Mount Piper as a local emblem, has been important, with information on ant–butterfly mutualisms and importance of hill-topping for butterflies provided through signage and incorporation into local environmental advices. Many of the recommended management steps extend beyond site details, as the fundamental need to maintain a natural environment with controls on removal of native vegetation is widespread. Ensuring supply of dead wood and living mistletoes, weed control, minimising vehicle disturbance and dam-

Table 9.3 Objectives proposed for conservation research and management in Recovery Plan for Butterfly Community No 1 in Victoria (New 1998), to indicate overall scope. Each objective was accompanied by a set of specific actions, with time-lines and criteria for success, and indicative costing

Group 1 (community emphasis)
To maintain at least the current number of butterfly species resident at Mt Piper, and to avoid extinction of any such species from the community
To maintain and enhance resources to foster the wellbeing of all resident species of butterfly and facilitate colonisation of other species from nearby areas
To manage environmental weeds invading natural vegetation, particularly grassland, at Mt Piper
To increase habitat protection through community awareness and involvement
Group 2 (species emphasis)
To further define critical habitat and critical resource needs for all focal species, and ensure the maintenance and enhancement of these in a condition suitable to sustain viable populations of each resident focal species at Mt Piper
To investigate the ecology and biology of the least-known focal species, *Acrodipsas brisbanensis*, at any site where a viable conspecific population might occur, and to continue to seek it at Mt Piper
To determine the host ant of *A. brisbanensis* and, if necessary, to establish it or enhance colonies at Mt Piper
To enhance populations of coconut ants, *Papyrius nitidus* agg., at Mt Piper
To develop reliable techniques for detecting and monitoring *Acrodipsas* adults at Mt Piper
To attempt translocations of *Papyrius nitidus* agg. within the Mt Piper reserve using trap nests and, if successful, to investigate feasibility of translocating *A. myrmecophila* larvae to additional nests within the Mt Piper area
To establish *A. myrmecophila* at another site
To improve quality and extent of native grasslands for *Synemon plana* and continue to investigate its ecology and monitor population size and extent
To continue to seek breeding colonies of *Ogyris g. genoveva* in the Mt Piper area, and investigate further links with *Camponotus consobrinus* group ants

age from over-grazing (whilst recognising that regulated grazing may be important for management) are all widespread concerns, together with summit maintenance.

The importance of hill tops for butterflies is acknowledged formally in New South Wales, where 'Loss and/or degradation of sites used for hilltopping by butterflies' was listed as a Key Threatening Process in April 2001. This listing recognised that disturbances to plants or topography of hill tops, together with their slopes and surroundings may affect suitability for hill-topping and lead to disappearance of butterflies. Suggestions were made that some local extinctions had already occurred in the State from this cause. The background to the listing noted a representative list of 14 species whose populations could become threatened by loss of hill-topping sites. A suite of nine desirable actions for conservation was proposed (Table 9.4), and these independently incorporate the major points arising from Mount Piper.

They go far towards an acceptable focus for definition of a 'threatened community', but in reality, managers and scientists in Victoria usually consider 'Butterfly Community no 1' as synonymous with 'Mount Piper', not least because no other sites have been formally included in the definition of this community! Surveys for butterflies have been undertaken on hilltops at a number of other sites in central Victoria (Fig. 9.12), in an attempt to determine their similarity to Mount Piper.

However, most sites were visited only once, so that detection of the rarer species would be highly uncertain. None yielded *A. myrmecophila*, but *A. brisbanensis* was

Table 9.4 Strategies and priority actions identified to help conserve sites used for hill-topping by butterflies in New South Wales, consequent upon this being a formal listed concern (formulated in 2005, Department of Environment and Conservation, New South Wales)

Community and land-holder liaison/awareness and/or education
Prepare and implement an education and community awareness publicity campaign to increase knowledge on the impacts of loss and/or degradation of butterfly hill-topping sites
Develop and implement protocols and guidelines
Develop habitat identification, management and enhancement
Guidelines
Prepare guidelines to assist environmental impact assessment of potential butterfly hill-topping sites
Establish management agreements with public authorities, catchment
Management Authorities and land managers/owners
Seek secure protection of key hill-topping sites
Habitat management: site protection (e.g. fencing/signage)
Erect interpretative signage at key hill-topping sites
Habitat rehabilitation/restoration and/or regeneration
Restore and manage degraded habitat in key hill-topping areas
Prepare Statement of Intent
Prepare Statement of Intent by 2007
Survey/mapping and habitat assessment
Conduct targeted surveys and identify priority sites used by hill-topping butterflies
Work with lepidopterist interest groups to undertake a community survey to identify butterfly hill-topping sites

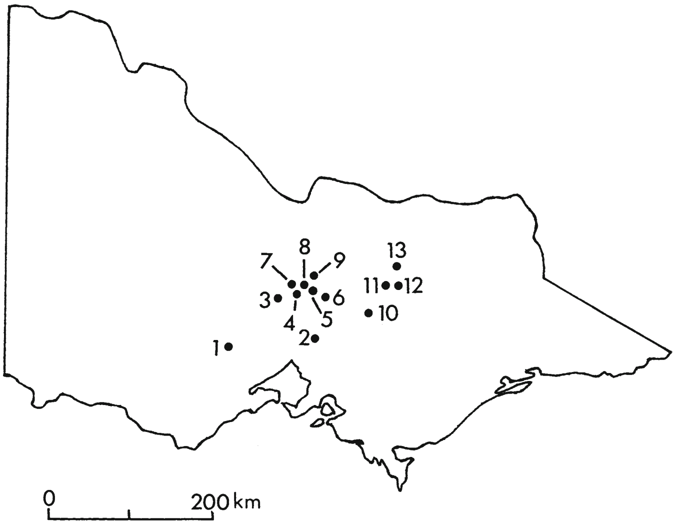

Fig. 9.12 Localities of hilltop sites visited in search of *Acrodipsas* in central Victoria, 1992–1993: 1 – Brisbane Ranges; 2 – Kangaroo Ground; 3 – Mount William Range; 4 – Mount Piper; 5 – Tallarook Ranges (Warragul Rocks); 6 – Yea Spur (Junction Hill); 7 – Glenaroura; 8 – Mount Hope; 9 – Seymour Bushland Reserve; 10 – Cathedral Ranges; 11 – The Papps; 12 – Blue Range; 13 – Mount Samaria (from Britton et al. 1995)

found at 'The Papps', together with *Ogyris genoveva*, so that two of the most notable species from Mount Piper also co-occur elsewhere. The Papps was selected for more intensive study, as it was a historical site for *A. brisbanensis*, and considered similar to Mount Piper, and 19 hill-topping species of butterflies (of a total of 21 species in their survey) were reported by Wainer and Yen (2000), with previous records raising the total to 27 recorded species. Searches for *Papyrius* failed to reveal it. The Papps has a similar history of despoliation to Mount Piper, with summit clearing for telecommunications and vehicle access. Nevertheless, Wainer and Yen (2000) suggested that it cannot be included in the same community definition as Mount Piper but that this opinion may need revision should *A. myrmecophila* and *Papyrius* be found there.

The extent of difference between species composition in an assemblage to constitute a different 'threatened community' is undoubtedly subjective, and all current delimitations are unsatisfactory. Any such assemblage comprises several ecological groups of species – breeding residents, regular migrants (that may appear reasonably predictably in most years), vagrants (occasional visitors, non-resident, and highly unpredictable in incidence), and aliens (introduced species). The 'community' is characterised mainly by the resident core species containing specified threatened taxa, and the considerable variation in the various satellite species present poses 'noise' to the extent that their inclusion in any formal definition might indeed result in every assemblage being regarded as different. For Mount Piper, alone at present, the co-occurrence of the two species of

Acrodipsas is a far simpler condition for community characterisation, as is any such combination of notable species. However, extending such lists to contain more species as obligatory components inevitably leads to further ambiguity based on inconsistent occurrences. Ideally, any threatened community should be defined in terms that are both biologically unambiguous and convincing and comprehensible to managers and others who need to interpret that definition.

Part III
Lessons Learned, and Future Endeavour

Chapter 10
Building on the Current Foundation

10.1 Introduction

The variety of case histories for butterfly taxa discussed in the previous sections exemplifies two major geographical contexts for conservation interest. First, a few threatened taxa, mainly those found close to urban centres and demonstrably threatened by human activities – predominantly those associated with density and extent of settlement and accompanying land-clearing and drainage activities – have become high profile cases as individual conservation targets and have received (and, in most cases, continue to receive) individual conservation attention based on relatively comprehensive understanding and planning. Second, others are known, or strongly suspected, to need equivalent attention but occur either (1) across wider landscapes or biotopes rather than on discrete sites and/or (2) in relatively remote areas where the capability to study and manage them is very limited and their management needs difficult to define. Particularly in relation to the second category, many of these are essentially 'out of sight' of conservation authorities. Notwithstanding that many such areas have been degraded substantially, with presumed fragmentation of the distributions of many butterfly and other taxa to create presumed remnant populations, conservation needs are difficult to define beyond broad generalities. However, better definition of needs and priorities is itself a clear priority for progress to be made. In addition, most practical conservation beyond obvious generalities (such as assuring site security and abatement of major conspicuous threats) is experimental, with research to augment basic ecological knowledge an important, even initially prevalent, precursor to practical management. Establishing and understanding the dynamics of their resource needs is fundamental in increasing the effectiveness of butterfly conservation management.

10.2 Taxonomic Uncertainty

For butterflies in both of the above categories, taxonomic confusion or uncertainty can create ambiguity: authorities are naturally concerned over allocation of all-too-scarce conservation expertise and funding to cases of dubious worth (for example,

T.R. New, *Butterfly Conservation in South-Eastern Australia: Progress and Prospects*,
DOI 10.1007/978-90-481-9926-6_10,

should the target 'taxon' prove to be the same as another currently perceived as more secure, or even be suggested to be the same by variety of opinion) and, over much of Australia, some formal listing or equivalent recognition on a schedule of threatened species is a passport condition to eligibility for central funds. Occasional philosophical problems arise because conservationists may opt for the precautionary position of presuming taxonomic distinctiveness until proven otherwise, whilst others may volubly disagree with this stance. This distinction becomes important because a high proportion of butterflies targeted for conservation in Australia are treated currently as subspecies, rather than as full species or more trivial local variants, so that ambiguity over proper status is both inevitable and likely to be subjective, depending on a proponent's viewpoint. And, because the term 'species' can be defined in many ways, not distinguished in Australian legislation, controversy can also arise from inconsistency of interpretation. Thus, the two *Paralucia* coppers of conservation interest (Chapter 6) differ clearly in status, because *P. spinifera* is unambiguously a full species whereas the differences between *P. pyrodiscus lucida* and the nominate *P. p. pyrodiscus* are not universally accepted and the distinctiveness of the former doubted (Braby 2000). In this example, and some others discussed earlier, the case for conservation in part rests on distribution. In central and western Victoria, populations of *P. pyrodiscus* are small, highly disjunct, and far from any possible conspecifics. As such they are, at the least, 'significant populations' (p. 6) and the attention they receive is on the basis of subspecific status, which can not at present be refuted fully. They are novel 'flagships' in spreading awareness of the wider plight of butterflies in the region. The skippers of the *Hesperilla flavescens* complex (p. 55) are a parallel case, in which the substantial saturation of phenotypically distinct characters and wider background to understanding distributions renders the case for taxonomic recognition easier to accept. In contrast, the various subspecies of *Pseudalmenus chlorinda* are sometimes difficult to separate objectively other than by distribution. In all these examples, genetic information may eventually help to clarify some of the anomalies – but all such cases document the considerable variety present in the region's butterflies. Genetic differences will assuredly be found between different populations, but the problems of how to interpret that variation and allocate it taxonomically will persist.

This suite of uncertainties arising from inadequate taxonomic knowledge emphasises the importance of two basic topics of much wider relevance in practising insect conservation in Australia. First, considerable additional survey work is needed to establish the distribution and range limits of any target taxon. Second, such surveys must incorporate study of variation and integrity of any such taxon, so must allow for capture and responsible retention of voucher series from any newly-found population (particularly if outside the documented range) as a basis for taxonomic study. These acquisitions should thereby be permitted under any protective legislation that may otherwise fully prohibit take, in cases where such detailed examination is integral to appraising the taxonomic status of the population. In practice, this stricture applies to most taxa of concern in Australia. Despite well-meaning calls for good photographs of living butterflies as identification surrogates for pinned specimens, commonly feasible in well-documented faunas such as for many of the butterflies of western Europe, knowledge of Australia's butterflies has not yet reached the stage where this substitute is adequate; actual specimens remain vital and are likely to be so the foreseeable future. Genetic information may indeed be obtainable from single legs or wing fragments taken from living individuals later released, but interpretation of that information is not yet generally realistic in the absence of a strong framework of more conventional specimen-based systematics. In most cases the requisite basic information is not yet available. It is, perhaps, salutary to emphasise that many problems of taxonomic interpretation persist even amongst European butterflies, where numerous 'fuzzy species' are acknowledged. As Descimon and Mallet (2009) put it in considering the status of 'bad species' in that fauna 'It is a Sisyphean task to devise a definitive irrefutable definition of species'. The hill is at least as steep in Australia as it is in Europe.

10.3 Needs for Conservation

Whatever their precise taxonomic or evolutionary status, many of the more distinctive and unusual butterflies in the region – including those that have become important flagship taxa for wider conservation advocacy - appear to have very limited distributions, and to have either (1) demonstrably declined in range or abundance, or (2) be currently threatened by ongoing and future changes, or both. Their conservation necessitates clarification of the major threats to each, as a basis for informed ameliorative management, with the realisation that the impacts of any threat may differ substantially on each taxon and on each site or population. At present much management can be formulated only in more general, precautionary, terms, and the detailed cases noted earlier are exceptional rather than the rule. Many justifications for listing butterflies can specify threats only in very general terms, so that further investigations to understand these are almost always needed. At this stage in planning it is critical to ensure that no major threatening processes have been overlooked, and preparing a 'checklist' of contenders – perhaps using the themes of Table 2.1 (p. 26) as an initial but not exclusive guide - may be a valuable exercise. Wide consultation with local planners and checks on land tenure status are routine needs when particular sites are involved.

10.4 Fire as a Management Tool

Ambiguities in threat evaluation are common and are illustrated well by ambivalence and uncertainties over the influences of a single emotive process, burning, for which the balance between threat and management tool can be appraised properly only for particular taxa and sites, but which is sometimes desired over much larger areas for fuel reduction or property protection from intense wildfires. Recent calls for massively increased planned burns in Victoria have followed the devastating fires in 2009, for example. Safety considerations are of major public interest in leading to more predictable protection of life and property, not least because such massive and uncontrollable events may become more frequent in the future as climates change. The wider roles of fire in maintenance of some Australian ecosystems and as a structuring force in floral associations is widely accepted, but different ecologists have widely divergent opinions on the universality of these influences (background discussed by Attiwill and Wilson 2006). The extent to which Bassian landscapes have been modified by fire is debated widely: very clearly, some vegetation types are highly susceptible to burning, and others more resilient. *Nothofagus* forests, for example, are susceptible, as Kirkpatrick (1994) reported from Tasmania, where he also suggested that some grasslands may have been created by fires. Changes in vegetation composition from burning are common, and may be deliberate in 'land improvement' exercises. As an example from New Zealand, overuse of fire in tussock grassland to convert it to improved pasture has led to replacement of tall tussock species by shorter species and exotic weeds, and better management regimes are being sought to ameliorate this (Barratt et al. 2009); and the spread of exotic grasses in Australian native grasslands has undoubtedly been aided by burning. In practice, almost any study on the influences of fires on invertebrates is unlikely to be replicated validly, so that any individual case history should be documented as carefully as possible. Thus, the New Zealand study mentioned above was focused mainly on beetles and showed the widespread scenario that different taxa may differ substantially in their responses but that initial decrease in species richness was followed to regain pre-burn levels within 3 years. As in Australia (Neville 2000), some higher taxa (orders) of invertebrates are more susceptible to loss than others. Influences of fires on invertebrates in south eastern Australia are very varied (New et al. 2010), with the numerous variables to be considered in employing fire in species management including intensity, season, frequency (reflected in time since fire) and area of burn, all ideally considered and planned in relation to the biology of the focal taxa or biotope. Management by fire has been incorporated experimentally into management of several of the Lycaenidae discussed earlier, with *Paralucia* (p. 141) illustrating some of the relevant considerations. The most important of these was the existence of presumed 'refuges', with the caterpillars naturally sheltered from both direct cremation and radiant heat by being underground during the day. However, this is unusual – only about 20 of Australia's butterflies have parallels in characteristic subterranean phases or life stages, and all others are likely to be more vulnerable to direct effects of fires. In the case of *P. pyrodiscus lucida*, the highly seasonal life history facilitates use of carefully timed fires in habitat management.

Availability of spatial or temporal refuges is a critical consideration in fire management. Another is the area to be burned, in relation to recolonisation from nearby occupied sites in cases where the butterfly is indeed destroyed by site fires (*Ogyris otanes*, p. 102). Several of the butterflies discussed here are apparently naturally sedentary and do not normally disperse over large distances, so that large scale fires may affect the connectivity between small remnant habitat patches in the landscape.

As a safeguard, at least, management fires for butterfly species conservation programmes should be planned on a micromosaic level, so that parts of any occupied site, or any potentially suitable nearby site should be left unburned. The Eltham copper burn noted on p. 84 was one such example; the principle of micromosaic burning management may extend even to individual plants, as for *Gahnia filum* tussocks for *Hesperilla flavescens* (p. 60). The wider influences of larger scale or very hot fires on butterfly communities are presumed destructive, but there is strong need to understand 'ecological fire regimes' in order to use fire responsibly in any projected conservation management in which risks of extirpations occur. However, 'not burning' may also be a threat. In a recent policy statement on temperate grasslands in Victoria, DEWHA (2008), for example, listed 'lack of fire' as a threat because of choking of wildflowers by dense grass cover and loss of habitat for (unspecified) native animals, with a management recommendation to 'develop strategic fire regimes'. Parallels occur with grazing, with examples such as damage to *Bursaria* by hares or rabbits seen as a threat to *Paralucia*, but excessive grass or weed growth also threatening. In the absence of detailed knowledge of impacts of such processes, some caution is wise – so that use of fire in weed control (*P. pyrodiscus lucida*) or host plant regeneration (*Hesperilla flavescens*), sometimes on sites with public concerns over heightened fuel loads and related safety issues, carries both benefit and risk with the balance difficult to assess before the exercise is undertaken. Fire may then be employed on a mosaic basis, with total protection of some key areas as refuges and provision to monitor and document the outcomes (with adequate experienced supervision of the exercise) to help refine similar operations in the future. Maintenance of particular early successional stages of vegetation by burning is difficult. Suitable habitat for *Antipodia chaostola* in Victoria, for example, is acknowledged likely to depend on fire (Wainer and Yen 2009) but the unusual two year life cycle of this skipper means that there is no season in which potentially fire-vulnerable caterpillars are absent: there is no clear 'temporal refuge' from burning. On one hand, fire helps to conserve and regenerate the early successional vegetation and sedges needed by the butterfly; but on the other hand early stages may be eliminated. The skipper reappeared at one site only after 8 years following a fire (Wainer and Yen 2009), and early prescriptions suggested a minimum interval of 5–7 years between fires. Wainer and Yen (2009) suggested mosaic burning with fires over a 9–12 year cycle.

However, definition of a pertinently scaled 'mosaic' for any given butterfly necessitates very careful consideration, with widespread precautionary calls for so-called 'micromosaic' (above) burning for invertebrate conservation, to heed both the very narrow distributions that they may have, and their considerable spatial and temporal heterogeneity. The allied problem is how to achieve this in practice (Gill 2008) both in space and time, with the latter, as fire interval, in principle providing for maintenance of a variety of successional stages with collectively higher conservation value on a site. Any such exercise should ideally be monitored carefully and over a considerable period (at least several years) to assess the outcome; this in itself is a rare commitment, not least because funding can rarely be assured that far ahead. Hill top fires may be particularly disruptive to butterfly assemblages characterised by hill-topping behaviour: Grund (2001) even suggested positioning of lightning conductors on sensitive hill tops as a means to protect them against fire harmful to *Ogyris*.

The principles of mosaic treatment are equally relevant for other management techniques, such as imposed slashing or grazing regimes.

10.5 Conservation and Landscape Issues

Very few site-based or landscape level studies on population dynamics or dispersal capability have been made on Australian butterflies, but analogy with studies on butterfly metapopulations elsewhere suggests the importance of mosaics including suitable habitat fragments within the normal anticipated dispersal range and that fire may be a useful tool in achieving this – but whether such fragments can be separated by several kilometres or only tens to hundreds of metres in the relatively inhospitable matrix is almost wholly unknown. Mark-release-recapture studies showed *P. p. lucida* to move between isolated patches of *Bursaria spinosa* up to 100 m apart (A. Canzano, 2009, personal communication), but the maximum distance is unknown as dispersal was constrained by the occurrence of *Bursaria* in the region and butterflies moving further afield would not be detected. Observations of some hill-topping lycaenids imply that they may move over at least several kilo metres, but more quantitative information is rarely available. However, in the absence of this knowledge, much conservation activity is inevitably focused on 'local' rather than landscape environments.

One major exception is the conservation of an equally exceptional butterfly, the Richmond birdwing (*Ornithoptera richmondia*) in northern New South Wales and southern Queensland. This is one of Australia's most spectacular papilionids and, in common with other birdwings, flies strongly so that individuals can traverse at least several tens of kilometres. It has declined substantially in its rainforest habitats, largely due to clearing of the forest (to now constitute less than 1% of the original area of subtropical rainforest in the region), and *O. richmondia* has now been lost from more than two thirds of its original range (Sands et al. 1997). A major conservation campaign commenced in 1992 (Sands and Scott 2002). A predominant contributor to its decline was loss of the principal larval foodplant, the vine *Pararistolochia praevenosa*, coupled with the spread (from extensive garden plantings) of the ornamental Dutchman's pipe vine, *Aristolochia elegans*, from South America. The latter is of major concern because it attracts female birdwings to oviposit, but the foliage is toxic to hatchling caterpillars, which die after feeding on it. Conservation has focused on progressive removal of Dutchmans's pipe and extensive planting of nursery-grown *P. praevenosa*. The latter include planting in corridors or as 'stepping stones' to help the butterfly to recolonise much of its former range (Sands 2008). Such deliberate landscape scale planning is unusual for butterflies and, with one important exception of context, may not apply as vitally to most Bassian species – other than perhaps to counter increasing fragmentation increasing the isolation of the scattered known populations. As far as we know – and this caveat is important - the satyrines, lycaenids and skippers of greatest conservation concern at present are not strong flyers, and current site-focused or 'local' conservation management is likely to remain the most useful approach and may, of course, incorporate plans to both increase habitat area and quality and foster greater connectivity between known populations in that area. Landscape considerations are included in restoration plantings for *Tisiphone abeona* and *Hesperilla flavescens*, but these do not yet extend over more than a few kilometres and focus mainly on enrichment of occupied sites. However, in general, the effects of more general revegetation on butterfly richness in Australia are not known in detail. Preliminary comparison of unrestored pasture areas and forest remnants with revegetated areas prepared with the aim of restoring the endangered Cumberland Plain Woodland ecosystem near Sydney yielded a total of 18 butterfly species during short visual surveys (Lomov et al. 2006). Only two, both widespread generalists, were restricted to pastures, and revegetated areas were intermediate in richness (eight species) between pasture (four) and forest remnants (15). Such remnant habitat patches in highly altered landscapes are almost invariably important.

10.6 Climate Change

The exceptional context noted above as departing somewhat from this viewpoint is consideration of possible range changes that may be driven by climate changes over the next few decades. This theme, introduced earlier (p. 50) merits more detailed consideration in suggesting optimal conservation planning, but is still viewed widely as distinct from demonstrably urgent short term needs, and often dismissed as comparatively intangible to consider. In essence, it raises the possibility that existing sites may become unsuitable for continued occupation, from increased temperatures, disruption of synchrony between butterflies and critical resources, loss of those resources and changes of assemblages influencing competitive interactions and influences of natural enemies as those species are obliged to move around the landscape. Invasion of local communities by species moving southward or upward as conditions change may exacerbate any 'stress' that resident species undergo from climate change alone by leading to increasing domination by taxa adapted to warmer conditions. A few species may succumb to sea level rise – the entire coastal range of the locally endemic skipper *Ocybadistes knightorum* in New South Wales is lower than 5 m elevation, and within the 'king tide' zone, for example. Whether such species will be able to track their resources, or even whether those resources will continue to be available as conditions change, is unknown and will depend on both extent and rate of changes.

Although local endemic species were not considered specifically in modeling studies by Beaumont and her colleagues (Beaumont and Hughes 2002, Beaumont et al. 2005, 2007), 24 of the 77 butterfly species initially appraised were suggested likely to undergo distributional change, and the most susceptible species (Table 3.8, p. 51) all share features regarded as ecologically specialised and common to others of conservation interest. Five had very narrow 'climate envelopes', with mean annual temperature ranges at present spanning less than 4°C. Factors widely limiting butterfly distributions almost certainly include temperature (although this has been experimentally verified in rather few cases) and critical resources, predominantly 'consumables' (sensu Dennis et al. 2006). Earlier, Dennis (1993) emphasised the importance of three components of climate change in considering effects on butterfly biology, namely (1) regional temperature rise and consequent changes in other attributes, including precipitation; (2) the rate at which these changes occur; and (3) the magnitude and frequency of 'extreme weather events'. The last of these links with the above comments on fire effects, because the frequency of 'extreme fire days' in the south east is believed widely likely to increase in the future (as a component of 'extreme weather events'), in parallel with decreased precipitation regimes. It is difficult to predict distributional changes of Australian butterflies with changing climate, but by analogy with well-documented British changes (in which northward extensions have been mapped together, in some cases, with losses on the southernmost range) and upward elevational movements (as in Spain: Wilson et al. 2007), both southward and upward movements may be anticipated, with retention of close links with critical resources as a major determining need (see Menendez et al. 2007 on British butterflies), which is by no means assured. Several of the taxa of interest fit the priority categories of susceptibility to climate change noted by Peters and Darling (1985), but lack of capability to predict range correspondence in suitability between species and resources under future scenarios necessitates more subjective evaluation based largely on current distribution patterns. About five main patterns occur (New 2008b, 2009) and may be appraised in relation to movements along possible 'gradient habitats' of elevation, latitude or aridity through which butterflies might move progressively if they lack capability to remain in their present ranges. Gradients, however, have ends.

Perhaps the most difficult taxa for which to anticipate change are those perceived as of severe risk through being already at the 'difficult' extremes of an anticipated possible range gradient. If alpine *Oreixenica* species are indeed restricted in range by cool temperatures, either directly or by needs of their food plant grasses, they may most obviously need to move to higher elevations. *O. latialis theddora* (p. 114) has little opportunity to do this because it already occupies the highest grassland plains areas of the Mount Buffalo plateau in Victoria. It is likely also in this example that the dynamics of alpine grasslands will be changed and that the sites will be 'invaded' by both insects and plants moving upward from lower elevations, so that the competitive environment may be influenced strongly. In short, the complex of threats noted earlier for *O. l. theddora* may be changed and augmented in ways that can only be inferred at this time. Close monitoring of this localised case may be very informative as a lesson for related contexts. But, from the point-of-view of wisest use of very limited expertise and funds, triage might suggest that such extreme cases be abandoned.

Butterflies currently distributed in some intermediate part of a gradient may have considerably greater flexibility for future movement, perhaps gradually in response to gradual changes, or more abruptly, to track their resources as these also change. Abrupt host plant changes or other major resource switches appear likely to be much more unusual. Potential for the extent of range change may reflect the current distribution as a ‘measure’ of ecological amplitude. Thus all populations of *Paralucia spinifera* (p. 88) occur within a regionally circumscribed area of New South Wales, and almost all are above 900 m elevation. One implication of this may be that the species is unlikely to move downward as climates warm, so that future conservation management could perhaps concentrate on the more likely uphill range for the butterfly. In contrast, populations of *P. pyrodiscus lucida* are more widely separated, although still latitudinally restricted and occurring at lower elevations, and the effective future range may be more extensive. Much is already occupied by the larval food plant, and reasons for this butterfly’s absence from several apparently suitable sites, particularly in outer Melbourne, are unclear.

Putatively contaxic populations may occur widely separated within an environmental range, suggesting (usually without direct evidence) high level of habitat fragmentation and their loss from intermediate areas, or possible taxonomic confusion between very similar animals. Whatever the cause, a broad distribution may suggest at least some insensitivity to climate change, through tolerance of a current wider range. For all butterflies with narrow or strongly circumscribed distributions, however, an ideal conservation programme should include consideration of possible range changes at a landscape level, for ‘evolutionary security’, and endeavour to anticipate how and where these might be facilitated. The twin tactics for this are (1) some modification of current management, for example to concentrate habitat restoration and enrichment work in directions and areas most likely to remain or become suitable in the near to mid-term and in some cases (2) to plan for colonisations or translocations (from either wild stocks or captive-bred insects) into suitable sites decades or more in advance. This approach is idealistic and largely impracticable – but will become far more so as land is used for other purposes in the future. Unless planning takes place now, or very soon, to secure possible sites along environmental gradients, and progressively manage these as they become suitable, they may never be available. However, the prospect for obtaining and managing sites that are not currently even within the distribution range of the focal butterflies will assuredly be small in a milieu in which support for conservation is already seriously inadequate, particularly as measures needed to conserve populations already known on the sites where they occur can not be abated, not least because they are the source populations for any future strategy and anything additional therefore requires additional resources. Acquisition of land is the most expensive and difficult measure in any such operation, and exploration of availability of suitable sites within any national parks or protected areas (and designating these for future butterfly conservation programmes) is a wise initial step. Exploration of establishing covenants on other lands for additional protection may also be valuable.

10.7 Expanding Ranges

Butterfly translocations or re-introductions have conventionally been considered for three major contexts (augmentation of very small or isolated populations on sites, establishment of new populations, and rescue or ‘salvage’ for release elsewhere of populations to be doomed through site destruction) all with the strong historical stricture that any such exercise involving release of individuals should take place within the taxon’s historical range. With this conventional caveat, questioned above for the future, the principles of range restoration, extension and improved connectivity are implicit in several current programmes, together with needs and planning for translocation.

Translocations to establish new populations have been suggested for several species of *Ogyris*, for example, with recovery plans for *O. otanes* and *O.halmaturia* in South Australia venturing how this might be achieved (Fisher and Watts 1994; Grund 1997). Enhanced connectivity and habitat restoration are the major conservation foci for *Ornithoptera richmondia*, as noted above. Translocation is a much more complex exercise than providing for re-colonisation by natural dispersal, and would normally include assessing the security of any donor population to ensure that removal of specimens for release elsewhere or with which to found a captive stock does not increase its vulnerability. ‘Salvage’ is an exception, simply because the remaining members of the donor population will be destroyed if left where they are at present, so that the aim is normally to ‘rescue’ (remove) as many of them as possible. Translocations to sites that are climatically suboptimal, even if they support the critical resources needed by the butterfly are likely not to succeed – usually for reasons that can only be suggested but reflecting changes in developmental rate and changed synchrony with consumables.

Translocations as a possible counter to climate changes that render parts of a range unsuitable as others ‘come on line’ add the complexity of deliberately extending the species’ range by planning introductions to areas beyond its current distribution but anticipated to become suitable in the future. They also imply acceptance (or supposition) that the species may not continue to thrive where it does so at present. Preferred sites for salvage in this context may be those on the anticipated ‘trailing edge’ of the occupied range, but monitoring the fate of butterflies on those sites may, conversely, provide the badly needed information on tolerance and susceptibility to climate changes. Usually, at present, that information can only be inferred. Experimental translocations of a skipper (*Atalopedes campestris*) in North America (Crozier 2004) indicated some of the issues of relevance, but no parallel studies have been made in Australia. Probably, none is likely in the near future. Considerable differences in biology of *A. campestris* occurred over a gradient of 3°C, reflecting current resource availability (likely to be most intense for annual food plants and particular growth stages or foliage ages of these, for which even small phenological change may be critical in affecting synchrony with the butterfly) and which might (or might not!) track climate change in the same way and to the same extent as the butterfly.

The distance involved for successful movement to occur may not be large: dispersal upward in elevational change, for example, may be only a few hundred metres, or less. And, indeed, many butterflies may be able to colonise naturally over rather small distances in each generation. Following its re-introduction to Britain, the large blue, *Maculinea arion*, took 14 years to progressively colonise (through stepping-stone patches of neighbouring sites) over a range of only 4.4 km (Thomas et al. 2009). However, capability for normally strong-flying migrant species to establish elsewhere may be changed by climate changes. The disrupted migrations of the skipper *Badamia exclamationis* (p. 29) is one such case. Presence of critical resources in the destination area is an obvious need for successful colonisation, but it is not always clear whether these are overridden by climatic tolerances. The pierid *Belenois java teutonia* (caper white) does not breed in southern Victoria because of general absence of its larval food plants, but is a well known migrant with enormous numbers of butterflies flying from the north in spring to reach this region in many years. Establishment of this and other vagrant/migrant taxa may be facilitated in the future. The orchard swallowtail, *Papilio aegeus* is noted sporadically in Melbourne, and is reportedly a 'rare visitor' to South Australia. Melbourne records are often considered to be escapees from captivity, and the proportion of those that represent natural arrivals is unknown. Two unintentional introductions of butterflies to the Melbourne area are informative, both associated with widespread planting of introduced vegetation. The palm-feeding skipper *Cephrenes augiades sperthias* occurs naturally in more northerly eastern coastal Australia, extending southward to central New South Wales. It was recorded first in Melbourne in 1990 (Crosby 1990b), and spread within a few years to be clearly established by 1994 (Crosby 1994; Eichler 1999). Almost certainly it was imported as caterpillars or pupae on palm trees used for garden and other ornamental plantings. No palms occur naturally in central Victoria, so the butterfly is thought unlikely to spread into natural areas, or to compete with other resident species. In this example, food availability has allowed establishment, without apparent restriction from the cooler climate encountered. Likewise, a second skipper has become established in urban Melbourne. *Ocybadistes walkeri sothis* (Fig. 10.1) was first reported in Melbourne in 1977 and is also now quite widespread.

It is believed to have been introduced (as eggs or caterpillars) in rolls of turf grown for lawns (Crosby and Dunn 1989), with some of its preferred grass food plants used widely also in public areas such as sports grounds. Three options for its presence were discussed by Crosby and Dunn, namely: (1) that it may have been present for a long time but in an isolated, undetected population that 'suddenly' expanded and spread (this option was regarded as highly unlikely in view of the substantial collector attention to the near-Melbourne area); (2) that it may have reached the city by natural dispersal (large numbers and rapid expansion, together with paucity of near-Melbourne records suggested that this alone was unlikely); and (3) artificial introduction, as above, possible coupled with limited natural arrivals. No deliberate introductions are known to have been made. However, large quantities of grasses (including three important food plants of the skipper: *Pennisetum clandestinum* – Kikuyu grass, *Cynodon dactylon* – common couch,

Fig. 10.1 *Ocybadistes walkeri sothis*, a grass-feeding skipper recently introduced to Victoria

Stenotaphrum secundatum – Buffalo grass) grown for 'instant lawns' were imported to Melbourne in 1974–1976, much from areas of New South Wales within the skipper's range. Transport costs reduced this trade by the early 1980s, but Crosby and Dunn (1989) noted that large numbers of eggs and caterpillars might have been imported in this way to provide the opportunity for establishment from a substantial seeding population.

The possible anomaly of introduction by collectors leading to false distribution records was noted earlier (p. 16).

10.8 Effective Butterfly Conservation

Two interrelated themes of considerable practical importance follow from the above comments: (1) the general lack of resources available for regional butterfly conservation and (2) the need to use these for the greatest collective conservation benefit. The first is reflected in the restricted budgets and expertise available to undertake complex, specialised surveys and resource appraisals and sensitive management on sites. The second demands considerations of 'value adding' for wider conservation reward from any such activity. Most conservation agencies in Australia have few, or no, entomologists on their staff, and calls for this to be redressed (p. 50, Yen and Butcher 1997; Sands and New 2002) have not yet been fully satisfied, so that informed leadership of butterfly conservation projects may be difficult to achieve. Participation in a management team from any informed lepidopterist may be critical, and the substantial field assessments, monitoring and habitat management exercises need to be facilitated by involving the wider community. The various cases discussed earlier have almost all benefitted by such wider interest, and some could not have progressed without community support. Butterfly conservation in Australia is still sufficiently novel that any local enterprise is likely to attract initial interest and offers of aid. Organising this constructively, and garnering and sustaining longer-term support is a more complex task, as exemplified for *Paralucia spinifera* by Nally (2003, p. 92), but may be pivotal in being able to continue existing conservation steps and introduce new ones.

The role of community networks in Australian conservation is recognised widely (Saunders et al. 1996), but that participation can not be taken for granted, with Table 10.1 outlining some of the many factors that may encourage or discourage support. 'Trust' is essential in fostering communication between 'officialdom' (including scientists) and community interests, and Moore (1996) noted the major factors in this as honesty (largely equivalent to reliability), benevolence (not being motivated solely by individualistic concerns) and reciprocity (need to reciprocate for benefits received in order to continue receiving them). The stages suggested by Nally (2003) in fostering community interests for *P. spinifera* (p. 88) endorse this, and were (1) understanding the community and identifying opportunities for cooperation; (2) creating awareness; and (3) involving the community in recovery actions and further enhancing their awareness.

A major demonstration of the success possible from community involvement in Australian butterfly conservation has been the long campaign for *Ornithoptera richmondia,* with the then coordinating group (the Richmond Birdwing Recovery Network Inc.) having more than 400 members in early 2009, many of them working actively in the propagation and planting of vines, and monitoring the butterfly. Continued interest is encouraged through a lively newsletter, workshops and meetings and, perhaps most importantly, by a purpose that people understand and believe in as a cooperative venture. The community must see the worth of the project in order to volunteer their time and efforts to support it.

Table 10.1 Factors that may encourage or discourage community participation and interest in species conservation (Adapted from Williams1996)

1. Encourage
   (a) Focus for conservation initiative that community identifies with personally
   (b) Encourage community involvement from earliest stages of a conservation initiative
   (c) Develop programmes that are beneficial to the community as well as to conservation
   (d) Listen to the community's concerns
   (e) Gain the community's trust
   (f) Provide community with appropriate information at the appropriate level and at the appropriate time
2. Discourage
   (a) Failing to recognise community's understanding of ecological concepts can create resentment
   (b) Failing to appreciate what the community hopes to gain from participating can dampen enthusiasm
   (c) Failing to provide appropriate support after community-based programmes have been initiated can threaten continued commitment
   (d) When an agency starts to behave as if management belongs only to it, community is discouraged from developing a personal responsibility for conservation

People already interested in environmental matters are simply one of many possible constituencies, and Australia's National Threatened Species Network has, since 1990, operated to link the community with work on endangered species, with one aspect of its activities being to encourage community support groups. The interests of young people are also important: for *O. richmondia* the programme involved up to 300 schools in 1997, and the massive participation of school children was summarised by Scott (2002). In the initial stages of seeking such support, the above considerations by Nally (2003, p. 93) largely complement comments by Craig et al. (1996), which included (1) early identification of stakeholder groups as comprehensively as possible by direct communication and assuring provision for including any other interest groups as they are detected; (2) formulating common objectives as a mutual exercise rather than by direction from 'on high'; (3) recognising that communication is essential to this, and to establishing and maintaining trust and credibility, and that communication may have to consider many different interests; and (4) recognising that education – to a variety of audiences - is a pivotal form of communication. Communities should ideally see themselves as 'owners' of a project, and as partners with scientists and managers, rather than as a subservient work force. It follows that they should be represented fully, as major stakeholder groups, on recovery or other management teams overseeing the project. It is also important that the group has an accessible contact point for community/public engagement. In conjunction with media notices and campaigns, additional volunteers or interest may be forthcoming at any time, and any vague or 'difficult' access to advice may discourage much-needed help. A newsletter (as for the Richmond birdwing) or information leaflet can also be invaluable.

The above cases emphasise involvement in particular, well-defined projects, but another level for general education is simply introducing people to butterfly biology and conservation in a more general way, perhaps emphasising the local fauna and problems that it faces. Britton and Ginn (2008) had enthusiastic community responses to workshops they organised in New South Wales, for example, and similar exercises in Victoria – some organised through environmental groups – have proved very worthwhile in increasing awareness and sustained interest. 'Handouts' distributed to participants in such workshops have lasting value, and can cover topics such as surveys, sources of information, recognition of species, basic biology, and contact details for obtaining further advice and information. Where possible, an accompanying field visit to a site with a variety of butterflies, or one of conservation significance can help to reinforce an indoor instruction session very effectively by exploring the needs in a 'real' context. Participation in such exercises by site managers is often appreciated greatly as adding to the significance of a field visit.

The second approach to increasing conservation benefits, not necessarily separate from the above, involves moving from single taxa as the primary or sole focus to examine what else, or what other species, may benefit from the management proposed or needed – in essence moving toward a 'coarser filter' level of conservation (sensu Samways 2005) on particular sites or on an even wider landscape scale. In a straightforward case, the specific food plant for a butterfly may be threatened in its own right and already be a major concern for the butterfly's wellbeing, and botanical expertise and concern recruited to augment the entomological dimension alone. If the plant is independently listed or otherwise signalled as threatened, additional resources may become available for their joint conservation. The specific grass food plant of *Ocybadistes knightorum* (p. 145), *Alexfloydia repens*, for example, is almost equally restricted in range and habitat on subsaline peatlands, with this plant community listed as of special concern (Sands 1997). As for some sedges that have been lost from a variety of wetland and other habitats (p. 62) propagation and extension planting may be the most important conservation step both for the butterfly, and also for the plant itself.

Plants of independent conservation concern and not obviously necessary to any butterfly may occur: the orchids found on some sites of the Eltham copper (p. 83) are one example, in which management for the different focal taxa needs to be integrated carefully and dictate measures that can be undertaken. Other animals, including mutualistic ants may also be threatened or scarce. Threatened vertebrates, in particular, may substantially increase public perceptions of the overall conservation significance of isolated sites and may suffer from similar threats of vegetation clearing and anthropogenic land use as the site is changed to a less hospitable condition. Indeed, the central tenet of conserving a 'threatened community' is that more than one focal taxon may be present and that these taxa have opportunity to coexist. Signage for Mount Piper, for example, draws attention to several taxa and ecological features other than *Acrodipsas* butterflies.

A related level of concern, as the major practical descriptor of communities, is 'vegetation class' or 'vegetation type'. These are characteristically defined for legislation at least in part by a listing of typical and/or notable plant species, to which similarly characteristic butterflies (and other animals that are largely dependent, as herbivores, on vegetation) may be added. Broad communities, such as 'alpine grassland' and 'sedgeland' noted earlier are amongst vulnerable habitats for particular butterflies. Sands and New (2002) listed a number of similarly broad categories for priority concern. An obvious economy in butterfly conservation is to promote conjoint surveys for the different species of concern found in any such habitat, and inventory surveys to list the various species present (with any background on their relative abundance and biology) may provide valuable supporting information, not least in helping to rank particular sites for conservation need or priority. The vegetation associations noted include several of significant concern in the south east as hosting suites of butterflies that depend on them wholly or to a large extent. They include coastal grasslands and associated *Melaleuca* wetland; saline sedgelands; and inland native grasslands and heathlands, including alpine and subalpine associations. Most woodland and forest ecosystems were not included in that list simply because, notwithstanding the massive conservation significance of these, most butterflies of major concern in the region occur in more open habitats. However, to the north, lowland coastal subtropical rainforest is a critical need for *Ornithoptera richmondia* and many other taxa, and any patch of rainforest may be of importance (Nadolny 1987).

Conserving communities may go hand-in-hand with conserving 'place', but particular features of topography may dictate or suggest priority. Hill-tops were noted as such by Sands and New, with recommendation that isolated hilltops should be protected, as now obligatory under New South Wales legislation (p. 89). Many hilltops in the region have been changed considerably, with the summit areas cleared of original vegetation and various constructions for telegraphic, fire-watching, commemorative or wider tourist and recreational purposes accompanied by increased access (Fig 10.2). Their significance for assembly sites for otherwise elusive butterflies is well-known to collectors, with some hills being 'classic' collecting sites likely to yield species of genera such as *Acrodipsas* and *Ogyris*, some species of which are scarcely known elsewhere, and a generally inflated butterfly richness associated with hill-topping behaviour. The importance of maintaining vegetational complexity (structure) on hill tops was exemplified at Mount Piper, where particular butterfly species occupied very circumscribed 'territories' (such as single trees) on the summit area (Britton et al. 1995). However, successful assembly sites do not necessarily require 'real hills', simply some topographical prominence in the landscape: sand dune crests in semiarid or coastal regions elicit similar behaviour, and losses of *Ogyris otanes* (p. 102) have been attributed to disturbance of desert dunes by recreational vehicles, so that dunes in sensitive butterfly areas may also warrant declared protection.

Surveys of hilltops, some prompted by the New South Wales legislation, can indicate much about local butterfly richness. One of the most intensively investigated hill topping sites, a well-known collecting locality near Grafton (New South Wales), has yielded 49 species, some of them known elsewhere only in Queensland, and including four species of the elusive lycaenid genus *Acrodipsas*. *Acrodipsas arcana*, for example, is one of the rarest species of this genus, was discovered on that hill, and is now known from elsewhere only from several hills in Queensland: its biology is largely unknown and this elusive species was ranked as 'Data Deficient' by Sands and New (2002). Surveys of 13 hill tops within the Hawkesbury-Nepean Catchment of New South Wales, based on five visits to each within a single season (and with the guidelines noted in Table 10.2), collectively yielded 51 species (Britton and Ginn 2008), of which 40% were hill-topping species. The greatest richness at a single site was 29 species, with an average of 17 species per site. Eleven species were found only at a single site, and only three occurred at all the sites inspected. Forty-seven of the species are known to breed in the Sydney region. Somewhat unexpectedly, no species of *Acrodipsas* or *Ogyris* was recorded and, despite the normal uncertainties over detecting these taxa in short surveys (p. 119), Britton and Ginn voiced concerns over not finding them. However, lack of historical data for the condition of the sites precluded any inferences of loss, but Britton and Ginn (2008) suggested that these genera could not be confirmed as absent and, rather, it should be assumed that they might occur there. Whilst this may well be the case, unfortunately such precautions may not carry much influence to those who arbitrate over land use in the future.

Attention drawn to the importance of hill tops (broadly, topography) in maintaining normal butterfly behaviour patterns leads to the wider theme of 'utilities' in suites of critical resources and their wider conservation importance. Site suitability for a butterfly entails far more than the fundamental presence of food

Fig. 10.2 Examples of hilltop sites changed substantially by human interest in Victoria: (**a**) Mt Donna Buang, summit area cleared for picnic and winter sports staging, shelter and toilet block, and visitor/fire watch tower and carpark, with paved roadwork; (**b**) Kangaroo Ground, war memorial tower, used also for fire watch, with accompanying carpark, picnic/museum area, toilet block and exotic tree plantings as screen

plants and the place of the site in the landscape occupied by the insect. For a multi-species assemblage to thrive, the site must furnish an array of overlapping resource suites and, as Dennis et al. (2007) emphasised, simply that two or more

Table 10.2 Survey guidelines: the minimum requirements for adequate surveys of butterflies on hilltops (designated for selected hill tops in New South Wales: Britton and Ginn 2008)

Operator	
Able to carry out accurate field identifications and observations	
Willing and able to collect voucher specimens when appropriate	
Frequency of observations	
Season	Visit at least once in October and in either January/February/March
Species accumulation	Visit a site at least three times at the above times of year in appropriate weather conditions
Observation conditions	
Hill-top structure.	Most areas are clearly visible to the observer, including tops of trees
Temperature	>22°C, <35°C
Humidity	Not critical except at very high temperatures, when low humidity will restrict activity
Cloud cover	Low or no cloud cover is generally preferable, although in higher temperatures activity will still occur during overcast periods
Wind	Wind speeds <2 m/s: higher wind speeds do not completely prevent activity, but will make observation difficult
Observation period	
	One hour per site, depending on butterfly activity, changing weather conditions and operator experience
Time of day	In hot weather, between mid-morning and midday: some species arrive only in late afternoon

butterfly species exploit the same host plant species does not change the fact that their other resource needs may differ considerably and necessitate individually tailored 'micromanagement'. As they put it, 'one species' matrix may well contain another species' resources'. A greater variety (richness) of species inevitably demands a correspondingly greater variety of resources, and overemphasis on supplying needs of one focal species may inadvertently deprive others. Following Dennis et al. (2006), a resource-based concept of habitat can do much to clarify conservation needs. In this approach, the critical resources for a butterfly can be divided into two main categories: (1) 'consumables' (larval food plants, adult nectar plants, other foods – such as specific ants for myrmecophagous lycaenids), and (2) 'utilities'. The latter embraces the conditions that allow the consumables to be exploited, and the regimes suitable for development and normal activity. For example, a given butterfly must be able to find its consumables, perhaps need territorial perches on vegetation or bare ground for display, or vegetation edges to patrol in finding mates, dead wood or loose bark for pupation sites or refuges from predators, a given temperature regime or insolation for development – and so on – so that the physical and climatic conditions at a site are inextricably linked with presence and accessibility of food. Utilities include, by obvious extension, the conditions necessary for consumables and mutualists to thrive, such as grass or other low vegetation influencing microclimate near the ground surface and likely occurrence or abundance of particular ground-nesting ants.

Primary conservation management for a butterfly on a site must consider both these categories of resources. Historically, it has often not done so fully, with immediate (or, often, the only) attention to consumables alone. Cases of declines of butterflies amidst apparent plentiful food have helped to widen this perspective, as weed invasions, overshading and other structural changes have not always been correlated directly with decreasing amounts of consumables but have helped to draw attention to the importance of microclimates or physical accessibility of the more obvious consumables. Whilst vegetation is a primary characterisor for butterfly habitats, it is by no means the sole descriptor. Each patch of similar vegetation may differ in suitability from every other one from the butterfly's point-of-view, and each will change over time, either by succession or through the influences of processes such as climate change.

If this approach is pursued further, it could also follow that any single habitat patch (site) may not be wholly suitable for a butterfly but may be lacking in one or more resource dimensions or needs, even though it supports a substantial and healthy population. This realisation becomes important in assessing aspects of habitat suitability and its extension to characterise models for emulation – for example, in restoration of degraded sites to a preconceived 'good condition' to receive translocated populations. Much effort, indeed, might be devoted to restoration or ecological engineering for deliberate creation of habitats modeled on suboptimal areas of occupancy – and, for many threatened species, these may be the only models available. Conservationists tend to assume that areas supporting populations of a threatened species are fully suitable to do so – in fact, the conditions might be little more than marginally suitable to sustain it, as the last remnants of its former range and with all the 'good' sites lost previously. Without some local equivalent to the historical detail that has led to diagnosis of 'good' sites in Britain, for example, 'better conditions' for many Australian butterflies are not always easy to define. Where possible, the process discussed by Dennis et al. (2007) of seeking 'functional habitat units' based both on consumables and utilities, and how consumables are tracked in the landscape, is a sound practical approach. But, again as Dennis et al. noted, this can be achieved only following detailed autecological study, intrinsically difficult on threatened species and very rare for even abundant butterflies. A suite of such studies in Australia sufficient to refine conservation management is far off, perhaps utopian and, whilst conservation practice will continue to benefit from approaches developed elsewhere in the world, much will remain essentially basic, with attempts to secure sites, detect and ameliorate threats and assure supply of the most obvious resources needed. Whereas a good management plan entails a combination of management and targeted research on the focal butterfly, much of the research needed will continue to accumulate largely on an ad hoc basis, rather than as centrally funded core endeavour or as part of an embracing conservation strategy.

10.9 Towards Management

Key elements for assessment and management in butterfly conservation include those relevant to site tenure and security, and clarifying selected aspects of the species' biology as a basis for appraising and controlling threats. The last may entail activities well beyond the site, for example to enhance landscape connectivity and control nearby weed sources or pollution. Many of the basic elements needed for an effective insect species management plan (discussed by New 2009) have been derived from studies on butterflies. However, few such complete plans have been produced for Australian butterflies, and many of the taxa of concern have still to be managed under any comprehensive and range-wide strategy. Many of the Action Statements and brief conservation statements that exist are invaluable pointers to the main needs but are not obviously accountable or monitorable, so that proposed objectives and actions appear more as 'wish lists' than formal commitments to action. Idealistically, and in the interest of both efficiency and accountability, a management plan should progressively contain clearly-formulated objectives and actions that conform to 'SMART' criteria, and have been independently reviewed to assure this. Monitoring outcomes thoroughly is a central component of this, together with ensuring that the initial plan is sufficiently dynamic to undergo progressive adaptive changes as responses to its actions are assessed in the field. Without this, a management plan can easily become 'open-ended' and non-accountable, with no way to determine whether the resources devoted to it have been worthwhile. Trends such as increased butterfly numbers, increased distribution or increased number of populations or food plants, lessening of threats, increased habitat security and condition, and many others are invaluable indices of management outcome, but can be confirmed only by periodical appraisal, monitoring, perhaps over several years to detect changes ranked against some predetermined threshold values of numbers, distribution or threat incidence. Standard monitoring - for example through transect walks or spot counts as standard approaches adopted widely to count adult butterflies - is an exercise attractive to community volunteers, and outcomes revealing successful management can be a great morale booster! However, any such formal appraisal and review of a project involving volunteers and community participants can occasionally lead to undesirable complications: some community participants may be alienated by any audit or criticism of their activities, treating it as offensive and insulting. Considerable tact may be necessary not to cause such offence, and the principles and aims of any such exercise must be transparent from the start – the initial management plan should thereby have built-in review intervals or dates. However, such deadlines may be very difficult to enforce, and non-compliance is very common, in Australia even at the initial stage of instigating such a document within a legally-obligatory interval of 'listing' a taxon. Adding a butterfly's name to such a list is emphatically not equivalent to practical conservation management, but simply a first step to formal recognition of threat and, under some Australian legislations, a visa granting eligibility for competing for funds.

However, unlike much similar legislation elsewhere, under which ‘listing’ is regarded widely as a permanent condition, several of the Australian acts incorporate provision to de-list a taxon by a process of nomination and review similar to that used in the initial listing process. ‘Listing’ is thereby a dynamic state, reflecting that conservation status (purported or real) can also change and lending credence to the ‘precautionary’ approach to listing. Two major contexts are the predominant grounds for considering de-listing. First, and more commonly, the act of listing facilitates further field surveys and investigations on the species. A butterfly may be found to be more abundant, more widely distributed, or less threatened than initially supposed. Listing of *Paralucia spinifera* (p. 88), for example, led to intensive surveys throughout its likely range in New South Wales that markedly increased the number of populations known. In some such cases, this additional knowledge may reveal that the species is not in such a parlous position as implied from information available at the time of listing it, and removal from the threatened species schedule may then allow expertise and funds to be switched to other, more needy taxa. A second context is when a recovery plan (whether formal or less formal!) has succeeded, so that reliable monitoring has deemed the butterfly secure (such as by security of occupied sites, resources assured for the foreseeable future, numbers of individuals and/or populations increased, connectivity increased, threats abated, and other defined management milestones achieved) and no longer in need of focused management. *Ornithoptera richmondia* appears to be well on the way to achieving this status, with public interest in its wellbeing likely to continue. The two contexts are rather different – the first is an outcome of listing inducing the research needed to clarify the insect’s proper status, and the second is the positive reward from, perhaps considerable, investment in time and effort for conservation management.

Simply de-listing a species that has been recovered by conservation management may be seen as rather ‘casual’ in not protecting that conservation investment – should a further threat or threat cycle emerge in the future, it may again need protection. The term ‘rehabilitated species’ has been suggested (Sands and New 2002, New and Sands 2004) to designate butterflies de-listed as a direct result of management or recovery success, as a category that ensures they are not fully dismissed from consideration and that signals need for a ‘watching brief’, perhaps through intermittent monitoring to confirm their continuing welfare.

Not all conservation targets may be suitable for de-listing, however, despite management appearing successful. The outer Melbourne populations of *Paralucia pyrodiscus lucida* (p. 71) receive continuing attention necessitated by their restriction to small isolated sites with very little possibility of natural movements of butterflies between these. Conservation measures are obligatorily site-specific and relatively intensive, so that the butterfly is essentially conservation-dependent and, if abandoned, would probably decline considerably or even be lost within a few generations. Continuing community interest may be a vital contribution to conservation needs that persist indefinitely - but it is (1) easy for interests or participation by all parties to drift as other, perhaps more exciting or urgent issues arise, and also (2) difficult to sustain funding and effective supervision on any continuing basis or over many years.

10.10 The Future

There is no room for complacency over the future for many Bassian butterflies, despite the conservation impetus demonstrated here. Many are indeed now accepted widely as organisms worthy of strenuous conservation effort, and the public sympathy they engender as 'likeable' non-threatening insects gives butterflies an important ambassadorial role in promoting invertebrate conservation in Australia, as elsewhere. Many also need considerably more study and surveys on order to focus conservation status and needs beyond rather broad generalisations, and the limited resources available for this need to be nurtured and deployed as effectively as possible. Only a small proportion of the taxa so far designated as needy have yet received formal remedial management that extends beyond initial documentation, sometimes tentative and inevitably often incomplete, of those needs. Belief, for example, that the Australian butterflies designated as threatened by Sands and New (2002) would be considered rapidly for inclusion in schedules of the Environment Protection and Biodiversity Conservation Act (p. 35) did not eventuate, and some clearly threatened taxa still languish other than by concerns from non-professional enthusiasts. The relatively high profile cases discussed earlier remain exceptional, rather than a predictable outcome from concerns expressed. Nevertheless, simply listing the taxon as of concern may commit agencies and developers to determine its presence and future security on any sites scheduled for development or change and, perhaps, oblige consideration of habitat offsets or other compensatory measures to counter destruction of any critical areas.

Selecting which taxa should receive priority for conservation is, as exemplified in the Butterfly Action Plan, a very difficult exercise, even when guidelines are available. Some form of triage, however ethically challenging this may be, is almost inevitable whilst resources available to support conservation activities are far too sparse to support all needy species. The criteria applied for selection, most commonly based on urgency of threat alleviation, continue to be debated, but acceptance of any taxon must be accompanied by realisation that this decision may also condemn non-selected taxa to increased risk of loss. The various cases that have proceeded have all been selected largely by informed consensus over need, and urgency of that need, rather than by application of strictly quantitative criteria. They could thus be considered to have been selected somewhat subjectively, rather than as the outcomes of ranking all available candidates for priority. Principles for according priority, including those suggested by Sands and New (2002), have been developed largely from the position of incomplete knowledge and understanding of the precise threat status of many butterflies in the region. The widespread need for extensive surveys of many taxa to clarify the reality of currently documented distributional knowledge and narrow ranges is unlikely to be satisfied within the next few decades, even though distributional knowledge and trends are amongst the most tangible criteria for threat assessment. All the taxa so far subjected to conservation management are indeed amongst those designated as threatened, most of them clearly recognised as such well before the Butterfly Action Plan eventuated.

They share a number of features likely to reveal other taxa in need – as regional or local endemic taxa, occurring in few populations and over small numbers of sites, ecologically specialised and depending on particular habitats and resources that may themselves be scarce or threatened, showing evidence of decline in abundance or distributions (commonly through habitat loss and fragmentation), and considered to need attention to halt further decline. A number of other butterflies clearly show such features of potential vulnerability, but have not yet received equivalent attention: some of these, listed in Table 10.3, are obvious candidates for future conservation effort. A 'working ambition' for the future might be to conserve secure populations of all these notable taxa within the region and not allowing any others to decline to the extent of needing equivalent attention.

These additional species of concern listed by Sands and New (2002) comprise several Hesperiidae and a single Satyrine, but the additional taxa noted as 'Data Deficient' also need attention. Some, indeed, may be investigated with little additional effort, as likely to co-occur with species already being managed in similar habitats or on the same sites. Thus, the satyrine *Oreixenica kershawi kanunda* has a range almost wholly overlapping with that of *Heteronympha cordace wilsoni* across the southern junction of Victoria and South Australia, and occurs in similar swampy habitats, so that conjoint surveys would be feasible, although not yet successful in finding the butterfly at many sites (Grund and Hunt 2000). Two main sites, both near the coast, are known currently in South Australia, and Grund (2002c) pondered whether it might previously have been found further inland in the state. The two sites are both reasonably secure (Grund 2002c), and *O. k. kanunda* may be more secure in the Glenelg National Park of Victoria. As for *H.c.wilsoni*, clearance and draining of wetlands, protection from stock grazing, and weed control appear to be the most urgent conservation needs. Two of the skippers needing further appraisal are known only from South Australia, and considered Vulnerable.

Table 10.3 Additional east Bassian butterfly taxa of current conservation interest, as primary candidates for more detailed attention (Status from Sands and New 2002 [DD, Data Deficient; LR, Lower Risk, least concern]; taxa noted in Table 3.5 not repeated here)

Taxon	Region	Status
Hesperiidae		
[a] *Anisynta dominula*	NSW possible subspecies	DD
Antipodia chaostola leucophaea	TAS	DD
Hesperilla chrysotricha leucosia	SA, VIC	LR (SA)
H. c. lunawanna	TAS	DD
H. mastersi marakupa	TAS	DD
Oreisplanus munionga larana	TAS	LR
Telicota eurychlora	Q, NSW, VIC	LR
Nymphalidae		
[a] *Tisiphone abeona*	NSW possible subspecies	DD
Lycaenidae		
Acrodipsas arcana	Q, NSW	DD

[a] Possible undescribed subspecies, each known from a small area of NSW, and apparently distinctive

Anisynta cynone cynone has been of concern for some time, but has not been found in recent surveys in the southeast and is known at present from only one locality – a small conservation park near Victor Harbour, where it may be threatened by nearby developments. Likewise, the extent of range occupied by *Herimosa albovenata albovenata* is by no means clear, with strong suggestions of range decline from habitat change (Fisher and Watts 1994).

As for several other butterflies in the region, the conservation needs of this skipper are noted in wider management reports, in this case for the Eyre Penisula (Matthews et al. 2001).

Particular attention may be needed to conserve sites on which two or more threatened taxa coexist, as noted above. Some sites, such as type localities or those supporting significant populations (p. 6), may have enhanced conservation values (that parallel the principle of Sites of Special Scientific Interest [SSSIs] in the United Kingdom). Whilst no site supporting any listed or threatened butterfly should be sacrificed without strenuous effort to protect it, some form of site or landscape triage for multiple similar sites is largely inevitable in selecting those given priority for conservation.

SSSIs can be designated on representation of any taxonomic group, and dragonflies and butterflies are the most tangible of those utilized in the UK. The guidelines for site selection have considerable relevance for Australia: the category 'outstanding assemblage', for example, has strong parallels with the concept of 'Butterfly Community no. 1' (p. 119). No universally prescribed number of species is needed to constitute an outstanding assemblage in Britain, and considerable variation is allowed, to reflect the habitat features and the geographical area. Thus, threshold figures advanced for Odonata in Britain range from 17 species for parts of southern England to nine or fewer for more northerly areas of Scotland and adjacent island groups. The principle for SSSIs is that within any such region, all sites that reach or exceed the relevant qualifying richness may merit consideration for selection. It can thereby account for parameters such as typicalness and representativeness, largely based on more common species not individually threatened at present, as well as scarce or threatened taxa – but does not rely exclusively on the latter for declaring significance. One aim is that the assemblage be 'recurrent', as reflecting high quality of the habitat on the various sites. Commentary on the UK guidelines (JNCC 2009) noted that it may not be possible to use assemblages to permanently define localised areas of highest conservation importance because these will change over time, particularly in the absence of prescriptive rotational management to conserve successional stages of key vegetation. Preventing further isolation and disturbance of small remnant sites is a critical conservation step, but does obviate the need to conserve larger sites on which rotational mosaic management may be practicable. Within the context of managing for richness and typicalness, more specific management for individual threatened taxa may need to be superimposed carefully to avoid increasing threats to other taxa. An outstanding assemblage can thus comprise elements of species richness and presence of notable species, without the obligation to incorporate conservation of every taxon in a formal definition. In principle, it could be applied to cover different taxonomic levels, because the major practical application is to help qualify and rank sites by representation of members of a known and well-documented fauna. In our context, this might be 'all butterflies' or particular designated families alone. Rather rarely, occurrence of particular butterflies has been important in declaring an area as a Conservation Reserve, Flora and Fauna Reserve, or similar. One such case is the Sweetwater Creek reserve in eastern Victoria, as a stronghold for *Antipodia chaostola* (p. 48), with a more easterly site for this species also declared, largely as a result of advocacy from D.F. Crosby (personal communication)

A further formal avenue for recognition of particularly important sites in Australia and increasing potential for their protection, explored by Greenslade (1994, who discussed the complex requirements of consultation and documentation involved in preparing a nomination), has been to seek listing on the National Estate Register. Nominations for 30 invertebrate sites in southeastern Australia were selected to encompass the various values for listing that apply to invertebrates (Table 10.4). Site-specific taxa can be primary foci for nominations, with the benefit of perhaps bringing them to wider public attention than otherwise possible. Greenslade (1994) noted the possible advantages over simply 'listing' the species, in that the focus on site features renders it likely that the habitat will indeed be protected. Six of the nominations involved individual taxa of butterflies, all of them Lycaenidae, and most of them cases discussed earlier in this book. The two Victorian cases were both for hill-topping sites – the Mount Piper reserve (p. 119) and a group of small sand dunes in northwestern Victoria that harbours *Ogyris otanes* (p. 103). A third hill-topping nomination was for the New South Wales site noted above for *Acrodipsas arcana* (p. 154), and the only other nomination for New South Wales involved two small sites (with different land tenures) for *Paralucia spinifera* (p. 88). For South Australia, a small site (about 100 × 200 m) in the Innes National Park (York Peninsula) was nominated for *O. otanes*, and a further site in the same national park for *Hypochrysops ignitus*, which has attracted conservation attention because of habitat losses in the

Table 10.4 Criteria relevant to invertebrate values for nomination to the Register of the National Estate (Compiled by the Australian Heritage Commission, November 1988, after Greenslade 1994)

1.1 Be important in the evolution of Australian fauna
1.2 Be important in maintaining existing processes of natural systems at the regional or national scale
1.3 Be important in exhibiting unusual richness or diversity of fauna
2.1 Be important for rare, endangered or uncommon fauna, communities, ecosystems or phenomena
3.1 Be important in demonstrating the principal characteristics of the range of ecosystems, the attributes of which identify them as being characteristic of their class
4.1 Be important for their close association with individuals whose activities have been significant within the history of the nation, state or region
5.1 Be important as places highly valued by a community for reasons of educational associations
7.1 Be important for information contributing to a wider understanding of Australian natural history by virtue of their use as research sites, teaching sites, type localities, reference or benchmark sites

State (see Fisher 1978). Sites nominated for the Register can be on private or public land. With more recent changes in legislative responsibility since the system was founded under the Australian Heritage Commission Act 1975, future national commitment to the national estate register is somewhat uncertain. It will continue as a statutory register until February 2012, and contains more than 13,000 places nominated up to 2007, when nominations ceased. The new national heritage system, initiated in 2004, has led to some changes, but the essential features of the earlier National Estate Register are anticipated to remain in place.

Formal recognition and protection of sites may facilitate conservation management, simply by increasing site security, and allow this to occur as a long-term exercise whilst treating the assemblage present as a possibly unique entity. For each of the more notable butterfly taxa present and its obligatory resources (such as food plant, mutualistic ant), the need to consider all of these together as a functional interdependent unit (or ‘community module’), increases conservation considerations beyond the butterfly alone. A key need may then be to delimit that module by encompassing other obligatory contributors to its maintenance. For example, the caterpillar’s food plant may have a specific insect pollinator whose wellbeing must be considered (Hochberg et al. 1996), and specific parasitoids are also members (Mouquet et al. 2005). However, this level of conservation has not been defined formally for any Bassian butterfly. Whereas there are indeed records of parasitoids for some threatened species (such as for *Hesperilla flavescens flavescens* at Altona: Crosby 1990a), there has been no systematic review of parasitoids of Australian butterflies, and the levels of mortality they impose and their host specificity are largely unknown. In part this reflects that hobbyists have tended to regard parasitoids as undesirable, and sometimes countered their presence by collecting larger numbers of caterpillars or pupae to increase chances of rearing butterflies, rather than wasps or flies. A corollary to this is that many reared parasitoids have been discarded, rather than preserved and archived to provide host records. It is likely that a considerable collective variety of parasitoid Hymenoptera and tachinid flies are involved and that at least some of these will exhibit patterns of variation paralleling those of their hosts and, viewed dispassionately, be just as much in need of conservation. A study of two co-occurring hymenopteran parasitoids of the European *Melitaea cinxia* (Glanville fritillary), which forms a classic metapopulation structure across a network of around 4,000 small patches of suitable habitat in the Aland Islands of Finland, showed considerable differences between the wasps. Both species, *Cotesia melitaearum* (Braconidae) and *Hyposoter horticola* (Ichneumonidae), are wholly specific to this butterfly and, unusually, have been studied in considerable detail (Kankare et al. 2005). Genetic and ecological information revealed them to differ substantially in their population structure, in part reflecting dispersal. *Cotesia* exhibited a clear metapopulation structure, whereas *Hyposoter* comprised a single panmictic population. The implication for conservation was that the latter may be relatively secure, whereas *Cotesia* was regarded as ‘on the brink of regional extinction’ and declining more rapidly than its host *Melitaea*. There is no reason to suppose that similar situations do not occur elsewhere, including Australia: but, for the present, we simply do not know.

The term 'ensemble' was used by Hochberg (2000) to encompass the various interacting taxa in entities such as guilds, assemblages or modules, and he emphasised that conservation efforts directed at such a group may be more rewarding than those for any single member alone. To conserve a parasitoid, for example, it might be vital to conserve the threatened food plant of its caterpillar host. The practical (or, at least, ethical) dilemma arising is reflected in the butterfly usually being the primary conservation focus or target – as in all the cases discussed in this book – and a specific parasitoid (likely to be even scarcer and more threatened than its host) may be regarded as a threat to the reduced butterfly population. The apparently tiny populations of several species of *Acrodipsas* or *Ogyris* inferred earlier suggest that any additional mortality may indeed increase vulnerability; but nothing is known of usual levels of parasitoid incidence on these possible hosts. Limited surveys at Eltham have revealed that eggs of *Paralucia pyrodiscus lucida* are attacked by a species of *Telenomus* (Scelionidae). However, because caterpillars of the above lycaenid genera are either fully inhabitants of ant nests or are tended by ants during their nocturnal forays, they may be largely protected against parasitoid attack.

Most of the development summarised in this book has echoed the major conservation impetus of focus on butterflies regarded in some way as 'threatened', of defining their needs, and attempting to assure these for the future, with the overall purpose of rescuing them from increasing vulnerability and the possibility of extinction. However, the magnitude of this mission could easily be increased substantially, should additional taxa become threatened. Butterfly conservation must also heed the taxa currently common and deemed secure, collectively a very low priority on any conservation agenda. 'Threats' can arise rapidly and, whilst many of these species may be buffered by features such as polyphagy, wide range, and high dispersal capability, any measures to prevent their declines must be encouraged. Several Australian naturalists, as have those elsewhere in the world, have written on methods of attracting butterflies to feed and breed in home gardens, for example, and simple provision of nectar plants by individuals planting these – now commonly advocated from local nurseries as 'butterfly plants' or some similar epithet – can be a very positive conservation step, from which adult parasitoids also benefit. Planting of specific caterpillar food plants, as illustrated for several of the cases discussed earlier, need not be restricted to those for known threatened species. Butterfly conservation in the region is by no means the sole province of the scientist, government agency manager, or organized local community, alone but is a theme to which everyone can contribute.

10.11 Lessons from and for Elsewhere

This synthesis illustrates the ways in which interest in conservation of Australia's butterflies has started to develop and to gain impetus through a variety of cases and approaches. The initial focus of individual species (or subspecies) conservation flows naturally from similar enterprises for vertebrates and vascular plants, which have widely preceded insects for conservation interest. However, the perspective from these better-documented taxa is sometimes difficult to transfer directly to butterflies and other invertebrates, with application of categories of threat based on quantitative estimates of risk of extinction sometimes highly subjective. The approaches to butterfly conservation perspective and practice exemplified in this book are founded largely in the earlier and more extensive example of butterfly conservation in Europe. Despite the differences in species richness and geographical scale, emphasised further by the far more limited expertise and logistic support available in Australia, together with the weaker tradition of natural history and lower acceptance of insects as worthy of such attention in Australia, progress in the south east is encouraging. European experiences, particularly from the British butterflies, draw on extensive and well-recorded knowledge of biology and distribution, so that changes in distribution and abundances can be interpreted realistically and with some confidence from records of sufficient extent to examine changes over a given period. In contrast, other than for a few comments, mainly not quantitative, we have very little knowledge of Australia's butterfly distribution and abundance from before the end of the nineteenth century and no great improvement for many decades thereafter. Such knowledge of many of the scarcer taxa remains very incomplete, so that allocations of conservation status must be considered dynamic, and legislation or regulation allow for rapid revision of this as new data accumulate. Prospects for large scale augmentation of this foundation knowledge are likely to remain limited and its accumulation largely serendipitous and reflecting the zeal of individual hobbyists rather than any concerted programme. Setting optimal priorities for butterfly conservation in the region, whether on criteria related to intensity of threat or other conditions, is thereby difficult.

One persistent danger continues to be that of assuming we know, and understand, far more than we really do. In general, extrapolating uncritically from cases in better-understood faunas and environments, or treating these as analogues for emulation in a very different arena, has limitations. Every further taxon treated, particularly if scattered across a large geographical or ecological arena, is a 'new experiment', but a wider body of experience is indeed accumulating, and is leading to greater confidence in the programmes formulated. Parallel exercises on related taxa, such as the two species of *Paralucia* and the two forms of *Hesperilla flavescens* are helping to display wider general themes and reveal the kinds of information still needed to hone management, together with refining monitoring methods and sampling techniques, and the central importance of fostering and sustaining community interests in the programmes.

The central theme of threat evaluation in temperate southern Australia has many parallels with Western Europe, with differences reflecting the duration and extent of intensive human influences. For Europe, agricultural intensification appears to be the most pervasive threat to butterflies, influencing about 90% of all threatened species (that is, threats to 63 butterfly species), closely followed by the 62 species regarded as threatened by habitat isolation and fragmentation (Van Swaay et al. 2009). Agricultural improvement incorporates many factors, from conversion of natural vegetation to cropping or pastoral areas, to wetland modification, fertiliser applications and pesticide use. Urban development is also a major threat in Europe. These influences are important in Australia, with the large extent of agricultural change affecting large areas of vegetation over a rather short period – so that in some cases the changes (such as loss of lowland grasslands) are indeed dramatic rather than seen as the gradual increments of centuries of change. This contrast is emphasized by about half the European butterflies occurring in semi-natural grassland created by traditional agricultural practices such as stock grazing and hay production (Settele et al. 2009) – practices that, in part reflecting their extent and more recent development, are regarded widely as threats to butterflies in Australia, and where the emphasis is on preventing further such despoliation of native vegetation. To some extent, however, wild fires contribute to maintenance of successional stages and to regeneration of vegetation, and the proper manipulative use of control burning in habitat management for butterflies needs to be placed on a much firmer theoretical and practical basis. Most of the butterflies, however, seem to have no defined refuge strategies to cope with a long history of fire intervention. Their continued presence in burned areas probably normally reflects recolonisation, again emphasising the importance of landscape connectivity to promote and facilitate this from either a metapopulation or more open population structure, to counter the almost inevitable local extinctions from intense wildfires. Likewise, most of the regional butterflies seem not to have yet evolved to thrive in cultural environments – and conservation interests are predominantly focused on those most unlikely to do so.

Settele et al. (2009) suggested some common features that may help to guide butterfly conservation in diverse European ecosystems (Table 10.5) and, as one of

Table 10.5 Factors that may help guide conservation of butterflies, based on the European fauna (After Settele et al. 2009)

Butterflies in modern landscapes cannot survive without active management
Traditional management practices have been (and still are) the driving force for the evolution of plant and animal communities of European ecosystems
A recurrent pattern of dependence on early successional stages is evident
Continuation of natural disturbance (exemplified by landslides, avalanches, outbreaks of defoliating insects, animal grazing) is critical
Many remaining sites are too small for sustaining populations of specialised species, so increased connectivity may be critical for long-term survival
When remnant habitats remain small and isolated (as for many species) management must adopt a mosaic (patchy) approach
Where large habitat areas occur, management should also be mosaic, but to create networks of different land use regimes and intensities
Indirect effects on sites important, in addition to direct alterations
Agrienvironment schemes are vital and should target resources needed by wildlife
Support programmes for these need to increase consideration of needs of biodiversity, rather than just expediency
Urban areas are also a primary focus for the future
Avoid unified prescriptions

few concerted efforts to suggest wider conservation strategy for a regional butterfly fauna, this summary has considerable interest for Australia. The initial realisation of almost universal needs for active habitat management is still difficult to communicate, particularly to overcome any complacency wrought by declaring dedicated reserves. The initial step of site reservation, or other effective protection, either as dedicated reserves (Eltham copper, p. 71) or National Parks in which particular notable taxa occur (Alpine National Park, Mt Buffalo National Park, p. 107) provide the security from which necessary habitat manipulations can flow. These manipulations may involve both local (resource supply, weed control, successional control) and landscape level issues (such as connectivity). Small sites are often of critical importance, and may be particularly difficult (and expensive) to manage. Any means to increase their carrying capacity and to facilitate connectivity in the wider landscape, such as by landscape engineering or restoration, must be considered for each case. Ideally, a successful programme should overcome the state of 'conservation dependence' but where this is unlikely to occur (as on isolated urban remnants) continuing need for management must be acknowledged and catered over long periods.

Agrienvironment schemes for enhancing conservation are in their infancy in Australia, but agricultural areas are indeed a key component of butterfly environments for the future, and across which networks of natural remnant or other vegetation must be fostered. They are regarded by Settele et al. (2009, for Europe) as currently appearing 'to be the only mechanism with the potential to safeguard species of the wider countryside'. Most butterflies in the south east of Australia are predominantly open country species – even in closed woodlands, few species obligatorily occur, and the predominance of forest species found further north is absent. Wider considerations of facilitating butterfly conservation through habitat manipulations incorporating sympathetic management of agricultural environments may be of critical importance. Successful agrienvironment schemes in Britain are voluntary, with farmers subsidised by payment to meet compliance with various wildlife and landscape conservation objectives, and there is strong inference that declines of some priority butterfly species have been slowed by such measures. However, wider results are very mixed, and Warren et al. (2005) urged that newer schemes incorporate the lessons learned from earlier exercises; this suggestion applies also to adoption of any similar approaches elsewhere in the world, although local examples for study or emulation are often elusive.

The final caveat from Settele et al. (2009), that unified prescriptions for conservation management – such as those applied across whole regions and necessitating standard, uniform, management – are 'surely deleterious and possibly disastrous for some species' is a sobering reality. Conservation management for a given butterfly, whilst bounded by more general parameters, must be sufficiently flexible to be tailored for the individual taxon, site, and needs. Phenological variations and differences in site quality, threat incidence and severity help to indicate the management needed. This will inevitably become modified by confines of the local regulatory/legislative environment, and the logistic support available may be pivotal in determining the outcome. Again, European precedents – for example with

Maculinea – demonstrate the extent of local variations that may occur, but knowledge of Australian butterflies generally lags far behind that taken for granted as an information base in Western Europe. Knowledge of ant-lycaenid relationships, for example, although advanced considerably in recent years, is still sketchy and the factors that determine the distribution of most mutualistic ant species are also largely unknown.

The transition of butterfly conservation from taxon-focused to wider landscape level endeavours, likewise, must depend in part on incorporating specific taxon needs into the broader programmes rather than overlooking these. Such wider strategies are indeed attractive, as they are elsewhere, in anticipating greater benefits for the efforts involved. However, without appreciating the detailed needs of the more significant taxa included in the ambit of those strategies, individual losses of these may not be prevented. The advocacy and interest engendered at the 'taxon-level' of butterfly conservation in Australia is at present one of the most important avenues through which the science can advance.

10.12 Broader Regional Context

Whilst butterflies have dominated the development of insect conservation or, more broadly, invertebrate conservation in south east Australia and have remained the major focal group, brief comment on other insect conservation in this area helps to augment the perspective in which these developments have occurred. Only for butterflies has even reasonably comprehensive appraisal been made, and most other insects of concern are simply examples likely to reflect much wider needs within the groups they represent but which, for one reason or another, have elevated conservation concern.

Thus, the tiny damselfly *Hemiphlebia mirabilis* is of global interest as a purported living fossil amongst Odonata, and is classified in a superfamily of its own and so has major evolutionary interest. It was long believed extinct until it was re-discovered in Victoria in the 1980s and, with the Eltham copper, was amongst the first insect candidates for listing under the then new state Act. It was found within a major national park (Wilsons Promontory), so that aspects of its biology could be studied in a protected environment and, following accidental burning of the main site – a small seasonally inundated swampy area – allowed for long-term monitoring after this unfortunate event (Sant and New 1988; New 1993). Continued surveys have revealed other populations in central Victoria (including re-discovery at historical sites reported in the early twentieth century), in north-eastern Tasmania and on Flinders Island (between Wilsons Promontory and eastern Tasmania, and formerly part of the land-bridge connecting these). In 2008 a large population was discovered in south western Victoria and since then has been reported just across the State border in South Australia, so increasing the conservation importance of areas also significant for butterflies. *Hemiphlebia* stimulated wider interest in Odonata, for which a preliminary species-level appraisal of conservation status for

Australian species has been produced (Hawking 1999), in which it was assessed as 'Vulnerable', with the additional populations by then known serving to downgrade it from the 'Endangered' level allocated from Wells et al. (1983). *Austroargiolestes isabellae* was also ranked as Vulnerable, and several others of concern. However, *Archaeophya adamsi*, the only species ranked as 'Critically Endangered' by Hawking, has been described as 'possibly Australia's rarest dragonfly', and occurs in New South Wales and Queensland. These, and other dragonflies of conservation concern, are mainly species with very restricted habitats, and whose plight may reflect that, yet unclear, of many other aquatic insects, such as alpine and montane stoneflies in Victoria whose vulnerability reflects that of butterflies in other alpine habitats. Part of the importance of *Hemiphlebia* has been in stimulating wider interest in Australian Odonata for them to become one of the best-documented insect orders in the country, with recent handbooks facilitating recognition of adults and larvae of most species, and confirming their widespread parallels with butterflies as an attractive and popular 'flagship' group of insects that joins them amongst the conspicuous 'birdwatcher's bugs'. *Hemiphlebia mirabilis*, with the Eltham copper and the giant Gippsland earthworm (*Megascolides australis*), comprised a small portfolio of invertebrates protected formally in Victoria and used to help demonstrate the ecological variety of invertebrates to non-initiates (Yen et al. 1990). Nevertheless, the persistent butterfly bias is illustrated by the number of butterflies listed in Victoria still (January 2010) exceeding that of all other insects together.

Moths, also, are strongly under-represented in conservation schedules, but two important exceptions occur – both amongst diurnal moths that are seen by butterfly hobbyists, and that parallel butterflies in the ways in which they can be found and assessed.

The primitive endemic representatives of the Castniidae (sun-moths) are the more widely-known, with the various species of *Synemon* occurring in grassland to open woodland habitats in the south east, but wholly absent from Tasmania. Five species of *Synemon* are listed under Victoria's FFG Act, and one of these has become particularly important. The golden sun-moth, *Synemon plana*, is listed separately in each of its three range administrations (Victoria, New South Wales, Australian Capital Territory) and as 'Critically endangered' under the Commonwealth EPBC Act. Loss of native grasslands and similar habitats throughout the region has led to declines in most sun-moth species, with soil cultivation affecting both the subterranean caterpillars and the native perennial grasses used for food. Of eight species of *Synemon* in Victoria, Douglas (1993) then believed only one to be secure, with the others assessed as vulnerable (1), endangered (3, one with two 'morphs'), critically endangered (2) and the last believed to be extinct. Australia's first dedicated moth reserve, of 4.5 ha, was created for the unique co-occurrence of two species at Nhill (western Victoria) (Douglas 2004), on land that – highly unusually – had never been ploughed or artificially fertilised but used solely for grazing since European settlement. One of the moths conserved there is the only known population (apparently very small, with 10–15 adults seen each year by Douglas) of the 'Nhill morph' of *S. selene*, and the other is the more widespread *S. plana*. Management for *S. selene* includes annual mowing or grazing (by periodic grazing with sheep during winter) to prevent the area becoming overgrown by introduced grasses, with provision also for micromosaic burning to control additional invasions by alien plants. As for *Paralucia* butterflies, the refuge of subterranean early stages (but in Castniidae without any surface-active phases) facilitates use of burning outside the limited adult flight and oviposition season.

Despite its formal critically endangered status, *S. plana* is widespread, with additional populations discovered in recent years. The perspective on its conservation need has thereby changed rapidly, as exemplified by increase in the number of known Victorian populations from around 6 in the mid 1990s to more than 50 by 2009. The species is genetically very variable (Clarke 2000), suggesting that many populations have long been isolated across the species' range. Despite the substantial number of populations now known, in part reflecting better knowledge of how to survey the adult moths (which fly only over very limited times and under particular weather conditions: Gibson and New 2007), most of the sites on which it occurs are small. Many are desirable for development, and vulnerable because of urban and industrial expansion on the remaining flat lowlands close to cities. The moth has become an important flagship species for threatened native grasslands (p. 121), but many aspects of its life cycle are still unclear. It is likely that it takes 2, or even 3, years to complete a generation – so that a given site reveals annual cohorts that, however carefully and accurately they are assessed, are only an unknown part of the total resident population. Repeated visits during a season are needed to estimate numbers - adults cannot feed and live for only a few days, but emerge at any site over a period of around 6–8 weeks. The assessment is thereby much more complex (and costly) than a single annual count during the flight season being a valid index of intergenerational change, as is used commonly for butterflies with more synchronized emergence and longer adult life. Additional complications have arisen for *S. plana* conservation planning: in addition to association with native grasses, it has been found abundantly on some sites with only sparse native grasses but high levels of Chilean needle grass (*Nassella neesiana*), an alien declared noxious weed and target for eradication wherever it occurs in Australia. It remains to be confirmed that *S. plana* caterpillars use *Nassella* for food, but the possibility introduces a conflict of interest for the conservation programmes.

The second notable context for moth conservation interest involves a more diverse taxonomic array, comprising day-flying representatives of several families that occur on alpine and subalpine grasslands and heathlands, in some cases overlapping with butterflies of interest in the same regions. They have received attention mainly in Tasmania, where many parallels with the New Zealand moth fauna have been noted (McQuillan 1986). The two regions support closely related species of tiger moths (Arctiidae) and Geometridae, in particular. Some alpine geometrids parallel the satyrine butterflies in being locally abundant where they occur, but being distributed patchily and locally, and having short flight seasons; they are likely to be vulnerable to the same influences as the browns. The moths have been studied far less than the alpine butterflies, but the wider general threats to Tasmania's Geometridae (McQuillan 2004) mirror many of those better defined for butterflies, but with forest clearing perhaps more significantly threatening moths, continued uncertainties over the effects of burning, and the root fungus disease *Phytophthora cinnamomi* contributing substantially to losses of some important moth food plant groups such as Epacridaceae, Proteaceae and conifers such as the pencil pine, *Arthrotaxis cupressoides*. The last is the foodplant of several endemic Tasmanian Geometridae, one of which (the pencil pine moth, *Dirce aesiodora*) is of particular conservation interest. *D. aesiodora* is a high elevation species, found above about 960 m, but recent surveys imply that it is distributed more widely than supposed previously. Monophagy is seen in this case as important in increasing vulnerability and, whilst much *Arthrotaxis* has been lost to fires, much of what remains is within the extensive Tasmanian World Heritage Area. Nevertheless, the common situation of lack of hard evidence on decline of the moth's abundance and distribution rendered it ineligible for listing under EPBC (DEWHA 2007), and it has also been removed from its former listing as 'Vulnerable' under the Tasmanian Act. Although many Tasmanian and Victorian moths remain poorly known, diurnal species have been treated as 'honorary butterflies' by collectors, so that the distributions of some are reasonably well documented. Many alpine geometrids (Larentiini) are associated predominantly with herb-rich grasslands, and have declined as this habitat has done so, with few species having made the transition to feed on introduced herbs that replace their normal food plants (McQuillan 1999). If native herbs remain, many of the moths survive in small remnant patches. One species, *Chrysolarentia (Coremia) decisaria*, was long presumed extinct in Tasmania as it was not seen after 1904 until a small population was discovered in 1996 in a small reserve (10 ha) surrounded by farmland. It is also known from Victoria. Many of its relatives are also known from single or few sites, and their conservation reflects needs to maintain native herbs in grasslands, so that successional maintenance may become critical. Pressures such as recreational off-road vehicle driving, over-fertilisation with phosphate, heavy grazing, and unsuitable fire regimes are all possible threats. Pasture management includes regulating timing of grazing to create opportunities for small interstitial herbs and, somewhat unusually, several native species of *Oncopera* (Hepialidae) are important components of the grazer community in Tasmania: McQuillan (1999) referred to the genus as 'something of a keystone taxon in Tasmanian *Poa* tussock grasslands'. Local densities can exceed 50 caterpillars a square metre, severing grass stems near the base to constitute a loose grass mat amongst which herbs germinate. In contrast to the grassland satyrines, conservation of the moths must focus on non-grassy plants as the major resource needed. But, as for geometrids associated with saltmarshes and other restricted habitats, effective site protection is the primary foundation for management, with the insects helping to endorse the wider but specialised conservation values. Their potential for conservation advocacy has yet to be realized, but the remarkable Tasmanian moth *Proditrix nielseni* (an unusually large species of Yponomeutoidea) in forests featured in the nomination for the Tasmanian Wilderness World Heritage Area as one of several notable large invertebrates within that region (McQuillan 2003).

Grasshoppers have also helped to demonstrate the conservation needs of insects in the south-east. Flightless Morabinae (Eumastacidae), with around 250 species, are an important endemic radiation within Australia's Orthoptera. Although none has been the focus for a specific conservation programme, they have been used to illustrate the importance of small remnant grassland areas, such as protected pioneer cemeteries and rail or road reserves, from which grazing and other disturbance has been excluded since European settlement. Some species now are known only from such areas and have apparently been lost from the wider open landscape.

Forests, as the other major structural ecosystem category and key insect habitat subjected to massive losses in the region, have helped to highlight the plight of the many saproxylic beetles and others that depend on trees, whether living or dead. The conservation needs of several Tasmanian species of stag beetles (Lucanidae) in relation to forestry operations have been explored in some detail (summary in New 2010). They, as with beetles known only from particular cave systems or other restricted sites or resources, can help to draw attention to the conservation importance of features that may often be otherwise overlooked or neglected. Incorporation with butterflies of other notable insects found in the same areas or ecosystems - such as alpine stoneflies in Victoria – augment and support conservation significance in extending the ambit of umbrella taxa on which management can focus but benefit less heralded taxa in the same systems. However, conservation of most non-butterfly species in the region continues to draw on the principles and scenarios developed for local butterflies and discussed in this book.

These cases, and the variety of taxonomic and ecological levels on which butterfly conservation is still developing in the region, are likely to continue at the forefront of efforts for invertebrate conservation in Australia. They are gradually familiarising people with the needs to conserve invertebrates, and some ways in which this may be done. Demonstrating the need, the variety, and the unifying principles is a continuing endeavour in which fostering wider interest is critical.

References

Ahern LD (2002) Eltham copper butterfly. Land for Wildlife Notes, LW 0021. Department of Natural Resources and Environment, Victoria (first published, January 1993)

Anderson RAL, McQuillan PB (2003) Flight activity and territoriality in a threatened butterfly *Oreixenica ptunarra* Couchman (Lepidoptera: Nymphalidae: Satyrinae). Rec South Aust Mus, Monograph series 7: 297–301.

Angas GF (1847) South Australia illustrated. Thomas McLean, London

ARP (2001) (Approved Recovery Plan) Bathurst copper butterfly (*Paralucia spinifera*) recovery plan. New South Wales Parks and Wildlife Service, Hurstville

Attiwill P, Wilson B (2006) Succession, disturbance and fire. pp 361–377 in Attiwill P, Wilson B (eds) Ecology. An Australian perspective. Oxford University Press, Melbourne

Barratt BIP, Ferguson CM, Barton DM, Johnstone PD (2009) Impact of fire on tussock grassland invertebrate populations. Science for Conservation 291. Department of Conservation, Wellington

Beale JP (1997) Comment on the efficacy of Queensland nature conservation legislation in relation to *Acrodipsas illidgei* (Waterhouse and Lyell) (Lepidoptera: Lycaenidae: Theclinae). Pacif Conserv Biol 3: 392–396

Beale JP, Zalucki MP (1995) Status and distribution of *Acrodipsas illidgei* (Waterhouse and Lyell) (Lepidoptera: Lycaenidae) at Redland Bay, southeastern Queensland, and a new plant association record. J Aust Entomol Soc 34: 163–168

Beardsell C (1994) Report on field surveys from 22 October to 23 January 1994 for the small and large ant-blue butterflies and their attendant ant species. Unpublished report, Department of Conservation and Natural Resources, Melbourne

Beaumont LJ, Hughes L (2002) Potential changes in the distribution of latitudinally restricted Australian butterfly species in response to climate change. Global Change Biol 8: 954–971

Beaumont LJ, Hughes L, Poulsen M (2005) Predicting species distributions: use of climate parameters in BIOCLIM and its impact on prediction of species' current and future distributions. Ecol Model 186: 250–269

Beaumont LJ, Pitman AJ, Poulsen M, Hughes L (2007) Where will species go? Incorporating new advances in climate modeling into projections of species distributions. Global Change Biol 13: 1368–1385

Bell PJ (1999) Ptunarra brown butterfly recovery plan 1998–2003. Department of Primary Industries, Water and Environment, Hobart

Bell PJ (2002) Survey of known sites and potential habitat for the Marrawah skipper in northwest Tasmania. Nature Conservation Branch. Department of Primary Industries, Water and Environment, Hobart

Bell PJ, Miller B (2005) Marrawah skipper discovered at Penguin. For Prac News 6: 1–2

Belvedere M, Bain G, Steller P (1998) Sword-grass brown butterfly project. Vict Nat 115: 142–145

Braby MF (1987) The Eltham copper: a butterfly with special appeal. Habitat Austr 15: 16–18

Braby MF (1990) The life history and biology of *Paralucia pyrodiscus lucida* Crosby (Lepidoptera: Lycaenidae). J Aust Entomol Soc 29: 41–50
Braby MF (1991) City butterflies go bush. Wildl Aust 28: 20–21
Braby MF (2000) Butterflies of Australia, their identification, biology and distribution. CSIRO Publishing, Melbourne
Braby MF (2004) The complete field guide to butterflies of Australia. CSIRO Publishing, Melbourne
Braby MF (2008a) Biogeography of butterflies in the Australian monsoon tropics. Aust J Zool 56: 41–56
Braby MF (2008b) Taxonomic review of *Candalides absimilis* (C. Felder 1862) and *C. margarita* (Semper 1879) (Lepidoptera: Lycaenidae) with description of two new subspecies. Beagle, Rec N T Mus Arts Sci 24: 33–56
Braby MF, Douglas F (2004) The taxonomy, ecology and conservation status of the Golden-rayed blue, a threatened butterfly endemic to western Victoria, Australia. Biol J Linn Soc 81: 275–299
Braby MF, Douglas F (2008) The nomenclature, taxonomy and conservation status of *Ogyris waterhouseri* (Bethune-Baker, 1905) stat. nov. (Lepidoptera: Lycaenidae), a threatened butterfly from southern Australia. Aust J Entomol 47: 315–329
Braby MF, Edwards T (2006) The butterfly fauna of the Griffith district, a fragmented semi-arid landscape in inland southern New South Wales. Pacif Conserv Biol 12: 140–154
Braby MF, Crosby DF, Vaughan PJ (1992) Distribution and range restriction in Victoria of the Eltham copper butterfly *Paralucia pyrodiscus lucida* Crosby. Vict Nat 109: 154–161
Braby MF, Van Praagh BD, New TR (1999) The dull copper, *Paralucia pyrodiscus* (Lycaenidae). pp 247–260 in Kitching RL, Scheermeyer E, Jones RE, Pierce NE (eds) Biology of Australian butterflies. CSIRO Publishing, Collingwood
Bridgeman H, Warner R, Dodson J (1995) Urban biophysical environments. Oxford University Press, Melbourne
Britton DR (1997) Ant trap nests enable detection of a rare and localised butterfly *Acrodipsas myrmecophila* (Waterhouse & Lyell) (Lepidoptera: Lycaenidae) in the field. Mem Mus Vic 56: 383–387
Britton DR, Ginn SG (2008) Hill-topping butterflies of the Hawkesbury-Nepean CMA. Australian Museum, Sydney
Britton DR, New TR (1993) Communities of diurnal Lepidoptera in central Victoria with emphasis on the Mount Piper region, Broadford (unpublished report to Department of Conservation and Natural Resources, Victoria)
Britton DR, New TR, Jelinek A (1995) Rare Lepidoptera at Mount Piper, Victoria: the role of a threatened butterfly community in advancing understanding of insect conservation. J Lepidopt Soc 49: 97–113
Bryant S, Jackson J (1999) Tasmania's threatened fauna handbook. What, where and how to protect Tasmania's threatened animals? Parks and Wildlife Service, Hobart
Calder M, Calder J (1998) The scientific value of Mount Buffalo National Park. Vict Nat 115: 164–169
Canzano A (2009) (personal communication)
Canzano A, Whitfield J (2008) Discovery of a further population of the Eltham copper butterfly *Paralucia pyrodiscus lucida* Crosby (Lepidoptera; Lycaenidae) in Bendigo, Victoria. Vict Nat 125: 178–180
Canzano A, New TR, Yen AL (2007) The Eltham copper butterfly, *Paralucia pyrodiscus lucida* Crosby (Lepidoptera: Lycaenidae): local versus state conservation strategies in Victoria. Vict Nat 124: 236–242
Cavill GWK, Clark DV (1967) Insect venoms, attractants and repellents – VIII. Isohydronepetalactone. J Insect Physiol 13: 131–135
Cayzer LW, Crisp MD, Telford IRH (1999) *Bursaria* (Pittosporaceae): a morphometric analysis and revision. Aust System Bot 12: 117–143

Clarke GM (2000) Inferring demography from genetics: a case study of the endangered golden sun moth, *Synemon plana*. pp. 213–225 in Young AG, Clarke GM (eds) Genetics, demography and viability of fragmented populations. Cambridge University Press, Cambridge

Clarke GM, Grosse SP (2003) Genetic analysis of populations of the Bathurst copper butterfly, *Paralucia spinifera*. CSIRO Entomology, Canberra

Clarke G, Spier-Ashcroft F (2003) A review of the conservation status of selected Australian non-marine invertebrates. Environment Australia/National Heritage Trust, Canberra

Coleman P, Coleman F (2000) Local recovery plan for the yellowish sedge-skipper and thatching grass. Delta Environmental Consulting, Adelaide

Collier N, Mackay DA, Benkendorff K, Austin AD, Carthew SM (2006) Butterfly communities in South Australian urban reserves: estimating abundance and diversity using the Pollard walk. Aust Ecol 31: 282–290

Common IFB, Waterhouse DF (1972) Butterflies of Australia. Angus & Robertson, Sydney

Common IFB, Waterhouse DF (1981) Butterflies of Australia (revised edition). Angus & Robertson, Sydney

Corbet PS, Brooks SJ (2008) Dragonflies. New Naturalist 106. Collins, London

Couchman LE (1962) Notes on some Tasmanian and Australian Lepidoptera-Rhopalocera. Pap Proc Roy Soc Tasm 96: 73–81

Couchman LE (1965) Notes on some Tasmanian and Australian Lepidoptera-Rhopalocera. II. Pap Proc Roy Soc Tasm 99: 81–86

Couchman LE, Couchman R (1977) The butterflies of Tasmania. Tasmanian Year Book 1977: 66–96

Craig JL, Saunders DA, Mattiske EM (1996) Effective conservation requires people networked for action. pp.653–660 in Saunders DA, Craig JL, Mattiske EM (eds) Nature conservation 4. The role of networks. Surrey Beatty and Sons, Chipping Norton

Cranston PS, Naumann ID (1991) Biogeography. pp. 109–124 in Naumann ID, Carne PB (eds) The insects of Australia (2nd edn). Melbourne University Press, Carlton

Crosby DF (1951) A new geographical race of an Australian butterfly. Vict Nat 67: 165–166

Crosby DF (1987) The conservation status of the Eltham copper butterfly (*Paralucia pyrodiscus lucida* Crosby) (Lepidoptera: Lycaenidae). Technical Report Series No 81. Department of Conservation, Forests and Lands, Melbourne

Crosby DF (1990a) A management plan for the Altona skipper butterfly *Hesperilla flavescens flavescens* Waterhouse (Lepidoptera: Hesperiidae). Technical Report Series No 98. Department of Conservation, Forests and Lands, Melbourne

Crosby DF (1990b) The orange palmdart *Cephrenes augiades sperthias* (Felder) (Lepidoptera: Hesperiidae) in Victoria. Vict Entomol 20: 59–60

Crosby DF (1994) New distribution and food plant records for some Victorian butterflies (Lepidoptera: Hesperioidea, Papilionoidea). Aust Entomol 21: 65–68

Crosby DF (1998) The butterflies of Mount Buffalo National Park. Vict Nat 115: 222–225

Crosby DF, Dunn KL (1989) The distribution and range extension in Victoria of the butterfly *Ocybadistes walkeri sothis* Waterhouse. Vic Nat 106: 184–193

Crosby DF, Quick WNB (1996) CD-Rom: Victorian butterfly database. Viridans Biological Databases, Brighton East, Victoria

Crozier LG (2004) Field transplants and summer constraints on a butterfly range expansion. Oecologia 141: 148–157

Cushman JH, Rashbrook VK, Beattie AJ (1994) Assessing benefits to both participants in a lycaenid-ant association. Ecology 75: 1031–1041

DCE (Department of Conservation and Environment) (1991) What the Real Estate Institute of Victoria said about the value of natural vegetation in a property. Land for Wildlife News 1 (June 1991). Department of Conservation and Environment, Victoria

DEH (Department of the Environment and Heritage) (2006) EPBC Act Policy Statement 1.1. Significant impact guidelines. Matters of national environmental significance. Commonwealth of Australia, Canberrra

Dennis RLH (1977) The British butterflies. Their origin and establishment. EW Classey, Farringdon, Oxon

Dennis RLH (1993) Butterflies and climate change. Manchester University Press, Manchester

Dennis RLH, Shreeve TG, Van Dyck H (2006) Habitats and resources: the need for a resource-based definition to conserve butterflies. Biodiv Conserv 15: 1943–1968

Dennis RLH, Shreeve TG, Sheppard DA (2007) Species conservation and landscape management: a habitat perspective. pp. 92–126 in Stewart AJA, New TR, Lewis OT (eds) Insect Conservation Biology. CAB International, Wallingford

Descimon H, Mallet J (2009) Bad species. pp. 219–249 in Settele J, Shreeve T, Konvicka M, Van Dyck H (eds) Ecology of Butterflies in Europe. Cambridge University Press, Cambridge.

DEWHA (Department of the Environment, Water, Heritage and the Arts) (2007) Pencil Pine Moth (*Dirce aesiodora*) (Listing advice to the Minister for the Environment and Heritage) (http// www.environment.gov.au/biodiversity/threatened/species/dirce_aesiodora.html) (accessed 13 January 2010)

DEWHA (Department of the Environment, Water, Heritage and the Arts) (2008) Natural temperate grassland of the Victorian volcanic plain: a nationally threatened ecological community. Policy Statement 3.8. Environment Protection and Biodiversity Conservation Act 1999, Canberra.

Douglas F (1993) The conservation status, distribution and habitat requirements of diurnal Lepidoptera in central and western Victoria (Part 1: Family Castniidae). Department of Natural Resources and Environment, East Melbourne

Douglas F (1995) Recovery plan for threatened diurnal Lepidoptera in western Victoria. Part 2: Family Lycaenidae. Department of Conservation and Natural Resources, Melbourne

Douglas F (2003) Large brown azure butterfly *Ogyris idmo halmaturia*. Flora and Fauna Guarantee Act 1988 Action Statement No. 150. Department of Sustainability and Environment, Victoria

Douglas F (2004) A dedicated reserve for conservation of two species of *Synemon* (Lepidoptera: Castniidae) in Australia. J Insect Conserv 8: 221–228

Douglas F, Braby MF (1992) Notes on the distribution and biology of some Hesperiidae and Lycaenidae (Lepidoptera) in Victoria. Aust Entomol Mag 19: 117–124

Dunn KL (1997) Software review. CD-Rom: Victorian butterfly database, Viridans Biological Databases. Vict Entomol 27: 35–36

Dunn KL (2008) The butterfly database – its aims and purposes revisited. Myrmecia 2008: 18–27

Dunn KL (2009) Overview of the Butterfly database: part 1 – project history and inception. Vict Entomol 39: 73–79

Dunn KL, Dunn LE (1991) Review of Australian butterflies: distribution, life history and taxonomy. Parts 1–4. Privately published, Melbourne

Dunn KL, Dunn LE (2006) Review of Australian butterflies – 1991. (Annotated version on CD Rom). Privately published, Melbourne

Dunn KL, Kitching RL, Dexter EM (1994) The conservation status of Australian butterflies. Report to Australian National Parks and Wildlife Service, Canberra

Eastwood RG, Fraser AM (1999) Associations between lycaenid butterflies and ants in Australia. Aust J Ecol 24: 503–537

Eastwood R, Hughes JM (2003) Molecular phylogeny and evolutionary biology of *Acrodipsas* (Lepidoptera: Lycaenidae). Mol Phylog Evol 27: 93–102

Eastwood R, Braby MF, Schmidt DJ, Hughes JM (2008) Taxonomy, ecology, genetics and conservation status of the pale imperial hairstreak (*Jalmenus eubulus*) (Lepidoptera: Lycaenidae), a threatened butterfly from the brigalow belt, Australia. Invert Syst 22: 407–423

Edwards ED, Common IFB (1978) A new species of *Paralucia* Waterhouse and Turner from New South Wales (Lepidoptera: Lycaenidae). Aust Entomol Mag 5: 65–70

Eichler J (1999) The orange palm dart skipper *Cephrenes augiades sperthias* (Felder) in Melbourne. Vict Nat 116: 16–18

Endersby ID (1996) Some aspects of the biology and behaviour of *Paralucia pyrodiscus lucida* Crosby (Lepidoptera: Lycaenidae) at Eltham, Victoria. Proc R Soc Vic 107: 83–94

Entomological Society of Victoria (1986) Preliminary distribution maps of butterflies in Victoria. Entomological Society of Victoria, Melbourne

Fensham RJ, Kirkpatrick JB (1992) The Eucalypt forest-grassland/Grassy woodland boundary in central Tasmania. Aust J Bot 40: 123–138

Field RJ (1992) Research grant report. Myrmecia 26: 12–17

Field RJ (1997) The *Ogyris idmo* Hewitson (Lepidoptera: Lycaenidae) complex as flagship species for conservation in southern Australia. Mem Mus Vic 56: 389–392

Field RJ (1999) A new species of *Ogyris* Angas (Lepidoptera: Lycaenidae) from southern arid Australia. Mem Mus Vic 57: 251–259

Fisher RH (1978) Butterflies of South Australia. Government Printer, Adelaide, South Australia

Fisher RH (1985) Butterflies (Lepidoptera: Hesperioidea, Papilionoidea) of Kangaroo Island, South Australia. Aust Entomol Mag 12: 1–8

Fisher RH, Watts CHS (1994a) The small brown azure butterfly (*Ogyris otanes*) in South Australia. Recovery Plan. Australian Nature Conservation Agency, Canberra

Fisher RH, Watts CHS (1994b) The small white-veined skipper butterfly. (*Anisynta albovenata albovenata*). Recovery plan. Australian Nature Conservation Agency, Canberra

Galloway RW (1988) The potential impact of climatic changes on Australian ski fields. pp. 428–437 in Pearman GI (ed) Greenhouse. Planning for climate change. CSIRO, Melbourne

Gibson L, New TR (2007) Problems in studying populations of the golden sun-moth, *Synemon plana* (Lepidoptera: Castniidae) in south eastern Australia. J Insect Conserv 11: 309–313

Gilbert LE, Singer MC (1975) Butterfly ecology. Ann Rev Ecol Syst 6: 365–397

Gill AM (2008) Underpinnings of fire management for biodiversity conservation in reserves. Fire and adaptive management. Report No 73. Department of Sustainability and Environment, Victoria

Goss S (1999) They're planting a forest in Altona. Melbourne Age, 23 June

Grace R (1988) The social value of endangered wildlife. Economics Unit Discussion Paper no 45. Department of Conservation and Environment, Victoria

Graetz RD, Wilson MA, Campbell SK (1995) Landcover disturbance over the Australian continent, a contemporary assessment. Biodiversity series paper no 7. Department of Environment, Sport and Territories, Canberra

Green K, Osborne W (1994) Wildlife of the Australian snow-country. Reed, Chatswood

Greenslade P (1994) Heritage listing of invertebrate sites in southeastern Australia. Mem Qld Mus 36: 67–76

Greenslade P (1999) What entomologists think about listing species for protection. pp. 345–349 in Ponder W, Lunney D (eds) The other 99%. The conservation and biodiversity of invertebrates. Royal Zoological Society of New South Wales, Mosman

Grund R (1997) Interim recovery plan. Recovery of *Hesperilla flavescens flavia*, the yellowish skipper. Report to National Heritage Trust, Canberra

Grund R (1999) South Australian butterflies. Data sheet. *Acrodipsas brisbanensis* (Miskin) (Bronze Ant-blue). (http://users.sa.chariot.net.au/~rbg/acrodipsas_ds.htm, accessed July 2009)

Grund R (2001) South Australian butterflies. Data sheet. *Ogyris halmaturia* (Tepper) (Eastern Large Bronze Azure). (http://users.sa.chariot.net.au/~rbg/idmo_ds.htm, accessed July 2009)

Grund R (2002a) South Australian butterflies. Data sheet. *Jalmenus lithochroa* Waterhouse (Lithochroa Hairstreak). (http://users.sa.chariot.net.au/~rbg/lithochroa_ds.htm, accessed July 2009)

Grund R (2002b) South Australian butterflies. Data sheet. *Hesperilla donnysa donnysa* Hewitson (Donnysa Sedge-skipper), *Hesperilla donnysa donnysa* form *delos* Waterhouse (Donnysa sedge-skipper), *Hesperilla donnysa donnysa* form *flavescens* Waterhouse (Yellowish or Adelaide Plains Sedge-skipper) (http://users.sa.chariot.net.au/~rgrund/donnysa_ds.htm, accessed July 2009)

Grund R (2002c) South Australian butterflies. Data sheet. *Oreixenica kershawi kanunda* Tindale (Striped Xenica). (http://users.sa.chariot.net.au/~erg/kanunda_ds.htm, accessed July 2009)

Grund R (2003) A note on the first instar larva of *Ogyris idmo halmaturia* Tepper (Lepidoptera: Lycaenidae). Vict Entomol 33: 71

Grund R (2004) South Australian butterflies. Data sheet. *Candalides noelkeri* Braby and Douglas (Golden-rayed Blue). (http://users.sa.chariot.net.au/~rbg/noelkeri_ds.htm, accessed July 2009)

Grund R (2006) South Australian butterflies. Data sheet. *Heteronympha cordace wilsoni* Burns (Bright-eyed Brown). (http://users.sa.chariot.net.au/~erg/cordace_ds.htm, accessed July 2009)

Grund R (2008) South Australian butterflies. Data sheet. *Ogyris otanes otanes* (C. & R. Felder) (Small Bronze Azure). (http://users.sa.chariot.net.au/~rbg/otanes_ds.htm, accessed July 2009)

Grund R (2009) South Australian butterflies. Checklist. (http://users.sa.chariot.net.au/~rgrund/checklist.htm, accessed July 2009)

Grund R (2010) The taxonomy of *Ogyris halmaturia* (Tepper, 1890 stat. nov. (Lepidoptera: Lycaenidae). Aust J Entomol 49: 114–120

Grund R, Hunt L (2000) Butterfly conservation in the lower south-east region. Department of Environment and Aboriginal Affairs, South Australia

Grund R, Hunt L, Young D (2006) A survey for the endangered butterfly *Ogyris idmo* on Kangaroo Island. Butterfly Conservation SA Inc., Adelaide

Hawking, JH (1999) An evaluation of the current conservation status of Australian dragonflies (Odonata). pp. 354–360 in Ponder W, Lunney D (eds) The other 99%. The conservation and biodiversity of invertebrates. Royal Zoological Society of New South Wales, Mosman

Haywood BT, Natt V (2006) First confirmed record of *Heteronympha cordace wilsoni* Burns (Lepidoptera: Nymphalidae: Satyrinae) in South Australia. Aust Entomol 33: 5–7

Healy S, Wassens S (2008) Review of the impacts of fire on the ecology and population persistence of the purple copper butterfly (*Paralucia spinifera*). Report No 44. Department of Environment and Climate Change, New South Wales

Herbison–Evans D, Newman S (2008) Butterflies from around Sydney, Australia (http://linus.socs.uts.edu.au/ ~don/larvae/sydbuts.html. Accessed 30 July 2009)

Hill L, Michaelis FB (1988) Conservation of insects and related wildlife. Occasional Paper no 13. Australian National Parks and Wildlife Service, Canberra

Hill JK, Thomas CD, Fox R, Telfer MG, Willis SG, Asher J, Huntley B (2002) Responses of butterflies to twentieth century climate warming: implications for future ranges. Proc Roy Soc Lond Ser B Biol Sci 269: 2163–2171

Hochberg ME (2000) What conserve parasitoids? pp. 266–277 in Hochberg ME, Ive AR (eds) Parasitoid population biology. Princeton University Press, Princeton, NJ

Hochberg ME, Elmes GW, Thomas JA, Clarke RT (1996) Mechanisms of local persistence in coupled host-parasitoid associations: the case model of *Maculinea rebeli* and *Ichneumon eumerus*. Phil Trans Roy Soc B 351: 1713–1724

Hofmeister B (1988) Australia and its urban centres. Gebrueder Borntraeger, Berlin

IUCN (2001) IUCN Red List Categories and Criteria: Version 3.1. IUCN, Gland and Cambridge

Jelinek A (1991) Butterfly community No 1. Flora and Fauna Guarantee Action Statement No 6. Department of Conservation and Environment, Melbourne

Jelinek A (2005) Conservation strategy for a threatened butterfly community. Vict Nat 112: 47–50

Jelinek A, White M (1996a) Flora and Fauna Guarantee Action Statement No 70. Large ant-blue butterfly, *Acrodipsas brisbanensis*. Department of Natural Resources and Environment, Victoria

Jelinek A, White M (1996b) Flora and Fauna Guarantee Action Statement No 71. Small ant-blue butterfly, *Acrodipsas myrmecophila*. Department of Natural Resources and Environment, Victoria

Jelinek A, Britton DR, New TR (1994) Conservation of a 'threatened butterfly community' at Mount Piper, Victoria. Mem Qld Mus 36: 115–120

JNCC (Joint Nature Conservation Committee) (2009) Guidelines for selection of Sites of Special Scientific Interest. (http://www.jncc.gov.uk/page-2303, accessed 20 July 2009)

Johnson C (2002) Investigations of the monitoring methods and larval biology of *Paralucia pyrodiscus lucida* (Eltham copper butterfly) Unpublished Honours thesis, Institute of Land and Food, University of Melbourne

Kankare M, van Nouhuys S, Gaggiotti O, Hanski I (2005) Metapopulation genetic structure of two coexisting parasitoids of the Glanville fritillary butterfly. Oecologia 143: 77–84

Kirkpatrick J (1994) A continent transformed. Human impact on the vegetation of Australia. Oxford University Press, Melbourne

Kirkpatrick J, McDougall K, Hyde M (1995) Australia's most threatened ecosystems. The south-eastern lowland native grasslands. Surrey Beatty & Sons, Chipping Norton

Kitching RL, Dunn KL (1999) The biogeography of Australian butterflies. pp. 53–74 in Kitching RL, Scheermeyer E, Jones RE, Pierce NE (eds) Biology of Australian butterflies. CSIRO Publishing, Collingwood

Kitching RL, Edwards ED, Ferguson D, Fletcher MB, Walker JM (1978) The butterflies of the Australian Capital Territory. J Aust Entomol Soc 17: 125–133

Kitching RL, Scheermeyer E, Jones RE, Pierce NE (eds) (1999) Biology of Australian butterflies. CSIRO Publishing, Collingwood

Knox Environment Society (2006) Sword-grass brown butterfly project. Boronia

Koh LP, Sodhi NS (2004) Importance of reserves, fragments and parks for butterfly conservation in a tropical urban landscape. Ecol Appl 14: 1695–1708

Lewin JW (1822) Lepidopterous insects of New South Wales (2nd edition), London

Lomov B, Keith DA, Britton DR, Hochuli DF (2006) Are butterflies and moths useful indicators for restoration monitoring? A pilot study in Sydney's Cumberland Plain Woodland. Ecol Manage Restor 7: 204–210

Marion A (1998) Special protection zone management within Mount Buffalo National Park. Vict Nat 115: 169–174

Matthews E, Oppermann A, Inns R (2001) Biodiversity Plan for the Eyre Peninsula. Department for Environment and Heritage, South Australia

McArthur AJ, Adams M, Shattuck SO (1997) A morphological and molecular review of *Camponotus terebrans* (Lowne) (Hymenoptera: Formicidae). Aust J Zool 45: 579–598

McDougall KL, Morgan JW, Walsh NG, Williams RJ (2005) Plant invasions in treeless vegetation of the Australian Alps. Plant Ecol Evol Syst 7: 159–171

McQuillan PB (1986) Trans-Tasman relationships in the highland moth (Lepidoptera) fauna. pp. 263–276 in Barlow BA (ed) Flora and fauna of alpine Australasia. Ages and origins. CSIRO, Melbourne/E.J.Brill, Leiden

McQuillan P (1994) Butterflies of Tasmania. Tasmanian Field Naturalists Club Inc., Hobart

McQuillan PB (1999) The effects of changes in Tasmanian grasslands on the geometrid moth tribe Xanthorhoini (Geometridae: Larentiinae). pp. 121–128 in Ponder W, Lunney D (eds) The other 99%. The Conservation and biodiversity of invertebrates, Royal Zoological Society of New South Wales, Mosman

McQuillan PB (2003) The giant Tasmanian 'pandani' moth *Proditrix nielseni* sp. nov. (Lepidoptera: Yponomeutoidea: Plutellidae s.l.). Invert Syst 17: 59–66

McQuillan PB (2004) An overview of the Tasmanian geometrid moth fauna (Lepidoptera: Geometridae) and its conservation status. J Insect Conserv 8: 209–220

McQuillan PB, Ek CK (1997) A biogeographical analysis of the Tasmanian endemic ptunarra brown butterfly, *Oreixenica ptunarra* Couchman 1953 (Lepidoptera: Nymphalidae: Satyrinae). Aust J Zool 44: 21–37

Menendez R, Gonzales-Megías A, Collingham Y, Fox R, Roy DB, Ohlemüller R, Thomas CD (2007) Direct and indirect effects of climate and habitat factors on butterfly diversity. Ecology 88: 605–611

Mjadwesch R (2004) Purple copper butterfly management plan for the SH18 Lidsdale Realignment Project (unpublished report to Road Traffic Authority). Mjadwesch Environmental Service Support, cited by Mjadwesch R, Nally, S 2008

Mjadwesch R, Nally S (2008) Emergency relocation of a purple copper butterfly colony during roadworks: successes and lessons learned. Ecol Manage Restor 9: 100–109

Moore S (1996) The role of trust in social networks: formation, function and fragility. pp. 148–154 in Saunders DA, Craig JL, Mattiske EM (eds) Nature conservation 4. The role of networks. Surrey Beatty & Sons, Chipping Norton

Moulds MS (1999) The history of Australian butterfly research and collecting. pp 1–24 in Kitching RL, Scheermeyer E, Jones RE, Pierce NE (eds) Biology of Australian butterflies. CSIRO Publishing, Collingwood

Mount Buffalo National Park Management Plan (1996) Department of Natural Resources and Environment, Victoria

Mouquet N, Belrose V, Thomas JA, Elmes GW, Clarke RT, Hochberg ME (2005) Conserving community modules: a case study of the endangered lycaenid butterfly *Maculinea alcon*. Ecology 86: 3160–3173

Nadolny C (1987) Rainforest butterflies in New South Wales: their ecology, distribution and conservation. New South Wales National Parks and Wildlife Service, Sydney

Nally S (2003) Community involvement in the conservation of endangered purple copper butterfly *Paralucia spinifera* Edwards and Common (Lepidoptera: Lycaenidae). Rec South Aust Mus, Monograph series 7: 217–224

Neville PJ (2000) The effects of fire on ground-dwelling arthropods of the Dandenong Ranges National Park, Victoria, with particular reference to ants (Hymenoptera: Formicidae). PhD Thesis, La Trobe University, Melbourne

New TR (1984) Insect conservation – an Australian perspective. W Junk, Dordrecht

New TR (1993) *Hemiphlebia mirabilis* Selys: Recovery from habitat destruction at Wilsons Promontory, Victoria, Australia, and implications for conservation management (Zygoptera: Hemiphlebiidae). Odonatologica 22: 495–502

New TR (1998) Recovery plan for 'Butterfly community No.1', a threatened butterfly community at Mt Piper in central Victoria. Department of Natural Resources and Environment, Victoria

New TR (1999) The evolution and characteristics of the Australian butterfly fauna. pp 33–52 in Kitching RL, Scheermeyer E, Jones RE, Pierce NE (eds) Biology of Australian butterflies. CSIRO Publishing, Collingwood

New TR (2005) Recreation and reserves: values of golf courses for insect conservation. J Insect Conserv 9: 1–2

New TR (2008a) Legislative inconsistencies and species conservation status: understanding or confusion? The case of *Riekoperla darlingtoni* (Plecoptera) in Australia. J Insect Conserv 12: 1–2

New TR (2008b) Conserving narrow range endemic insects in the face of climate change: options for some Australian butterflies. J Insect Conserv 12: 585–589

New TR (2009) Insect species conservation. Cambridge University Press, Cambridge

New TR (2010) Beetles in conservation. Wiley/Blackwell, Oxford

New TR, Britton DR (1997) Refining a recovery plan for an endangered lycaenid butterfly, *Acrodipsas myrmecophila*, in Victoria. J Insect Conserv 1: 65–72

New TR, Sands DPA (2002) Narrow-range endemicity and conservation status: interpretations for Australian butterflies. Invert Syst 16: 665–670

New TR, Sands DPA (2003a) Conservation concerns for butterflies in urban areas of Australia. J Insect Conserv 6(2002): 207–215

New TR, Sands DPA (2003b) The listing and de-listing of invertebrate species for conservation in Australia. J Insect Conserv 7: 199–205

New TR, Sands DPA (2004) Management of threatened insect species in Australia, with particular reference to butterflies. Aust J Entomol 43: 258–270

New TR, Britton DR, Hinkley SD, Miller LJ (1996) The ant fauna of Mount Piper and its relevance to environmental assessment and the conservation of a threatened invertebrate community. Flora and Fauna Technical Report 143, Department of Natural Resources and Environment, Melbourne

New TR, Van Praagh BD, Yen AL (2000) Fire and the management of habitat quality in an Australian lycaenid butterfly, *Paralucia pyrodiscus lucida*, the Eltham copper. Metamorphosis 11: 154–163

New TR, Field RP, Sands DPA (2007) Victoria's butterflies in a national conservation context. Vict Nat 124: 243–249

New TR, Yen AL, Sands DPA, Greenslade P, Neville PJ, York A, Collett NG (2010) Planned fires and invertebrate conservation in south east Australia. J Insect Conserv 14: 567–574

Neyland M (1992) The ptunarra brown butterfly *Oreixenica ptunarra* conservation research statement. Scientific report 92/2, Department of Parks, Wildlife and Heritage, Hobart

Neyland M (1993) The ecology and conservation management of the ptunarra brown butterfly *Oreixenica ptunarra* (Lepidoptera: Nymphalidae: Satyrinae) in Tasmania, Australia. Pap Proc Roy Soc Tasm 127: 43–48

Neyland M (1994) The ecology and conservation status of three rare hesperiid butterflies in Tasmania. Wildlife Report 94/3. Parks and Wildlife Service, Tasmania

Neyland M (2001) Ecology and conservation of the Marrawah skipper (*Oreisplanus munionga*) in Tasmania. Tasm Nat 123: 48–56

Neyland M, Bell P (2000) Ecology and conservation of the Chaostola skipper butterfly (*Antipodia chaostola leucophaea*) in Tasmania. Tasm Nat 122: 47–54

Peters RL, Darling JDS (1985) The greenhouse effect and nature reserves. BioScience 35: 707–726

Pickering C, Hill W, Green K (2008) Vascular plant diversity and climate change in the alpine zone of the Snowy Mountains, Australia. Biodiv Conserv 17: 1627–1644

Pierce NE, Nash DR (1999) The imperial blue, *Jalmenus evagoras* (Lycaenidae). pp 279–315 in Kitching RL, Scheermeyer E, Jones RE, Pierce NE (eds) Biology of Australian butterflies. CSIRO Publishing, Collingwood

Pollard E, Eversham BC (1995) Butterfly monitoring 2 – interpreting the changes. pp. 23–36 in Pullin AS (ed) Ecology and conservation of butterflies. Chapman & Hall, London

Pollard E, Yates TJ (1993) Monitoring butterflies for ecology and conservation. Chapman & Hall, London

Prince GB (1988a) The habitat requirements and national conservation status of Tasmania's endemic butterflies. Report to Tasmanian Department of Lands, Parks and Wildlife, Hobart

Prince GB (1988b) The conservation status of the hairstreak butterfly *Pseudalmenus chlorinda* Blanchard in Tasmania. Report to Tasmanian Department of Lands, Parks and Wildlife, Hobart

Prince GB (1993) The Australian Hairstreak, *Pseudalmenus chlorinda* (Blanchard). pp. 171–172 in New T.R. (ed) Conservation biology of Lycaenidae (Butterflies). IUCN, Gland

Relf MC, New TR (2009) Conservation needs of the Altona skipper butterfly, *Hesperilla flavescens flavescens* Waterhouse (Lepidoptera: Hesperiidae) near Melbourne, Victoria. J Insect Conserv 13: 143–149

Samways MJ (2005) Insect diversity conservation. Cambridge University Press, Cambridge

Sands DPA (1997) *Alexfloydia repens* Simon: a food plant for *Ocybadistes knightorum* Lambkin and Donaldson (Lepidoptera: Hesperiidae) and their conservation significance. Aust Entomol 24: 117–1118

Sands D (2008) Conserving the Richmond birdwing butterfly over two decades: where to next? Ecol Manage Restor 9: 4–16

Sands DPA, New TR (2002) The Action Plan for Australian Butterflies. Environment Australia, Canberra

Sands DPA, New TR (2008) Irregular diapause, apparency and evaluating conservation status: anomalies from the Australian butterflies. J Insect Conserv 12: 81–85

Sands DPA, Scott S (2002) The Richmond birdwing butterfly (*Ornithoptera richmondia* [Gray]): its natural history and progress towards recovery. pp. 32–47 in Sands D, Scott S (eds) Conservation of birdwing butterflies. SciComEd Pty & THECA, Chapel Hill, Brisbane

Sands DPA, Scott SE, Moffatt R (1997) The threatened Richmond birdwing butterfly (*Ornithoptera richmondia* [Gray]): a community conservation project. Mem Mus Vic 56: 449–453

Sant GJ, New TR (1988) The biology and conservation of *Hemiphlebia mirabilis* Selys (Odonata: Hemiphlebiidae) in southern Victoria. Tech Rep no 82, Arthur Rylah Institute for Environmental Research, Melbourne

Sattler P, Creighton C (2002) Australian Terrestrial Biodiversity Assessment 2002. Department of Environment, Water, Heritage and the Arts, Canberra

Saunders DA, Craig JL, Mattiske EM (eds) (1996) Nature conservation 4. The role of networks. Surrey Beatty & Sons, Chipping Norton

Saunders DS (1987) The Eltham copper butterfly. Securing and managing the remaining colonies – options paper. National Parks and Wildlife Service, Victoria

Savage EJ (2002) Options and techniques for managing chaffy saw-sedge (*Gahnia filum*) as habitat for the Altona skipper butterfly (*Hesperilla flavescens flavescens*). Conservation and environmental management, Occasional paper series. Parks Victoria, Melbourne

Scott S (2002) School and community participation in the Richmond Birdwing conservation project. pp. 185–193 in Sands D, Scott S (eds) Conservation of birdwing butterflies. SciComEd Pty & THECA, Chapel Hill, Brisbane

Scriber JM, Allen GR, Walker PW (2006) Ecological monophagy in Tasmanian *Graphium macleayanum moggana* with evolutionary reflections of ancient angiosperm hosts. Insect Sci 13: 451–460

Scriber JM, Larsen ML, Allen GR, Walker PW, Zalucki MP (2008) Interactions between Papilionidae and ancient Australian angiosperms: evolutionary specialization or ecological monophagy? Entomol Exp Appl 128: 230–239

Settele J, Dover J, Dolek M, Konvicka M (2009) Butterflies of European ecosystems: impact of land use and options for conservation management. pp. 353–370 in Settele J, Shreeve T, Konvicka M, Van Dyck H (eds) Ecology of Butterflies in Europe. Cambridge University Press, Cambridge

Seymour B, Collett NG (2009) Effects of fire retardant application on heathland surface-dwelling ant species (Order Hymenoptera; Family Formicidae) in Victoria, Australia. For Ecol Manage 257: 1261–1270

Spencer WB (1896) Summary of the zoological, botanical and geological results of the expedition. pp. 139–199 in Spencer WB (ed) Report on the work of the Horn Scientific expedition to central Australia. Part 1. Dulau, London

Thomas JA, Simcox DJ, Clarke RT (2009) Successful conservation of a threatened *Maculinea* butterfly. Science 325: 80–83

TSS (Threatened Species Section) (2006) Draft Greater Freycinet Region Threatened Species Recovery Plan 2006–2010. Department of Primary Industries, Water and Environment, Hobart

Valentine PW (2004) The demise of mass migration of the brown awl *Badamia exclamationis* (Fabricius 1775) (Lepidoptera: Hesperiidae): a consequence of land clearing in Queensland? Pacif Conserv Biol 10: 67–69

Van Praagh BD (1996) Adult and larval counts of the Eltham copper butterfly *Paralucia pyrodiscus lucida* Crosby, 1993–1995. Fauna and Flora Technical Report No 144. Department of Conservation, Forests and Lands, Victoria

Van Swaay CAM, Maes D, Warren MS (2009) Conservation status of European butterflies. pp. 322–339 in Settele J, Shreeve T, Konvicka M, Van Dyck H (eds) Ecology of Butterflies in Europe. Cambridge University Press, Cambridge

Vaughan PJ (1987) The Eltham copper butterfly draft management plan. Fauna and Flora Technical Report No 57. Department of Conservation, Forests and Lands, Victoria

Vaughan PJ (1988) Management plan for the Eltham copper butterfly (*Paralucia pyrodiscus lucida* Crosby). Technical Report No 79. Department of Conservation, Forests and Lands, Victoria

Wainer JW, Yen AL (2000) A survey of the butterfly fauna of the Paps Scenic Reserve, Mansfield, Victoria. Vict Nat 117: 131–140

Wainer JW, Yen AL (2009) The heath sand-skipper butterfly *Antipodia chaostola* (Meyrick 1888) (Lepidoptera: Hesperiidae) in Central Gippsland, Victoria. Vict Nat 126: 192–202

Warren MS, Brereton T, Wigglesworth T (2005) Do agri-environment schemes help butterflies? experiences from the UK. pp. 121–123 in Kuhn E, Feldmann R, Thomas J, Settele J (eds) Studies on the ecology and conservation of butterflies in Europe. Vol. 1. General concepts and case studies. Pensoft, Sofia-Moscow

Waterhouse GA (1897) The genus *Heteronympha* in New South Wales Proc Linn Soc NSW 22: 240–243

Waterhouse GA (1932) What butterfly is that? Angus & Robertson, Sydney

Waterhouse GA, Lyell G (1914) The butterflies of Australia. A monograph of the Australian Rhopalocera. Angus & Robertson, Sydney

Wearne LJ, Morgan JW (2001) Recent forest encroachment into subalpine grasslands near Mt Hotham, Australia. Arct Antarct Alp Res 33: 369–377

Webster A (2008) Eltham copper butterfly *Paralucia pyrodiscus lucida*. Draft Flora and Fauna Guarantee Action Statement (revision, Action Statement no 39). Department of Sustainability and Environment, Victoria

Wells SM, Pyle RM, Collins NM (1983) The IUCN Invertebrate Red Data Book. IUCN, Gland and Cambridge.

Williams S (1996) Community involvement in the species recovery process: insights into successful partnerships. pp. 87–96 in Stephens S, Maxwell S (eds) Back from the brink. Refining the threatened species recovery process. Surrey Beatty & Sons, Chipping Norton

Williams MR (2009) Butterflies and day-flying moths in a fragmented urban landscape, south-western Western Australia: patterns of species richness. Pacif Conserv Biol 15: 32–46

Williams RJ, Costin AB (1994) Alpine and subalpine vegetation. pp. 467–500 in Groves RH (ed) Australian vegetation (2nd edn). Cambridge University Press, Melbourne

Williams MR, Hay RW (2001) Two new subspecies of *Ogyris otanes* C. & R. Felder (Lepidoptera: Lycaenidae) from Western Australia. Aust Entomol 28: 55–63

Wilson RJ, Gutierrez D, Gutierrez J, Monserrat VJ (2007) An elevational shift in butterfly species richness and composition accompanying recent climate change. Global Change Biol 13: 1873–1887

Wragg SA, Elgar MA (1997) Host plant use and ant interactions of the Victorian hairstreak *Pseudalmenus chlorinda zephyrus* Blanchard, a myrmecophilous lycaenid butterfly. Vict Nat 114: 74–76

Yen A, Butcher R (1997) An overview of the conservation of non-marine invertebrates in Australia. Environment Australia, Canberra

Yen AL, New TR, Van Praagh B, Vaughan PJ (1990) Invertebrate conservation: three case studies in southeastern Australia. pp. 207–224 in Clark T, Seebeck JH (eds) Management and conservation of small populations. Chicago Zoological Society, Brookfield, IL

Index