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The neglect of parasitic Hymenoptera in insect conservation strategies: The British fauna as a prime example

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Abstract

Parasitic Hymenoptera, the major group of insects having the parasitoid life style, are extremely species rich and of wide significance in terrestrial ecosystems. Although the nature of their role with respect to species richness and stability in their host communities is unclear, the evidence that parasitoids can have a profound impact on host populations is incontestable. Because parasitic Hymenoptera are typically very specialised and occupy a high trophic level, species in this group are likely to be particularly vulnerable to local or even global extinction. That their particular conservation needs and extinction risks are rarely considered stems largely from our ignorance of them, both taxonomically and biologically. In Britain, parasitic Hymenoptera comprise about 25% (or perhaps significantly more) of the total insect fauna. The view is advanced that neglect consequent on the continuing poor knowledge of parasitic Hymenoptera in such an otherwise well-studied fauna is a serious conservation problem, undermining the rationality of various current conservation initiatives and analyses. Recommendations to redress this are made.

Introduction

Within a framework of general acceptance that the world's declining biodiversity requires conservation, a volume edited by LaSalle and Gauld (1993a) made a strong case for the recognition of Hymenoptera as a group that has a disproportionately large role in maintaining the diversity of other animals and plants. This results from the profound, and often highly specialised, interactions between Hymenoptera and other organisms, particularly plants and other insects, and is additional to their inherent contribution to biodiversity in being a large and ramified group. The argument then ran that, because choices in where or how to focus conservation effort have to be made, such keystone groups as Hymenoptera warrant particular recognition and attention. Evidence was also advanced that many groups of Hymenoptera are particularly sensitive to environmental disturbance, which makes their populations especially prone to extinction – the familiar correlate of specialisation.

It may be too bleak to say that LaSalle and Gauld's (1993a) volume has had no impact, but it is certainly true that its messages have permeated less far than they deserved in the continuing process of debate on conservation strategy and ensuing actions. Here we examine some issues concerning the conservation of parasitic Hymenoptera (by which we mean those having the parasitoid life style, *sensu* Godfray 1994), especially in relation to current strategies for insect conservation in Britain. This context provides the clearest examples, as the British insect fauna is the best known in the world and conservation initiatives have reached perhaps their highest level of practical expression in Britain. Many of our points nonetheless have general application and we draw also on some examples from the world fauna.

Until recently, the neglect of parasitic Hymenoptera could be explained by their being particularly difficult to engage: not only was their taxonomy daunting but also there was a lack of authoritative introductory literature on their biology. However, over the past 15 years a number of good outline texts have been published, overviewing with varying emphasis the natural history and systematics of Hymenoptera in general or parasitoids in particular, in some cases with a somewhat narrower focus and/or special emphasis on the British fauna (e.g. Waage & Greathead 1986; Gauld & Bolton 1988; Shaw & Huddleston 1991; Goulet & Huber 1993; Achterberg 1993; Godfray 1994; Hawkins & Sheehan 1994; Hanson & Gauld 1995; Quicke 1997). Although many groups found in Britain remain intractable through not being covered by modern keys, some major ones have been newly monographed (Graham 1987; 1991; Graham & Gijswijt 1998) and generally the species-level identification literature (summarised by Noyes *et al.* in Barnard (1999): 196–319) has improved, especially in quality, over the last few decades. Major cataloguing projects, especially those covering world Chalcidoidea (Noyes 1998) and world Ichneumonidae (Yu & Horstmann 1997), but also such works as Pagliano & Scaramozzino (1990); Olmi (1984; 1989); Gibson (1995); and Grissell (1995) have made vast quantities of information accessible, and various forms of practical advice have been offered (e.g. Noyes 1982; Shaw 1997). Taken together, these works provide well for a better understanding of parasitic Hymenoptera: the basis is there for people now to start to engage them with reasonable confidence and, not least, with some idea of what and how they might contribute to further our knowledge. While most of this effort was made largely to 'open up' Hymenoptera so as to promote further study of what is by any standards a fascinating group, it seems not unreasonable for hymenopterists, having produced a foundation, to ask now that the science of conservation biology embraces parasitoids more widely and seriously than hitherto.

Importance of parasitic Hymenoptera

There are many possible facets of the vague term 'importance', but here we will discuss just three: the relative size of the fauna; the dynamic role of the group in their host communities; and their more specific value to humans.

Size and study of the fauna

Though troublesome, and undermined by an unknown level of undetected synonymy, it is possible to arrive at rough figures comparing the global numbers of described species in different groups of insects, in relation to a total of described insects (estimated at about 950,000: Hammond 1992). Examples are: over 115,000 (Gaston 1993) or 130,000 (Hammond 1992; 1995) Hymenoptera; at least 420,000 Coleoptera (P.M. Hammond, personal communication updating Hammond (1992) based on detailed catalogue counts); and 18–20,000 butterflies (Papilionoidea + Hesperioidea) (R.I. Vane-Wright, personal communication). However, such figures are indicative largely of the collecting methods, biases and industry of past taxonomists. Allowing for the existence of 5–10 million species of insects (Gaston 1991), which appears to be a robust estimate (Ødegaard 2000), it is apparent firstly that only around 10–20% of all insects have been described, and secondly that the percentage of species in different insect groups so treated varies hugely. Using the above groups as examples, it is estimated that 90% of butterflies species likely to be recognised in the next 50 years are already described (R.I. Vane-Wright, personal communication) and that the described Coleoptera represent about 20% of the actual fauna (P.M. Hammond, personal communication). For Hymenoptera – and especially for parasitic Hymenoptera – estimates are more vague. Hammond (1992) reached a figure of 7.7% for Hymenoptera overall, but levels as low as 5% have been estimated for some arguably typical parasitoid groups (e.g. Noyes (2000) for Chalcidoidea). These are 'morphospecies' estimates: the situation for parasitic Hymenoptera in particular is further complicated by the existence of species complexes consisting of biologically and genetically distinct entities that are scarcely or not at all separable morphologically.

As an example of how parasitic Hymenoptera can compare with better studied insect groups in a particular region, 452 (82%) of the 551 species treated so far by Gauld (1991; 1997; 2000) in his series 'Ichneumonidae of Costa Rica' are described as new to science, despite the fact that the groups covered include many of the largest and most distinctive species, not just of Ichneumonidae but of parasitic Hymenoptera as a whole. In contrast, the two parts so far published of 'The Butterflies of Costa Rica' (DeVries 1987; 1997) include 772 species-group taxa with confirmed records from the country, of which only 11 species and six

Table 1. Current expression of special interest in the four largest orders of insects by members of the British Entomological and Natural History Society (February 2000 membership list), in relation to the approximate size of the British fauna.

	Approximate number of British species	Number of devotees (% of membership)
Hymenoptera	7000	63 (7%)
Diptera	6700	96 (11%)
Coleoptera	4000	132 (16%)
Lepidoptera	2500	482 (57%)

subspecies (total 2.2%) had been recognised as new since 1976 (the start date of the project). Allowing for this kind of disparity, Hymenoptera may in fact be the largest order of insects in the world (LaSalle & Gauld 1993b; Grissell 2000) and, despite the ecological dominance of aculeate Hymenoptera in many tropical ecosystems, most Hymenoptera are parasitoids.

Certainly it is typical for Hymenoptera to constitute the largest group of insects in relatively well-studied temperate areas (Gaston 1991). In Britain, Hymenoptera, with about 7000 recorded species (Noyes *et al.* in Barnard (1999): 196), is just ahead of Diptera (about 6700: Chandler 1998) and well ahead of Coleoptera (about 4000: Pope 1977) in size. These relative numbers of recorded species have arisen despite the consistent bias of interest towards the large insect orders other than Hymenoptera shown by British entomologists over time (exemplified in Table 1). But even the figures in Table 1 paint too rosy a picture: the 6000 or so currently recorded parasitic Hymenoptera that comprise roughly a quarter of the entire British insect fauna (the quarter in which most British entomologists probably could not reliably and confidently recognise a single species) are the focus of interest for only a small fraction of the active British hymenopterists, almost all field and alpha-taxonomic activity on British parasitic Hymenoptera depending on scarcely more than half a dozen individuals. In contrast to low interest in parasitic Hymenoptera, Britain boasts a highly effective field work based society – the Bees, Wasps and Ants Recording Society (BWARS), whose 210 British members investigate and monitor the British Aculeate fauna (ca. 500 species) in a most enviably concerted way. A good illustration of the effect of dominance of interest in, and knowledge of, Aculeata over parasitic Hymenoptera on a somewhat broader front is seen in two Council of Europe booklets on the conservation status and needs of European Hymenoptera. One (Gauld *et al.* 1990) covers Hymenoptera as a whole and – despite being authored by two parasitic Hymenoptera specialists and a more general conservationist – it contains almost no species-level information about parasitic Hymenoptera at all. This is in sharp contrast with the other (Day 1991) dedicated to the Aculeata in which – despite emphasising the fragmentary nature of knowledge – the author is able to draw on several specific examples and to append a list of 860 species that are Red Listed by one or more countries in Europe.

Role in ecosystems

The extent to which communities (or ultimately ecosystems) are organised or stabilised by interactions between their component species is a central issue in community ecology. An important aspect of this is ascertaining how prey/resource diversity is affected by natural enemies/consumers. Most relevant studies, be they empirical or theoretical, have, however, been based on naturally simple or artificially simplified systems.

Semi-quantitative empirical studies on host–parasitoid communities (e.g. Askew 1961; Force 1974; Askew & Shaw 1974; 1979; 1986; Shaw & Askew 1976; Hawkins & Goeden 1984) and, more recently, fully quantitative food web studies (Memmott *et al.* 1994; Müller *et al.* 1999; Rott & Godfray 2000) have shown that parasitoids tend to be involved in extremely complex interactions at the community level. Models designed to elucidate the effects of parasitoids on host populations have, however, necessarily been constructed in much simpler terms, and considerable challenges lie ahead in the development and analysis of more realistic models (Hochberg & Hawkins 1993; 1994; Wilson *et al.* 1996).

Both empirical (Tscharntke 1992; Price 1994) and theoretical (Hochberg & Hawkins 1993; 1994) studies show that parasitoids are able to partition the niche space of their host communities such that parasitoids can persist at high species-richness. That parasitoids promote diversity and stability within insect communities at the second trophic level (and, through that, similarly influence plant communities) has been widely asserted (Freeland & Boulton 1992; LaSalle & Gauld 1992; 1993b), although it has yet to be substantiated. That parasitoids have an impact on host populations is incontestable by the many instances of invasive phytophagous insects that are unchecked by their natural enemies expanding their populations explosively and, indeed, by the success in reversing such situations that has regularly been seen in classical biological pest control. It is unfortunate that there is no consensus as to whether under natural conditions the impact of parasitoids on their host populations and the surrounding community tends to lead to more or less stable systems (Hochberg 1996).

Equally frustrating is the lack of information on the role of parasitoids in host coexistence in natural systems. However, preliminary models (e.g. Holt & Lawton 1993; 1994; Wilson *et al.* 1996; Hastings & Godfray 1999) suggest that a parasitoid can have either positive or negative effects on the species richness of its host community, depending on its host range and behaviour. Thus there can be no generalisation of role: parasitoids can diminish competition between host species, promoting their coexistence, or they can reinforce competitive processes between their hosts, accelerating the exclusion of species. Most simply, a single host species with a tendency to become dominant might be prevented from doing so by the presence of its specialised parasitoid(s), or an array of hosts each having host-specific parasitoids might all experience reduced population sizes such that competitive exclusion thresholds between the hosts are never reached. On the other hand, a polyphagous parasitoid, indiscriminately using a range of hosts, should drive all but the most fecund to extinction (Holt & Lawton 1993), whereas parasitoids employing past experience (Hastings & Godfray 1999) could in theory have neutral or positive effects on host coexistence.

Cohen (1990) has argued that quantitative food webs can be used to assess the extent of apparent competition (Holt 1970; Holt & Lawton 1993; 1994) in communities, and recent effort to construct quantitative food webs for host–parasitoid communities (Memmot *et al.* 1994; Müller *et al.* 1999; Rott & Godfray 2000) promises eventually to allow empirical studies on host–parasitoid communities to extend and refine more general ecological theory, as well as to answer questions such as 'to what extent may parasitoids stabilise and/or promote diversity in their host communities?' rather better than we can now.

Value to humankind

It would be unrealistic to try to project the kind of flagship values onto parasitic wasps that have so successfully been applied to some vertebrates and – occasionally – other insects as 'honorary birds', leaving little scope to fan emotions to assist the conservation of parasitic wasps. Consequently their objective importance – surely the real terms – must underlie their claim for nature conservation attention. Given the contributory role (even if uncertain in extent) of many parasitic wasps in maintaining balanced, species-rich communities, it is rather extraordinary that these very real terms are so poorly acknowledged. Humankind has a large and costly experience of accidentally introduced agricultural pests and much is made of the more general threats to community or even ecosystem stability from invasive species of plants and animals when their rate of increase goes unchecked by natural enemies. If the successes of many classical biological control programs (cf. Huffaker & Messenger 1976; DeBach & Rosen 1991) are representative of the impacts of parasitoids in general, then there is good reason to suspect that many indigenous insect populations could be released from control and attain pest status if their parasitic wasps were to be removed (Mills 2000). However, our ability to understand and express general predictions of such scenarios is extremely limited (Hochberg 1996; Hassell *et al.* 1998). Even when large changes are observed, possible keystone species and cascade effects are even more difficult to elucidate in nature, particularly *post hoc* when there are no prior data.

Actual economic value accrues to the considerable number of species that have been found to be important for their impact on pests of agroecosystems, and most documentation relates to deliberate manipulations for biological control. Mills (1994) estimates that globally 38% of 1450 parasitoid introductions have resulted in establishment, and that 44% of 551 established parasitoids gave some degree of pest control – an overall success rate of 17%. In a small number of cases, whereby relatively simple inoculative releases have achieved both dramatic and lasting control for crucial crops, the actions of parasitoids have been directly equated with enormous economic benefit to cost ratios (e.g. Norgaard 1988a,b) but in most successful programmes their effects are less spectacular, and direct values are difficult to estimate (Mills 2000).

The direct roles and benefits of manipulated parasitic wasps for pest control are the commonly accepted reasons for their value. It is our view that future attention should be turned to the somewhat less obvious, but surely economically valuable, influences of hymenopterous parasitoids in the ecosystem at large.

Threats to parasitic Hymenoptera

The main threats to parasitic Hymenoptera arise from two quite different sets of problems they face: they are intrinsically extinction prone because of their specialisation and high trophic level, and extrinsically vulnerable owing to our disregard of them.

Intrinsic threats

Parasitoid populations – as those of any organism – will be endangered when their numbers experience low levels such that combinations of chance events could result in no survivors. Assessing endangerment requires the quantification of risks of chance events and probabilities of extinction given the occurrence of these chance events (Lipton *et al.* 1996). Three characteristics of parasitoids may make them particularly vulnerable to local extinctions. First, because of their haplo-diploid reproductive system and the single-locus sex determination exhibited by many species (though not all), inbreeding can lead to male-biased sex ratios at low densities, putting populations into danger of local extinction. This is an additional problem to the possible failure to find mates modelled by Hopper and Roush (1993). Second, many parasitic wasps are distinguished from most other predatory organisms by their relatively high degree of resource (i.e. host) specificity (Godfray 1994). This means that many species cannot fall back on alternative hosts when populations of their normal host species are themselves reduced to low numbers. Therefore parasitoids often carry the additional stochastic burden of variation in the populations of their hosts. And third, it has only recently become appreciated that adult parasitoid behaviour can depend strongly on climatic conditions (Weisser & Hassell 1997), with the result that already vulnerable populations can rather easily be put over the brink of extinction simply by experiencing a string of bad weather conditions at crucial times.

Global climatic change

Changes in the atmosphere resulting in, for example, increased carbon dioxide levels and temperatures are expected to have knock-on effects via changes in primary productivity and plant species composition, which will, in turn, affect herbivores and their parasitoids (Kareiva *et al.* 1993; Hassell *et al.* 1993; Davis *et al.* 1998). Thus, in addition to having to adapt to the direct abiotic influences of climate change *per se*, parasitoids will inevitably be extremely sensitive to changes at the lower trophic level – the more specialised they are, the more so – because those parasitoids that are not fairly narrow taxon specialists are mostly at least rather profound niche specialists. Ostensibly, species which will fare best will have one or more of the following attributes to enable them to adapt to changing conditions: (i) high vagility, (ii) widespread hosts, and (iii) a range of host species. Beyond that there is no simple way of predicting outcomes: climatic influences on host–parasitoid systems can sometimes be profound (e.g. Porter 1983), but very few case studies exist.

Extrinsic threats

Above we have touched on factors that bear on parasitoids through their life history properties as 'intrinsic threats'. But some problems that parasitic wasps face are most usefully viewed as extrinsic to population biology.

In particular, the severe lack of knowledge of parasitic Hymenoptera poses a direct threat to them, both because they are easily ignored – indeed, some might argue that until very recently it was extremely difficult for the general entomologist, however well intentioned, to do otherwise! – and because their needs are excluded from approaches towards insect conservation that come to be dictated by the attributes of better-understood groups. This last point will be returned to later, but our general ignorance of the British parasitic Hymenoptera fauna in particular is worth some elaboration and rough quantification.

The lack of knowledge operates at two levels. In the first place we do not know very well which species occur in the British fauna, for the two reasons that insufficient collecting has been done and, in a western Palaearctic context, far too many groups have not received adequate alpha-taxonomic and revisionary attention. In the second place, even when species have been successfully recognised as being components of the British fauna, we know very little about what they are actually doing: for most species there is no biological information at all, while for the majority of others the supposed information that has been published is so full of error that the impression of knowledge is extremely misleading (Shaw 1994; Noyes 1994).

To take first the lack of faunistic knowledge, it is obvious that some groups will be far better worked than others, making reliable quantification well nigh impossible – even by extrapolation. The whole of the Platygastroidea, for example, remains more or less completely unassessed by modern taxonomists with large collections before them, as do significant parts of the Ichneumonoidea. Perhaps traditionally the best known part of the Ichneumonidae (itself the largest family, with over 2000 British species) is the subfamily Pimplinae, yet in a recent review of the British species (including those now placed in different subfamilies)

Fitton *et al.* (1988) added 16 and deleted seven species to give a total of 108, a 20% difference from the previous checklist (Fitton *et al.* 1978), discounting mere nomenclatural changes. Since then, a further four species have been recognised in Britain. In another ichneumonoid group, the somewhat less well-studied Cryptinae, the percentage change (almost entirely additions) largely resulting from an analysis of just one big institutional collection is about 33% in the groups reviewed so far (Schwarz & Shaw 1998; 1999; 2000). Figures for previously somewhat intractable groups of Chalcidoidea that have recently been monographed are even more extreme: 85 (41.7%) of the 204 species of British Tetrastichinae (Eulophidae) and 32 (42.7%) of the 75 species of British *Torymus* (Torymidae) were newly recorded from Britain (Graham 1987; 1991; Graham & Gijswijt 1998) as judged from their absence from the last British checklist (Fitton *et al.* 1978) and, allowing also for respectively 23 and nine deletions through synonymy or misidentification, current knowledge differs by 47.6% and 48.8% from the 1978 checklist of these groups. Other examples have been given elsewhere (Shaw 1996), and it seems likely that across parasitic Hymenoptera as a whole our knowledge of what is in the British fauna may be about 30–40% incorrect, or possibly even more. This is a level of ignorance very much higher than that supposed by Gaston (1993), and it strongly suggests that parasitic Hymenoptera will eventually turn out to be an even larger fraction of the total British insect fauna than the quarter that is presently documented.

The second great impediment is our poor knowledge, as biological entities, of the species that have in fact been recognised under the correct names. What interpretation can be put on a list of parasitic wasps collected at a given site? Almost none, even by a parasitic hymenopterist. Yet even quite a short list of most other insects would instantly imply information regarding the kind of habitat, its vegetation or other niche features, and – significantly – allow fairly accurate judgement on its history and probable richness to be made. Other insects are in a frame in which parasitic Hymenoptera are not, because parasitic wasps, with a low proportion of exceptions, are mostly just names; even if they have been reared, little circumstance is usually recorded beyond the name of the supposed host, and certainly the necessary process of evaluating host ranges, voltinism and the possibility of complex alternations of hosts, and other habitat requirements, on a species by species basis is under-developed in the extreme. Even at the simplest level of knowledge of host ranges, our extremely limited understanding is itself poorly understood.

This front of ignorance is far more encompassing than for any other major group of comparably complex terrestrial organisms. Because our approaches towards conservation of the environment and the biodiversity it contains is increasingly knowledge-based, wide-scale ignorance of particular groups will necessarily be a threat to them, as conservation effort – and especially assessment of the effect of actions – becomes tailored towards other groups that (inevitably) will not have quite the same requirements. Our ignorance of parasitic Hymenoptera thus places them under a real and specific threat by default within a framework of active conservation effort, in addition to the more direct bleeding-away of our parasitic Hymenoptera fauna that must – without any real doubt, given their high trophic level and characterising levels of specialisation and dependence – be happening at a rate that would surely be considered alarming if only it could be noticed.

This lack of specific knowledge of what has been lost – and, even more to the point, what is about to be lost – in Britain contrasts with unequivocal evidence of major losses identified in Belgium, a country with land-use changes and practices broadly similar to those of Britain. Therion (1976; 1981), reporting on the Ichneumonidae: Ichneumoninae fauna of Belgium, found that of the 122 species formerly present 32 (26%) could not be found in a period of intensive collecting between 1950 and 1974/1979, with at least 30 further species (25%) showing major declines. A parallel study on Ichneumonidae: Diplazontinae (Therion 1979) showed much less decline, presumably because in this case the abundance of the host resource (predatory Syrphidae, with many species common in disturbed habitats) had reduced less than the Lepidoptera serving as hosts of Ichneumoninae. As far as we are aware no studies comparable with Therion's are under way at present, in Britain or elsewhere.

In addition to underlying the weakness of not being able to point to specific cases of extinction in Britain, ignorance inhibits the effective promotion of parasitic Hymenoptera as flagship species. It is good that, for example, *Chalcis sispes* (Linnaeus) is featured on the cover of Fowles (1994), but the fact that we do not have a clear idea of its current distribution in Britain, which is certainly wider than stated, undermines its promotion in this way. Using parasitic Hymenoptera as flagship species might be challenging for other reasons, of course, given a public whose squeamishness tends to outweigh its sense of wonder, and the need for a better 'spin' for parasitoids is certainly real, if hard to address. If only there were enough collectors of parasitic Hymenoptera to fuel a debate about the possibly damaging effects of over-collecting!

Conservation aims

'What should we try to conserve?' is a fair question, but one that is as hard to answer for parasitic wasps as it is for other groups of organisms. The alpha-diversity of parasitic Hymenoptera, because of their characteristics, is likely to impact the alpha-diversity of other organisms, and it comprises a high proportion of unique and highly specialised life histories. Thus maximising the retention of alpha-diversity may be more appropriate as an aim than trying to ensure that the widest phylogenetic spread is conserved through targeting particular taxonomically isolated organisms. In addition, however, species-level conservation effort towards insects in other groups should certainly carry conservation effort towards any specialised parasitoids along with it. Thus one idealistic aim might be to try to ensure that the alpha-diversity of parasitic Hymenoptera on land under management for nature conservation (however vaguely) is not lost at a faster rate than the mean loss of alpha-diversity at that site – a tough remit, of course, for specialised organisms operating at high trophic levels, especially as we know so little about them, but surely a challenge for those concerned with conservation policy to consider. Indeed, how can this challenge be avoided? If, as we do, we have to accept a general land management strategy of conservation by proxy – hoping, that is, that getting it right for one set of organisms will also get it about as right for most others within the habitat frame – it would seem only logical that the analysis and monitoring criteria should be pitched at the highest trophic level at which substantial organism-dependent specialisation exists, not (as at present) at trophic levels below that. Without that focus, or at least an acknowledgement of merit for such an approach, attempts to audit progress towards conserving biodiversity will ring hollow. If nature conservation is not working for parasitic Hymenoptera, then nature conservation is not working as it should.

Parasitic wasps in relation to current thrusts of insect conservation in Britain

Much neglect has been alluded to in the foregoing sections, but it needs a little more focus. In Britain, thanks partly to recent legislation and initiatives surrounding the Biodiversity Action Plan, the conservation effort most relevant to insects has now come to focus firstly on habitat conservation and restoration, including improved awareness of the importance and potential of land under management principally for other purposes (e.g. forestry), and secondly on the evaluation and selection of particular target species, on which considerable conservation effort is then expended. It might be hoped that the first of these two approaches is likely to be appropriate for parasitic Hymenoptera, and may even cater for them successfully provided awareness and allowance of them is built into evaluation systems. Indeed for most parts of the world (and the great majority of circumstances), a focus on habitat conservation is the best practical approach. However, Britain also has a high-profile thrust for species-level insect conservation that, rather remarkably, has extended to some taxa with which the public are almost wholly unfamiliar. In general terms it has to be a concern that this second approach rather strongly excludes parasitic Hymenoptera. This is principally because it is a knowledge-based approach, building profiles of rare species through Red Data Books (Shirt 1987) and species-level reviews of various other kinds. The problem with this for parasitic Hymenoptera is that it can target only those species that are well enough known to be assessable, and practitioners appear not always to understand – or at any rate do not sufficiently acknowledge – the limitations of such analyses. The brief statement in the Insect Red Data Book (Shaw in Shirt (1987): 257–8) on parasitic wasps is to the effect that they must be considered among the most threatened of British insects, but that attempting a listing of endangered species would be quite hopeless in view of our poor knowledge. The message in this has, however, generally been as totally ignored as the parasitic wasps themselves. Sometimes this failing has further repercussions when Red Data Book listings are used in analyses on a proxy basis. For example, May *et al.* (1995) estimated a 1% extinction rate per century in the British insect fauna, and Hambler and Speight (1996) concluded that the rate for British non-marine invertebrates was about 1% per century and was unlikely to exceed 5%, in both cases drawing on data from the Red Data Book for British insects. Neither attempted to correct for intrinsically vulnerable, large, and unlisted groups such as parasitic wasps or acknowledged a possible weakness in their analyses in respect of them. Workers such as Thirion (1976; 1981) would surely disagree with such low estimates. Indeed, so far out of most entomologists' consciousness are parasitic wasps that Young and Rotheray (1997), in choosing a group of insects to cite as virtually un-worked in Scotland, gave the small order Neuroptera as their example with no mention of the huge and far less known parasitic Hymenoptera. Overall, our concern is that a focus on Red Data Book species (and other listings), whether for action or for analysis, is not as appropriate as it is generally implied to be, because ignoring parasitic Hymenoptera as a very large special case fails to bring a balanced approach to our insect biodiversity.

Some recommendations

Nothing would do as much for the conservation of parasitic Hymenoptera as the provision of properly funded, career-length posts for alpha-taxonomists in major collection-building research institutions. If positions were applied according to lacunae in knowledge, such an initiative could cover Entomology as a whole, at least in a British context, without much fear that the first several posts would not all be filled by parasitic hymenopterists. This sort of development would only be conceivable if alpha-taxonomy were to be accorded the higher scientific status it deserves: such recognition (really a re-admission) would result from a re-alignment of our current values of scientific endeavour from novelty in the processes of systematics to its most useful products. A lucid exposition of the plight of traditional taxonomy in respect to newer aspects of systematics research is given by Lee (2000). Basic science does not mean base science, despite the unfortunate widespread dismissal of alpha-taxonomy as such.

In the meantime, there are several ways in which the British insect conservation movement and others (including taxonomists) can take better note – and, indeed, make better use – of parasitic Hymenoptera. In no particular order:

1. Taxonomists working on parasitic Hymenoptera would contribute enormously to a better knowledge of host ranges if they firstly refrained from quoting host records from literature without proper bibliographic citation, secondly made it clear what reared material they have themselves examined, and thirdly dealt with the citation of host data in a strictly quantitative way based on host mortalities (i.e. number of rearings, but counting gregarious broods as one).

2. The understanding that a host-specific parasitoid will necessarily be rarer and more vulnerable than its host needs more recognition. Practical, field-based conservation ecologists doing autecological research should make a determined effort to investigate whether or not the target species has parasitoids, and if so to establish their identity and find out the extent to which they are specialists. Further, specimens should be preserved and deposited in repositories that are cited in their publications and reports. This effort should extend to inclusion of specialised parasitoids in Species Action Plans (to their credit, Butterfly Conservation have started to do this when knowledge exists).

3. Practical conservation ecologists involved in site evaluation and survey work should, when appropriate, attempt to use the higher trophic level represented by parasitic Hymenoptera as a survey tool for conservation purposes. There are many situations in which the presence of a species judged notable in conservation terms could be given an even higher score if its population at that site is supporting a dependent parasitoid. Whether or not it would be valuable to assess parasitoid complexes of easily sampled (and generally present) hosts, such as leaf-miners on deciduous trees, is also worth debating.

4. Theoretical and strategic conservation ecologists should always consider and openly acknowledge the problem posed by the lack of knowledge of such a large and extremely specialised group as the parasitic Hymenoptera. In particular, it must not be presented as sufficient to base analyses and actions on Red Data Book species, as they are not an effective proxy for parasitic Hymenoptera.

5. There is a profound need for biodiversity education which, of course, extends far beyond parasitic Hymenoptera. While the public may hold reasonably accurate perceptions that tropical ecosystems are teeming with unrecognised species, the average person in Britain is unaware that knowledge of the British biota – widely acknowledged as the best studied in the world – is also very limited. Because of the relatively high level of ignorance surrounding them, parasitic wasps could perhaps be given a key illustrative role in bringing awareness of the need for more knowledge to a wider public. If understanding precedes concern, and if concern precedes action, then this should help research on parasitic wasps (and also other poorly known organisms) to be funded, ultimately creating the knowledge that is a prerequisite for effective conservation action.

6. Parasitic hymenopterists should try to see a way round the problems preventing the successful launch of a recording scheme for a particular group that is easily recognised, contains sufficiently abundant species, and for which a reliable and user-friendly key can be provided. This is a formidable challenge, but it is common experience that recording schemes have had huge

success in promoting interest in particular groups of insects, and it would probably be the most valuable contribution that could be made by the existing practitioners. Attention should also be given to providing reference collections at regional centres to support such a scheme.

7. Ideally, land managers involved in conservation should be able to set – and monitor – targets that aim to conserve the trophic level occupied by parasitic Hymenoptera as effectively as lower levels. The performance indicator would be not to lose parasitic Hymenoptera at a rate higher than that of other terrestrial holometabolous insects. We should at least recognise this as something to aim at.

The latter sensible ideal takes us back, of course, to the overriding need to produce the identification literature necessary to conduct surveys, and that will only come if scientists are put into career-length posts and valued for producing these, rather than other, products of systematics research. Unless at least some of these measures are adopted, much of the most specialised 25% of the British insect fauna, which is arguably the most interesting in its biology and probably the most stabilising in its impact on biodiversity as a whole, will simply slip away unnoticed.

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