1 · *Needs and priorities for insect species conservation*

Introduction: extinctions and conservation need

Vast numbers of insect species exist on Earth. They are the predominant components of animal species richness in most terrestrial and freshwater environments. and by far outnumber many more familiar or popular animal groups, such as vertebrates. Estimates of the numbers of living insect species range up to several tens of millions; no one knows how many, but biologists accept easily estimates within the range of 5–10 million species as realistic. However, only about a million insect species have been formally described and named. The very levels of uncertainty over numbers of existing insect species are sobering reminders of what we do not know of our natural world. They help to emphasise our general ignorance over the diversity and ecological roles of many of the organisms that drive and maintain the ecological processes that sustain natural communities.

There is little doubt that very many insects have declined over the past century or so in response to human activities in many parts of the world. Such losses, reflecting changes we have made to their habitats and the resources on which they depend, have been documented most fully (but still with many substantial gaps in knowledge) in some temperate regions of the world (Stewart & New 2007). Insect extinctions and declines may be considerably greater in much of the tropics (Lewis & Basset 2007), where they are less heralded, but where numbers of insect species appear to be vastly higher than in many temperate regions. Unlike most groups of vertebrates, for which extinctions have sometimes been documented in considerable detail, extinctions of most insects have not been described – other than, predominantly, for a few Lepidoptera in northern temperate regions. Indeed, more than half of the recently documented insect extinctions are Lepidoptera. Many of the problems of determining the fact and likelihood of recent insect extinctions were explored by Dunn (2005), who suggested that insects might be especially prone to two forms of extinction that are rare in other taxa: extinctions of narrow habitat specialists, and coextinctions of species with their hosts, be these animals or plants. The two are to some extent parallel, and Dunn's conclusion that both these categories tend to be ignored by conservation programmes that focus on vertebrates or plants is relevant here. The second of his categories applies, for example, to insect parasitoids (p. 45) and ectoparasites, as well as to monophagous herbivores, many of which are among the cases noted in this book as causing major conservation concerns. Many intricate and obligate relationships are involved: thus, for the Singapore butterflies, Koh *et al.* (2004) suggested that many more butterflies are likely to become extinct along with their host plants, as they depend entirely on those particular host plants. Recent declines of pollinating insects in many parts of the world have caused concerns for the plants that depend on these. Again, such relationships may be very specific, and emphasise the intricacies of many of the ecological interactions in which insects participate. The need to hand-pollinate rare endemic plants in Hawaii and elsewhere demonstrate eloquently one category of the cascade effects that may flow from losses of ecologically specialised insects.

This lack of detailed knowledge of the extent of extinctions, however, cannot be allowed to lull us into false confidence that insects do not need attention to sustain them. In short, even though rather few global extinctions among recent insects have been confirmed (Mawdsley & Stork 1995), many insects are inferred strongly to have declined and are in need of conservation measures if they are to survive. Local extinctions of insects are frequent, and are the primary focus of much conservation. There are clear logistic limitations to the extent to which those deserving species can be treated individually, but attempts to do so have fundamentally increased our appreciation of insect biology and led to greatly improved conservation focus for species level conservation in many different contexts. These contexts range from the initial selection of candidates for consideration (and the criteria by which the 'most deserving species' may be given priority) to the effective design and implementation of management. In most parts of the world, even most of the insect species designated formally as 'threatened' have not become the subjects of focused species management plans. To some extent, this simply reflects the tyranny of large numbers of candidates and consequent impracticability of dealing with them, but this is often compounded by uncertainties over how to assess those priorities rationally and convincingly and, often, necessarily from an inadequate framework of biological knowledge and understanding.

At the outset, the conservation of insects (and of other invertebrates) reflects a number of features of scale that render them rather different from the vertebrates and higher plants generally more familiar to conservation managers, in addition to their taxonomic complexity, noted below. Some of these are noted here to aid perspective in conservation planning.

1. Most insects are small, and the normal population dynamics of many species is characterised by substantial intergenerational changes in numbers, so that detecting real trends in decline may necessitate observations over many generations.
2. Many conservation needs for insects arise from the focal species being extreme habitat specialists with very intricate resource requirements.
3. Many species have very narrow distributions in relation to those resources, with 'narrow range endemism' apparently a very common pattern. In most cases we do not know if narrow distributions are wholly natural, or represent declines from formerly broader ranges, for example as a result of habitat fragmentation.
4. Most insects have short generation times, with one–few generations a year being the most frequent patterns of development, but each insect species may have a largely predictable phenology within a given area. A univoltine (annual) life cycle implies a strongly seasonal pattern of development, so that differing resources for adult and immature stages must be available at particular times each year.
5. A corollary to this is that each life history stage may be available for inspection or monitoring only for a short period each year or each generation, with activity (essentially, opportunity for inspection) governed strongly by weather factors.
6. The suitability of a site for an insect depends not only on consumable resources but also on microclimate. Temperature is an important determinant of site suitability, so that attributes such as bare ground, vegetation cover and density, site aspect and slope may influence an insect's incidence and abundance in unexpectedly subtle ways.
7. Many insects are relatively immobile, so that they are predominantly restricted to particular sites or microhabitats. The factors that determine suitability of a microhabitat to an insect are commonly of little or no concern for other organisms. Likewise, very small sites (such as tiny patches of roadside vegetation) may be critically important for

particular insects but dismissed as too trivial to consider for vertebrates. Some insect species are known only from such minute areas, of a hectare or less.

8. Many insects manifest a metapopulation structure (p. 91), itself not always easy to define for species found in low numbers and widely dispersed, but of fundamental importance in estimating risk of extinction and, in conjunction with 7 (above), the accessibility of microhabitats in the wider landscape.

Planning priorities among species

Setting priorities for insect species conservation among an array of acknowledgedly worthy candidates is indeed difficult. This is despite species being the most tangible focus of practical conservation to many people, as entities to which we can relate, in contrast to more nebulous and complex entities such as communities and ecosystems. Formal listing of insects on a schedule of 'protected species' or 'threatened species' commonly obliges some form of further investigation or action. Yet the species which come to our notice as needing conservation attention, particularly when these are insects or other poorly documented organisms without a strong body of public support, are simply the small tip of a very large species iceberg. They are commonly simply those taxa over which someone, somewhere, has concerns, and are not fully representative of the greater needs of that group of organisms. Under Australia's federal Environment Protection and Biodiversity Conservation Act (EPBC), for example, and mirrored in all eight of the country's State or Territory legislations, together with virtually all similar or parallel legislations elsewhere in the world, only a handful or so of the possible tens of thousands of worthy candidate insects are scheduled at present, and numerous highly diverse groups of invertebrates are entirely missing. There is considerable bias in what invertebrates are listed, or can be included in such lists – or, perhaps, even that should be listed in this way, for two main reasons: (1) our lack of capability and resources to deal practically with large numbers of species to which we become committed, and (2) lack of rational bases based on sound information to designate the most 'deserving' species for our limited attention. It is no accident that a high proportion of insects listed in Australia, and elsewhere, are butterflies, the most popular group of insects and ones that can be promoted effectively as 'flagships' from a climate of sympathy for their wellbeing combined with reasonably sound evidence, arising largely from the concerns of hobbyists, of decline and conservation need. Thus the Bathurst copper butterfly (*Paralucia spinifera*) was the first invertebrate to be classified as 'endangered' in New South Wales, and its close relative the Eltham copper (*P. pyrodiscus lucida*) was amongst the first invertebrates listed formally in Victoria. Consequent concern for both these taxa has done much to promote wider interest in insect conservation in both states, with *P. spinifera* becoming the first butterfly to be listed federally in Australia, as 'vulnerable'. But this bias towards insects for which public sympathy is evident does not mean that others are of no concern; simply that listing many a psocid or small fly (in any part of the world) would serve little practical purpose other than conveying some slight message of political need – but, broadly, also likely to evoke a certain amount of ridicule. However, one outcome is clearly a strong bias toward favoured groups, although these groups need not necessarily be those that are well known. In an early survey of which insects in Australia might be threatened, Hill and Michaelis (1988) sought feedback from a wide circle of informed correspondents. One outcome of the exercise was that 56 of the 62 Diptera nominated were from the family Drosophilidae, representing the zeal of a single specialist. From that list, it could be inferred that no others of the hundred or so Australian families of flies are of concern, an inference that may be very misleading and which might not be apparent to politicians and managers relying on such lists for setting their priorities.

For many groups of insects, even in the best-documented regional faunas, taxonomic knowledge is still very incomplete, and our ability even to recognise species consistently is very limited. Within groups such as parasitoid Hymenoptera, for example, numerous complex suites of 'biological species' occur, differing in fundamental biological characteristics such as host specificity but indistinguishable on morphological features (Shaw & Hochberg 2001). As in numerous other insect groups, the proportion of species of these generally tiny wasps yet recognised may be of the order of only 10%–20% globally. Even fewer of these have been named scientifically. Up-to-date handbooks or other identification guides for many insect groups simply do not exist and, without ready access to a large and well-curated reference collection, a non-specialist has little chance of identifiying most of the species encountered. Even then, or with the best possible advice from acknowledged specialists, many problems of recognition and identification will persist.

Thus, discovering new, undescribed or undiagnosable insect species is a routine (and, commonly, unintentional) activity for entomologists taking up the study of almost any insect order or other group, particularly in the tropics or southern temperate regions of the world. In contrast, discovery of a new large vertebrate, particularly a mammal or bird, is a much rarer and more newsworthy event, as a consequence of much fuller early documentation of these animals, their wide interest and popular appeal, and their comparatively low diversity. Whereas virtually all species of animals such as mammals and birds have been recognised and assessed reliably for conservation need and allocation of conservation status, equivalent capability and coverage has not been achieved for insects, and such comprehensive assessment is utopian. Even for the best-known insect groups, many gaps remain. In addition, the real conservation status of many of the species that *are* included on protected species lists and the similar schedules that may accord them conservation priority remains controversial, with their practical conservation needs inferred rather than scientifically unambiguous. Many species listings have not been reviewed critically, and the species' status and needs may have changed considerably since it was originally signalled for conservation need.

In short, most lists of 'threatened' insects and other invertebrates tend to be either too short to be fully representative or too long for us to be able to cope with responsibly or comprehensively. Some level of selection or triage is almost inevitable in developing preliminary or idealistic 'lists' to 'practical conservation', with numerous species admitted as deserving and needing conservation neglected simply because our resources cannot cope with all of them. This problem is not peculiar to insects, of course, but the sheer numbers involved make the problem massive and very obvious. It follows that grounds for placing any insect species on such a list, and for later selecting it further for attention, must be sound, clearly understood, and responsible, as a foundation for committing effort and resources to its conservation based on credibility. It is also a step by which other species are likely to be deprived of any equivalent management. Many insects on such schedules are not necessarily threatened; and many threatened species are not necessarily listed. Referring to parasitoid Hymenoptera, Hochberg (2000) summarised the impracticability of species level conservation efforts by writing 'Their staggering diversity simply means that the focused conservation of, say, 1000 individual species over the next century may be numerically infinitesimal compared to the actual number of endangered species'.

This reality can appear overwhelming. Nevertheless, there is clear need to promote and undertake insect conservation on several levels, although many practitioners have emphasised the inadequacies of species level conservation as a mainstay procedure. However, and as noted earlier,

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'people relate to species', and insect species are undoubtedly important both in their own right and as vehicles through which the massive variety of insect ecology and its relationships to wider conservation of natural processes and ecosystems can be advertised and displayed.

It is thus important that conservation cases for the insect species we *do* select for individual conservation attention are presented on grounds that are convincing and objective, preferably measured against criteria that are accepted readily as suitable. Two main contexts of formally assessing conservation need may sometimes become confused: first, to provide an absolute statement of conservation status of the species, and, second, to rank that species for relative priority within the context of a local fauna or taxonomic group. In short, we need to determine (1) whether the insect species is threatened with extinction and, if so, how, and (2) the grounds for giving it priority for attention over other deserving threatened species. We are faced with both an absolute decision (is the insect threatened or not threatened?) and a relative decision for ranking (is it more or less 'deserving' than others found in the same higher taxon, biotope or area?). These determinations give our cases credibility. With that assured, each insect species selected for individual conservation attention can contribute to wider advocacy and understanding for the importance of invertebrate conservation, at any scale.

Criteria for assessing priority

Each of these contexts requires objective appraisal against some defined criterion/criteria, with the usual outcome being some form of advisory or legislative categorisation in the form of a list of threatened or protected species: broadly 'listing', ideally accompanied by assessment of priority or urgency of conservation need. In some cases, the criteria for categorising and listing insects are determined formally; in others they are a working guide. Table 1.1 exemplifies the variety of features that may be considered, in that case for European dragonflies (van Tol & Verdonk 1988). Formal criteria for listing insects differ substantially under various legislations, so that comparison of lists from different agencies and places and made at different times is difficult. Many of the assessment criteria are based on the IUCN categories of threat of extinction, historically mainly those promoted in 1994 but more recently revised (IUCN 2001), and such appraisals have become major drivers of assessing conservation status. However, many entomologists have found inadequacies and frustrations in trying to apply them to insects with confidence,

Table 1.1 *An example of a set of criteria used for ranking insect species in lists of threatened taxa: the parameters used for Odonata in Europe by van Tol and Verdonk (1988)*

	Likelihood of inclusion	
Parameter	Lower	Higher
Intraspecific variation	small	large
Species range	large	small
Position of Europe in species range	edge	centre
Species endemic to Europe	no	yes
Population density	high	low
Population trend: twentieth century	increase	decline
Trophic level of biotopes frequented	eutrophic	oligotrophic
Habitat range	eurytopic	stenotopic
Resilience to environmental changes	high	low
Dispersal power	high	low
Potential population growth	high	low
Ecological strategy	*r*-strategist	*K*-strategist
Conspicuousness	small	large
Effect of construction of artificial biotopes	high	small

and numerous modifications have been made in attempts to reduce the reliance on quantitative thresholds of extinction risk that are rarely, if ever, available for insects, and are commonly compounded by lack of knowledge of population structure. Clarke and Spier (2003) applied a form of analytical software (RAMAS Red ®: Akçakaya & Ferson 1999) to available population data for a variety of Australian invertebrates, but the considerable uncertainty involved led to polarisation between the categories of 'Data Deficient' and 'Critically Endangered'.

The IUCN criteria, displayed in Fig. 1.1, have central importance as an avenue to assessing conservation status, but include criteria that are difficult or impossible to apply to most insects. In particular, any data available for determining quantitative thresholds of population decline and likelihood of extinction involve considerable speculation, and usually cannot be employed with confidence for such poorly documented taxa. Nevertheless, some such categorisation reflecting urgency of need (so that, in the IUCN categories, 'Critically Endangered' ranks above 'Endangered' and this in turn ranks above 'Vulnerable' in a hierarchy of threat categories) is important in allocating priority on grounds of

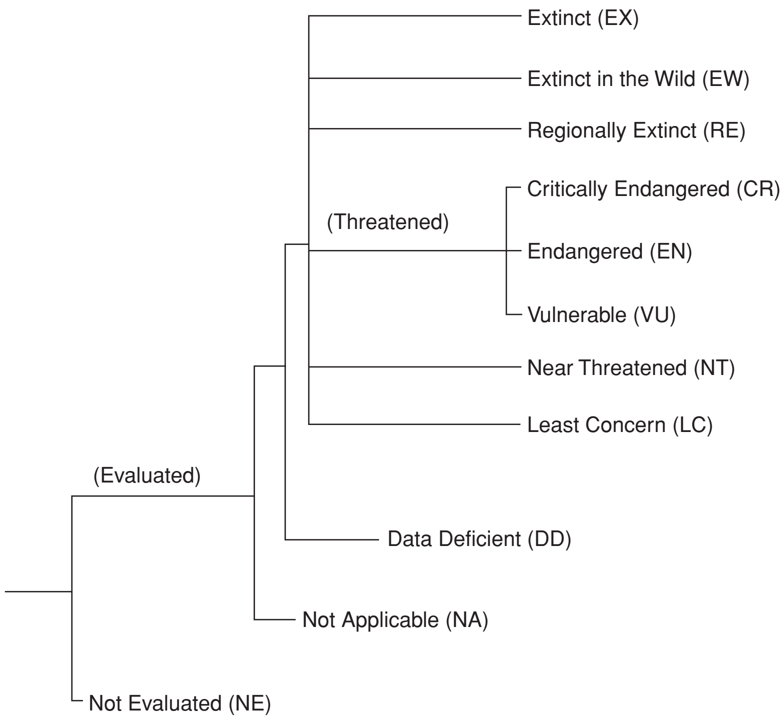

Fig. 1.1. Schematic representation of the IUCN Red List Categories (IUCN 2001). 'Threatened' includes the categories of 'Critically Endangered', 'Endangered' and 'Vulnerable'.

threat intensity. Guidelines to using the recent IUCN categories (IUCN 2003) note, as is commonly not acknowledged or appreciated elsewhere, that 'assessment of extinction risk' and 'setting conservation priority' are related but different processes. The former usually precedes the latter, which can also incorporate a variety of other considerations. Whatever the criteria used, the placing of an insect on any advisory or regulatory list of threatened or protected species must be a responsible action, with the grounds for doing so transparent and justifiable. Subsequent ranking for conservation attention is likely to involve a further round of triage, and neglect of the 'less worthy' species simply because they are ranked lower in a climate of limited support for action. At the least, including an insect species on any such list is likely to promote it for conservation attention over non-listed species, and may be a politically expedient action in indicating need for support.

Box 1.1 · *The IUCN categories of threat to species and the criteria used to designate these formally (after IUCN 2001)*

The following summary table emphasises the quantitative differences between the three categories of 'critically endangered' (CR), 'endangered' (E) and 'vulnerable' (Vu). Note that these data are rarely, if ever, available for insects, but the criteria serve to reflect the nature of differences between these designations of risk of extinction, which form the foundation of much categorisation of conservation status of species in legislation.

	Critically endangered	Endangered	Vulnerable
A *Declining population*			
Population declining at a rate of . . . using either	>80% in 10 years or 3 generations	>50% in 10 years or 3 generations	>20% in 10 years or 3 generations
1. Population reduction estimated, inferred or suspected in the past OR			
2. Population decline suspected or projected in the future, based on direct observation, an abundance index, decline of habitat, changes in exploitation, competitors, pathogens, etc.			
B *Small distribution*			
Either extent of occurrence . . .	<100 km^2	<5000 km^2	<20 000 km^2
OR			
Area of occupancy . . .	<10 km^2	<500 km^2	<2000 km^2
and 2 of the following 3:			
1. Either severely fragmented or known to exist at a number of locations			