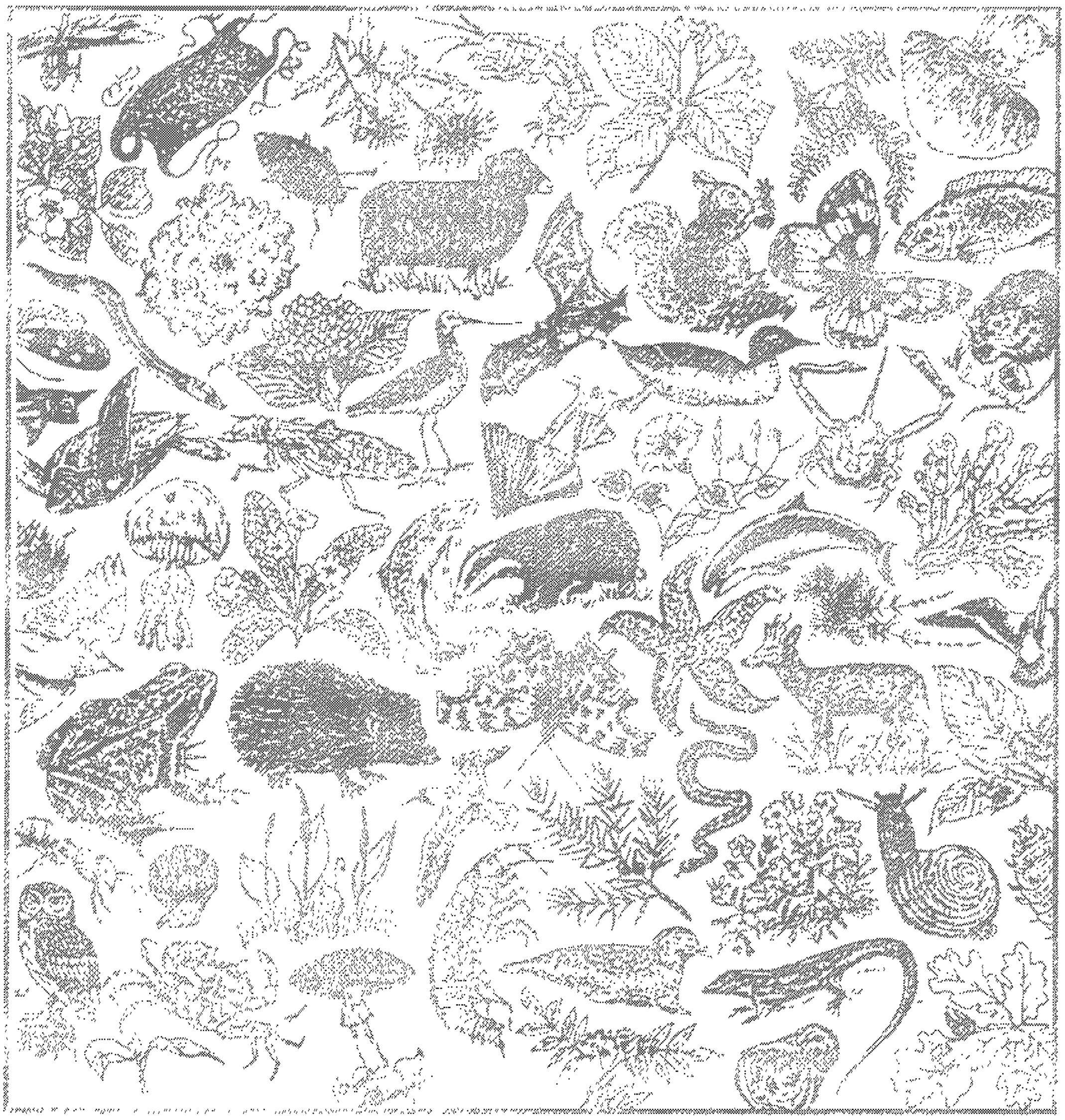
ENGLISH NATURE

Brownfield: red data

The values artificial habitats have for uncommon invertebrates

No. 273 - English Nature Research Reports



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English Nature research Reports

No. 273
Brownfield: red data
The values artificial habitats have for uncommon invertebrates

C.W.D. Gibson
Bioscan (UK) Limited
Staidingford House
Cave Street
Oxford OX4 1BA

Contract No. FIN/7.4/97-8

ISSN 0967-876X

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1 SUMMARY

1.1 This report reviews the state of knowledge on the invertebrate fauna of artificial habitats, concentrating on those in and around urban areas. Particular attention is paid to the status and likely origin of species found in such situations. Recommendations are then made concerning conservation of this fauna and for rectifying key gaps in knowledge.

1.2 Artificial habitats can support a diverse fauna and, between them, a high proportion of Britain's nationally scarce and rare species. Further, the current estimate of 12-15% of Britain's scarce and rare species found in these habitats is known to be an underestimate because each new data set examined adds new species records.

1.3 Not all species of conservation importance are equally likely to be found in artificial habitats. The typical coloniser is on the edge of its global range (south restricted), naturally occurs in more open lowland habitats and is nationally scarce rather than rare. Colonisation is also biased taxonomically, for example few rare Diptera but many rare aculeate Hymenoptera have appeared in artificial habitats. These biases are likely to be intercorrelated.

1.4 There are important gaps in knowledge of the fauna and of sites and in mechanisms for conservation. An additional layer to Phase 1 Habitat survey target notes is suggested and presented in draft to help remedy the former and concentrate the work of skilled recorders efficiently.

1.5 Some of the best sites are afforded statutory protection. This is a good base for conservation but not adequate by itself. There is a need for imaginative solutions to encourage derelict land to be allowed to develop good habitats while maintaining the cycle and spatial relations of its production and renewal. There is also scope for more sympathetic management of urban green space on all scales.

2 INTRODUCTION

2.1 Scope

This report arises from a commission to Bioscan from English Nature to review the state of knowledge about invertebrate communities associated with habitats fundamentally altered by man and often located in and around urban areas. They are variously referred to as "peri-urban" (around the urban area), "post-industrial" or "ruderal" communities but the single most important factor in common is that they are associated with artificial habitats, concentrating on the non-agricultural portion of Ratcliffe's (1977) "artificial ecosystems". In spite of their artificial nature, it has been repeatedly suggested in Britain and elsewhere that examples of such habitats can be important for nature conservation because they support a range of otherwise scarce, rare and/or specialised invertebrate species.

The need for the study arose from Britain's commitments to the conservation of biodiversity, in part to the inclusion of "urban" habitats as a Broad Habitat in the UK Biodiversity Action Plan (Biodiversity Steering Group 1995). In addition, it is possible that some artificial habitats may support important species (locally, nationally or internationally) which are more commonly regarded as members of semi-natural ecological communities.

The purpose of this report is to review the extent of current knowledge on these invertebrate communities of artificial habitats, attempt to identify and define the nature conservation interest of important sites, and to suggest ways forward for the gathering of key missing information and for possible conservation priorities.

The main concern of the review is towards the potential nature conservation interest of these artificial habitats for their own sake and away from two other frequently stated goals of nature conservation around intensive human activity, i.e. the preservation or survival of natural or semi-natural habitats within an urban setting and the "restoration" of more natural conditions on "derelict" land. Although studies directed at these latter goals may give insights which help with the goal desired here, they address fundamentally different problems. Indeed the restoration of derelict land may even be detrimental to conservation interest already there. The purpose of this report is to define what the invertebrate component of that interest is and so help in defining priorities for the treatment of apparently derelict land.

2.2 State of knowledge about communities

In terms of ecological functioning, very little is known about the invertebrate communities of artificial habitats. This is a common problem in ecology, simply because the amount of experimental and modelling work, and the time needed to understanding community functioning properly, is prohibitive (Paine 1988). So far, with a very few exceptions, the theoretical progress in community ecology far outstrips the understanding of how real communities work.

In part this is because of the past concentration in artificial habitats on goals for restoration which are very different from the observed habitats in artificial sites. Despite acknowledgement of the potential of artificial sites, their function (as opposed to merely describing their flora and fauna) has often been studied from a point of view which regards them as an impoverished version of some other, more desired system (e.g. Weigmann 1984, 1986). This is indeed true in that the soil processes fundamental to more mature systems are relatively undeveloped (e.g. Hollis 1992, Kühnelt 1986, Weigmann 1984). Nevertheless it fails to provide an understanding of the mechanisms which generate and maintain a high diversity of invertebrates in some artificial sites, which is now becoming more widely recognised (Kratochwil & Klatt 1989, Plant & Harvey 1997, Schmidtz 1996).

The studies which have been done have therefore been inevitably limited to experimental small components of communities such as individual guilds, or to observational and short-term studies of wider taxonomic components. Since the invertebrate component of ecological communities is usually dominated by species which have only one generation a year, the common three-year term of ecological studies is too short to gain the understanding of system dynamics necessary for community structure.

In effect, one is limited to comparative observations on patterns in communities. These must be treated with a great deal of caution before extrapolating to community function. However, the following observations on "sequencing limits" to colonisation may be of importance in understanding invertebrate communities in artificial habitats.

- Developing a trophic structure takes time. This (Sterling et al 1992) is at least in part independent of vegetation succession, which is only one of the steps in the following "sequence constraint".

- No specialist herbivore can colonise unless it has a suitable foodplant. This may be a "new" foodplant such as the mullein moth *Cucullia verbasci* on buddleia and the brown argus butterfly *Aricia agestis* on annual Geraniaceae.

- No parasitoid, predator, kleptoparasite or obligate commensal can colonise until it has a suitable host, prey or associate. This particular pattern has been used by Archer (1995) to help "calibrate" sites, i.e. its truth is assumed and sites are deemed better if they have more kleptoparasitic species.

- No hyperparasite can colonise until it likewise has a suitable host.

- Any invertebrate may have more than one food requirement during its lifetime, and each food source must be present at the right place and time. The commonest is where adult insects such as hoverflies, Lepidoptera and aculeate Hymenoptera require nectar plants differing from the larval food source.

- Each and all trophic levels may need additional habitat structures which take time to develop over and above the appearance of suitable food, such as aculeate Hymenoptera requiring dead wood within which to nest.

- Artificial habitats can support a high diversity of species. This pattern has mainly been associated with supposedly "early-successional" status of artificial habitats, with the diversity of habitat components, or both. A peculiar characteristic of many artificial habitats such as quarries or abandoned industrial sites is that they have small-scale diversity between areas which can support no plants, those which allow herbaceous plants to grow and those which have enough suitable substrate to support larger plants. This pattern can be persistent. It is important because it can allow a diversity of habitat structures and plant species to remain in the longer term without management by grazing or cutting. The latter is essential to maintain diversity in many semi-natural communities but inevitably removes structures required by some invertebrate species.

- Some artificial habitats can support nationally or otherwise scarce or rare species and have strong populations of the common hosts of rare species. Testing the extent to which this is true, and the circumstances in which it happens, is a key function of this study.

- It is possible that some artificial habitats of value are transient or ephemeral. The scale on which this is true is important, because it determines the balance needed between the conservation of single sites and the management of a pattern of individually transient sites to maintain metapopulations. Unfortunately, there is virtually no information on this aspect of community dynamics for invertebrates of artificial habitats.

In consequence of the above, it is inevitable that this study is mainly limited to examining the patterns of occurrence of species occurring at different sites. It is rarely possible even to examine a complete species list, let alone understand community functioning. Nevertheless, some of the patterns have proved to be strong enough to make reliable inferences about the priorities for conservation.

2.3 Where are the communities of value?

In a mainly urban area, any nucleus of biodiversity is of local value, even if all the species involved are commonplace and widespread in the surrounding countryside. The intensive management of many areas such as urban parks, small gardens and sports grounds has long been known to limit their value to this level alone (Teagle 1978). Impressive species lists can be gained from some sites, such as the Owens' Leicester garden (Owen 1991) or Buckingham Palace garden, but they support few scarce or rare species which are breeding on the site rather than part of the extensive dispersive fauna which occurs as a background in any location.

Against this perspective, other artificial sites can support large numbers of nationally scarce and rare or otherwise specialised species. In the south of England, some sites have been found to support a minimum of fifty or more such species, even where not all taxonomic groups have been considered (Penny Anderson Associates 1996, Plant & Harvey 1997). The purpose of this study is to attempt a more precise definition of the characteristics of these clearly important sites and of the species which tend to occur there.

Three other circumstances of historical or other interest are dealt with only briefly in the study. The first of the three concerns the development of urban environments against the perspective of archaeological time. There is a growing body of archaeological knowledge of invertebrate faunas which suggests that "ruderal" invertebrate species were being favoured in towns as early as Roman and subsequently Viking times in England (Kenward & Allison 1994). It is possible that the processes of colonisation described in this study have been going on for longer than previously suspected: some species which we tend to associate with semi-natural habitats may have a long association with artificial habitats as well.

The other two circumstances are linked to this. The first concerns the truly synanthropic species, usually regarded as pests or indicators of undesirable conditions. The archaeological literature shows that such species, including ecological groups such as parasites, stored-product pests and "foul decomposer" faunas, were widespread as might be expected in early urban conditions. Some of these species are now scarce or rare, such as *Cercyon ustulatus* and *C.atricapillis,* two pselaphid beetles recorded by Kenward in York (Hall & Kenward 1990, Kenward & Hall 1993), but it is difficult to envisage successful conservation measures which could be applied in practice without endangering human health.

The second consideration relates to those species of natural or semi-natural habitats which may still survive in enclaves (or special habitats such as untreated large timbers) in urban areas but are not particularly associated with people and do not appear to have found a modern artificial habitat which meets their needs. The analysis reported on below identifies a major group of such species, correlated with the nature of the natural or semi-natural habitats where they originate. In the past, such species by contrast often turned up in archaeological urban contexts (e.g. Kenward et al 1986, Kenward & Hall 1993). Their presence is usually explained in the archaeological literature by the importation of products ranging from large timbers (e.g. the endangered woodworm predator *Teretrius fabricii*) to hay and straw (e.g. the dyer's greenweed weevil *Apion difficile*) into towns from the surrounding countryside. Some such species can survive in modern times in enclaves of semi-natural habitat preserved in urban areas (e.g. the great oak beauty moth *Hypomecis roboraria* in a few London woods - Plant 1993), but this is not the same as adaptation to an artificial habitat.

The brief review above suggests that the understanding of the conservation of invertebrate communities in artificial habitats may be dauntingly complex. In an attempt to reduce this complexity to important and hopefully simpler components, this report begins by examining a series of conceptual models for the accumulation of such invertebrate faunas.

3 MODELS FOR THE ACCUMULATION OF RUDERAL INVERTEBRATE COMMUNITIES

In evolutionary terms the habitats of concern are new. The species we find in them are likely to be the same as ones once found, or still found, in pre-urban habitats. This includes the habitats provided by people before they lived in urban conditions or had the drastic effects on habitat structure associated with towns.

The mechanisms for this accumulation of species might seem hopelessly complex. If they are, then there is little hope for effective understanding and informed conservation measures. Accordingly, it is useful to explore simple conceptual (Southwood 1978) models and then test whether or not these models can explain the patterns we find adequately.

To begin with, as few as three different models may explain the most important features of accumulation of species into ruderal and peri-urban habitats. None of the ideas in these models are new: they are merely a framework which brings together existing knowledge in a way which can be examined critically.

A key assumption in all these models is that artificial ecosystems can often provide the habitat requirements of species of natural or semi-natural ecosystems without replicating the ecosystems themselves. From the evidence (see also section 3 below) there are many mechanisms for this, some straightforward but others poorly understood. A species naturally found in chalk grassland and requiring a hot dry microclimate with *Daucus carota*, for instance, may find its requirements in an artificial situation which bears little resemblance to real chalk grassland. Species naturally occurring in flood debris may find their habitat requirements in accumulations of rubbish unconnected with any real flood. More subtle mechanisms, such as local microclimate, may lie behind the ability of some naturally coastal species to colonise artificial sites inland. The information to explain these apparent complexities is not yet available, so one is restricted to the simple assumption: that artificial ecosystems can replicate natural habitats for species without necessarily replicating the natural ecosystem.

The models are presented in Figures 1 to 3. Each model shows three historical stages, which differ slightly between the models, but all end with a late 20th century "modern" situation typical of Britain.

Model 1 shows the relationship between a developing urban focus and surrounding semi-natural habitat. For the sake of simplicity only one such habitat is shown: we could pretend that it is calcareous grassland or woodland. A suitable "model example" for "Species X" might be the mining bee *Andrena bucephala* or the six-belted clearwing moth *Bembecia scopigera.*

In the pre-industrial state (Figure 1a), the correct semi-natural habitat for "Species X" is largely intact, its distribution determined by edaphic conditions alone. An urban focus has started, and with it small-scale exploitation of the sort (for instance quarrying) which will eventually provide potentially new habitats for Species X. If we were able to return in time and sample it, however, most of the species like "Species X" would still only be found in their semi-natural habitat.

This model also shows how easily species which depend on the semi-natural habitat but will never succeed in living permanently in the urban or peri-urban habitats could be found there. People exploiting the semi-natural habitat will bring products such as hay or wood to the nearby urban area and some of the associated invertebrates will inevitably find their way into the archaeological record.

In the industrial state (Figure 1b), unexploited parts of the semi-natural habitat still remain: they still have a function in people's use of the environment. However, the areas exploited have increased greatly. Also, part of the semi-natural habitat has been overtaken by completely urban uses. Species X is

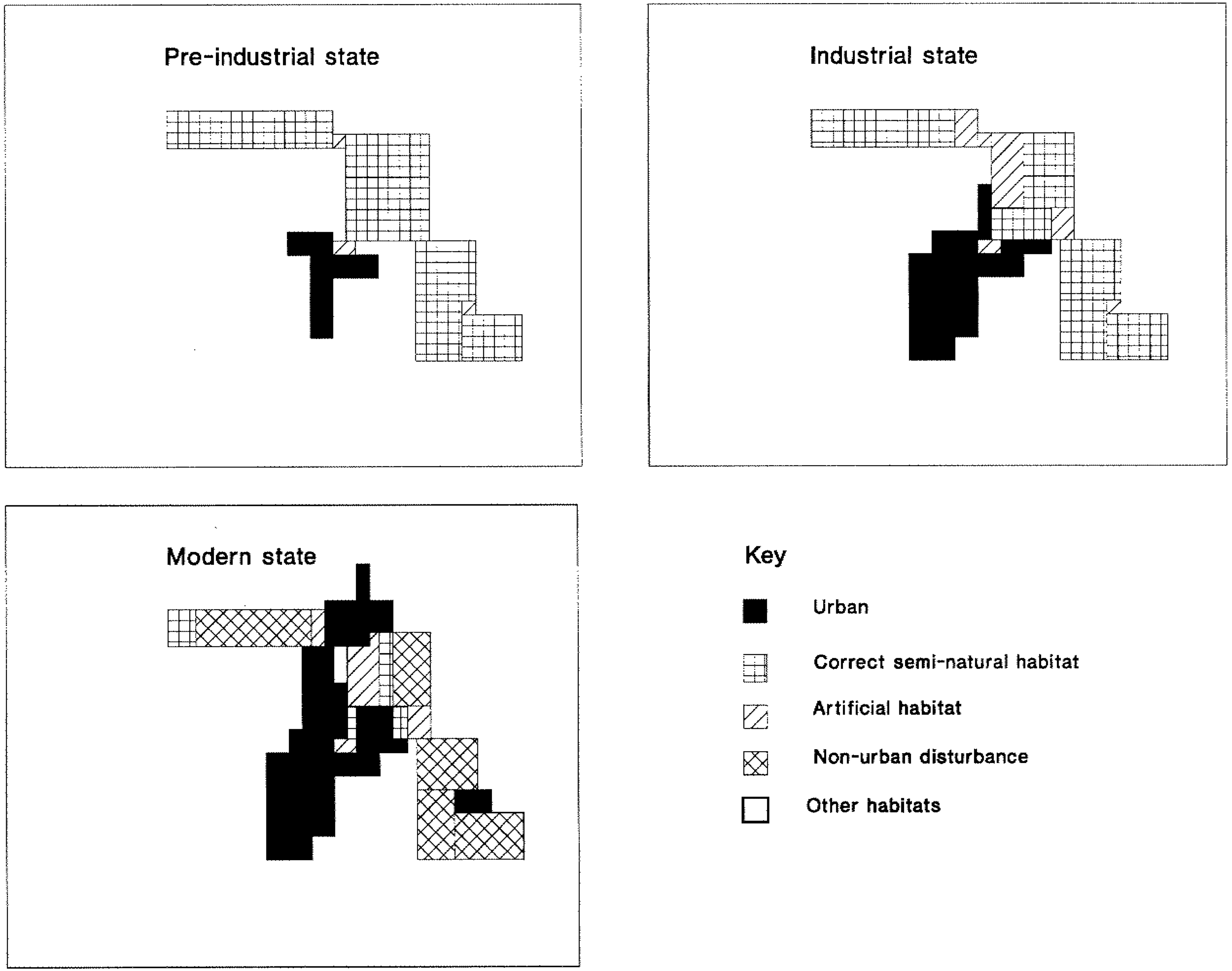


Figure 1: **Conceptual model for the historic colonisation of artificial habitats from nearby semi-natural ones.**

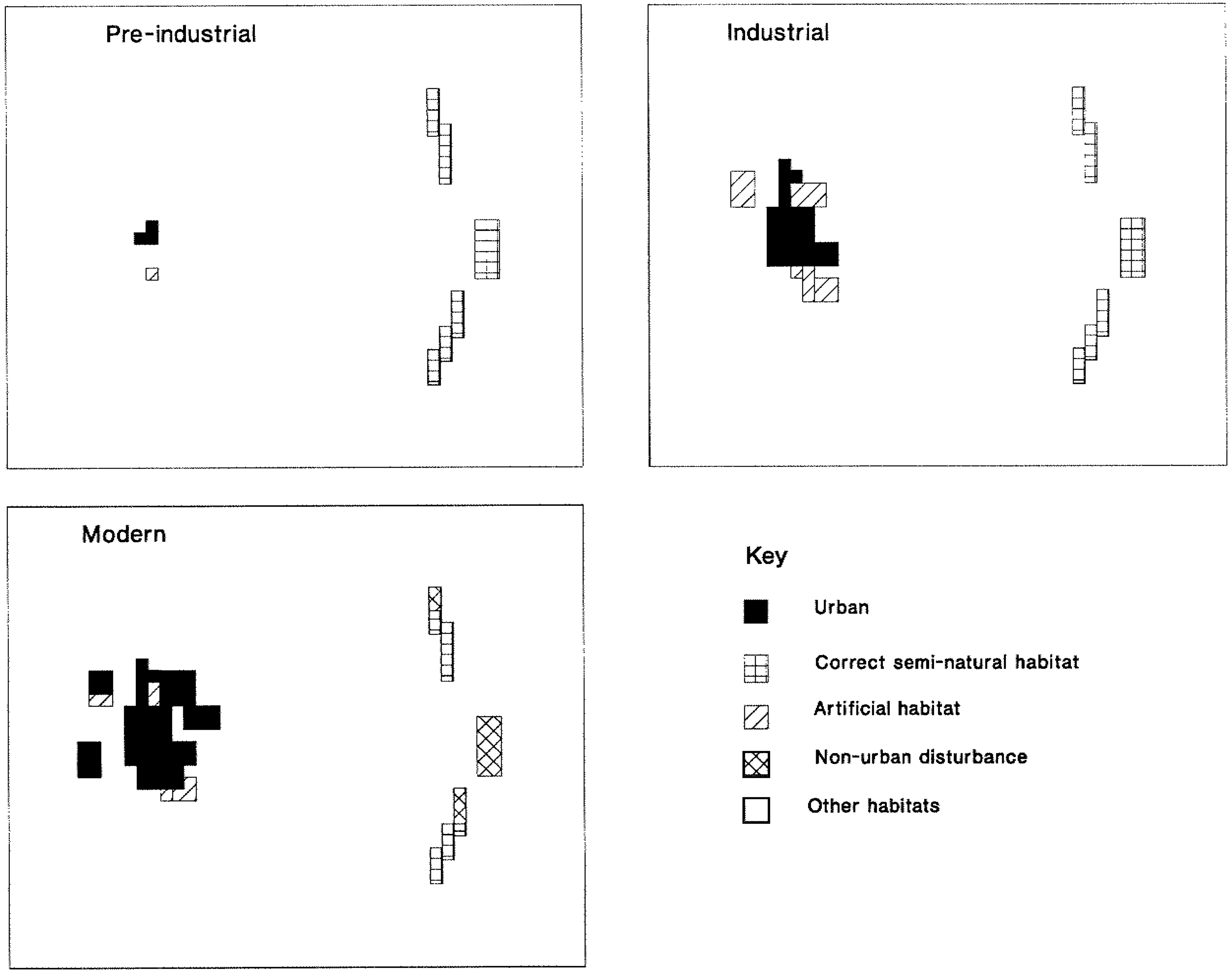


Figure 2: **Conceptual model for the historic colonisation of artificial habitats from remote semi-natural ones.**

quite likely to have colonised the alternative "artificial" habitat by now, but it is still likely to be widespread in its original semi-natural habitat.

By the late 20th century (Figure 1c), the pattern has changed fundamentally. The urban area has expanded, overtaking and isolating both surviving fragments of semi-natural habitat and parts of the artificial habitat associated with industry. The drawing reflects the fact that the areas associated with the industrial activity are quite likely to have become redundant with associated pressure for "restoration" for other purposes. Most of the remaining semi-natural habitat has been converted to different habitats, such as intensive agriculture, in which Species X cannot live. The remaining patches may also have changed because of different management. Species X will now be rare, and may even be absent from the fragments of its original semi-natural habitat and only found in the artificial habitat.

A second consequence of this pattern is that other species once living in the semi-natural habitat will no longer turn up accidentally in urban areas. They are now sparse and in any case, the function which caused them to be brought in in the first place (such as hay for animals kept in the town) has gone.

Model 2 again shows a developing urban focus, but this time there is no nearby semi-natural habitat suitable for our model species (Species Y). Species Y's habitat is elsewhere: it is drawn in a pattern as if it was a coastal species (such as for example the ground beetle *Amara convexiuscula* (Whiteley 1994) or the marram bug *Chorisoma schillingi* (Sheppard & Barker 1992) but this need not be the only situation.

In the pre-industrial state (Figure 2a), the urban focus and Species Y are totally separate. It is possible, as in Figure 1a, that potential habitat has been created on a small scale, but Species Y is unlikely to have found it yet.

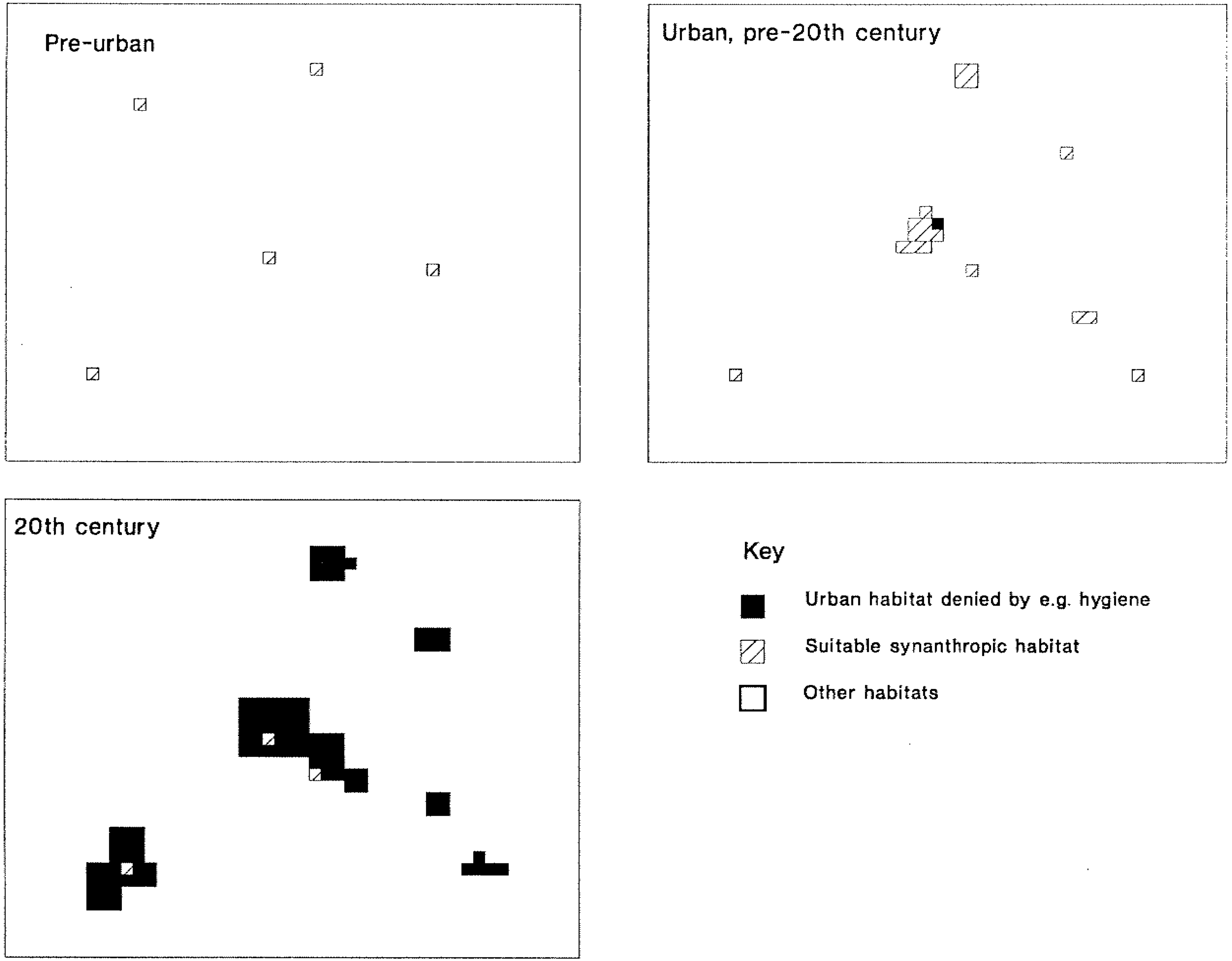


Figure 3: **Conceptual model for the historic development of habitat for synanthropic species.**

In the industrial state (Figure 2b), the original semi-natural habitat is intact or virtually so, but the urban focus has expanded greatly, associated with the industrial activity which provides potential habitat for Species Y. Species Y may colonise by itself or it may have been assisted by people's transport of goods, or both.

In the modern state (Figure 2c), the original semi-natural habitat is likely to have become partly degraded, so as in Model 1, Species Y may have become rare or even extinct there. However in either case it survives in remaining patches of artificial habitat geographically remote from its original localities as well as different in origin.

The third model (Figure 3) outlines a pattern for truly synanthropic species, including but by no means limited to parasites.

Figure 3a is a reminder that there was a time when people were sparse: synanthropic species had to have good independent dispersal mechanisms or be very tightly tied to their host's or associates' lifestyle to survive.

Throughout the development of towns and cities, such species found themselves in a situation where humans were crowded in ever-growing areas (Figure 3b). Clearly, individuals and classes of humans will have differed in their degree of effort to limit such species, but overall suitable habitats were both abundant and concentrated.

By the late 20th century in Britain (Figure 3c), potentially suitable habitats abound even more but are generally denied by deliberate efforts to remove synanthropic species of invertebrates. Potential effective habitat for most such species only occurs in relatively small and scattered foci where for one reason or another modern hygiene and control has lapsed. A minority of the species however have an ecology which happens to succeed in modern circumstances, remaining common sometimes in spite of people's best efforts at control. One such species is the human head louse *Pediculus humanus*: of very different ecology (slurry and abattoir waste) but even more successful are the moth flies *Pericoma nubila* and *P.trivialis.*

The fundamental hypothesis underlying all these conceptual models is that artificial habitats have been colonised by species of nature conservation importance from a variety of semi-natural habitats, including but not limited to those once near to the artificial habitats. If this is true, then careful evaluation, selection and subsequent conservation of artificial and peri-urban habitats will make an important contribution to nature conservation in general and to biodiversity conservation at the national level. If few species of nature conservation importance now depend on artificial habitats to a significant extent, then the contribution of such habitats to nature conservation is limited to the local level: the provision of diversity in otherwise impoverished areas.

The next section of this report tests the above, both by examining its truth in general and examining whether or not there are geographical, habitat type or other limits to the contribution which artificial and peri-urban habitats can make to nature conservation.

4 APPARENT LIMITS TO COLONISATION

4.1 Overview of artificial habitat colonists

The majority of the analysis in the following section could not have taken place without access to Kirby's (1995) data set arising from his review of the habitat preferences of nationally scarce and rare invertebrates. This provides a "snapshot" of knowledge in digital format which, while not comprehensive in scope, has allowed analysis of the state of knowledge of the better-known groups of invertebrates. It provides a synthesis of individual data sets which, although forming highly valuable contributions to the knowledge of peri-urban fauna, contain too few scarce and rare species for individual analysis (e.g. papers in Whiteley 1988 ed). The analyses described below assume that Kirby's review represents a single, and relatively recent, summary of the state of knowledge on different invertebrate groups, and is mainly restricted to simple comparisons between the numbers of species in different categories which had been reported then (1995) from artificial habitats or otherwise.

Overall, there are very few invertebrates except parasites or obligate commensals of man which are completely restricted to artificial habitats. In Kirby's data set, there are only 38, out of 2767 species, less than 1%. The great majority of these are species of very long-established artificial habitats which are often in the countryside (e.g. the old wall dwelling glowworm *Phosphaenus hemipterus* (RDB1), meloid beetle *Apalus muralis* (RDB1) and land snail *Lauria sempronia* (RDB1)) or species on the edge of their range which depend on ruderal plants and/or on prey found in hot micro-sites with much bare ground (e.g. the carabid beetle *Harpalus cupreus* (RDB1), the tortoise beetle *Cassida nebulosa* (RDB1)and the picture-wing fly *Tephritis praecox* (RDB1)). A very few are on the northern edge of their range and associated with plant species introduced to Britain (such as the true bug *Anthocoris minki* (RDB3), only known from galls of the aphid *Pemphigus spirothecae* on Lombardy poplar). In the circumstances it is difficult to identify any of these species which are now extinct in a natural or semi-natural habitat in Britain and survive as relicts in artificial habitat.

Many may only have found suitable warm and open microhabitats in sites influenced by people. They are equally likely to have been able to colonise Britain only in the wake of development of extensive open areas from the Neolithic onwards.

Other species may have depended mostly on artificial habitats, such as the geometrid moth *Lithostege griseata* (RDB3) and the beetle *Psylliodes sophiae*, which are specialist herbivores on flixweed *Descurainia sophia*. Flixweed is an annual of disturbed ground and in Britain, like these rare insects, is associated with pre-modern arable cultivation and the margins of disturbed ground on the Breckland heaths. A similar example is the henbane leaf beetle *Psylliodes hyoscyami*, with records from artificial habitats but also from disturbed areas such as rabbit warrens in chalk grassland, where its foodplant can be favoured. The overall impression is that "true" artificial habitat species are either common and widespread or restricted to human parasites and obligate commensals not covered in Kirby's review.

National scarcity is perhaps a parochial way of judging conservation importance. It could be that artificial habitats are only capable of conserving British rarities which are on the edge of their range and merely curiosities in Britain: they are common elsewhere in the world. To the limits of the data available, this is partly true. The lists of nationally scarce and rare species are focused on Britain, but the Biodiversity Action Plan lists (Biodiversity Steering Group 1995 and subsequent updated Middle List drafts) are intended to reflect Britain's importance in global conservation more appropriately.

There is a highly significant difference (chi-square 24.7, $p<0.001$) between the likelihood of Biodiversity Action Plan (BAP) species being found in artificial habitats and the chance of other nationally scarce and rare species being found there. Only 3.6% of the BAP species had been reported from artificial habitats by the time of Kirby's review (13 out of 360 species covered), compared to 12.5% of other nationally scarce and rare species (300 out of 2407 species). The BAP species from artificial habitats are so few that a list is relevant: they are the bumblebees *Bombus ruderatus* and *B.subterraneus*, aculeate Hymenoptera *Cerceris quadricincta*, *C.quinquefasciata* and *Osmia parietina*, the beetles *Harpalus froelichi*, *H.obscurus*, *Mycetophagus quadriguttatus* and *Psylliodes sophiae*, and four moths: the toadflax brocade *Calophasia lunula*, the striped lychnis *Cucullia lychnitis*, the Brighton wainscot *Oria musculosa* and the four-spotted *Tyta luctuosa*.

The results must be treated with a certain degree of caution because the BAP lists are still in the process of development (Sheppard personal communication). In a few cases it is certain that Britain makes little contribution to the global population of a species (such as the leaf beetle *Bromius obscurus* - RDB1 in Britain but common and even a pest on grape vine in parts of Europe). In many other cases the position is much less clear and its resolution may depend on ecological knowledge of the global position which is simply not yet available.

Because there are so few BAP species involved in artificial habitats, further analysis in the following sections is of necessity restricted to the much greater number of nationally scarce and rare species recorded there.

The total number of these species (313) is substantial. The first question raised by the conceptual models is answered: there is a substantial number of species of conservation importance by virtue of being nationally scarce and rare which are found in artificial habitats and the great majority of these are drawn from semi-natural habitats, not completely restricted to artificial habitats.

4.2 Habitat Limits to Colonising Artificial Habitats

However not all semi-natural habitats are equally likely to contain scarce species which have succeeded in colonising artificial habitats. Figure 4 shows that there is indeed a sharp dichotomy between semi-natural habitats whose species are unlikely (2-4% of all scarce species) to have been recorded from artificial habitats and semi-natural habitats whose species are much more likely (12-20%) to have been so

Figure 4: Species from different source habitats in artificial habitats

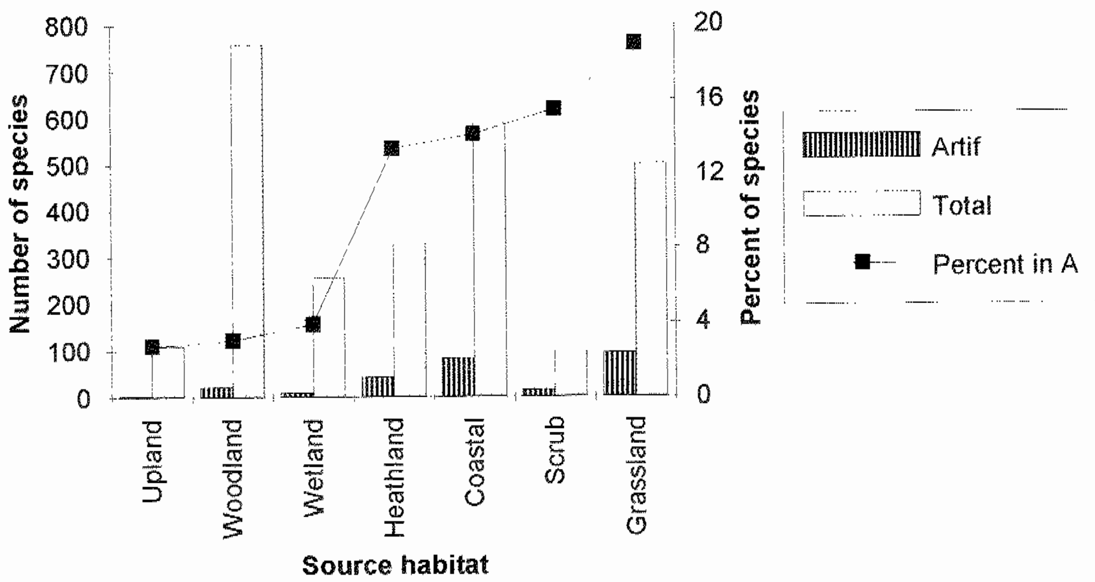
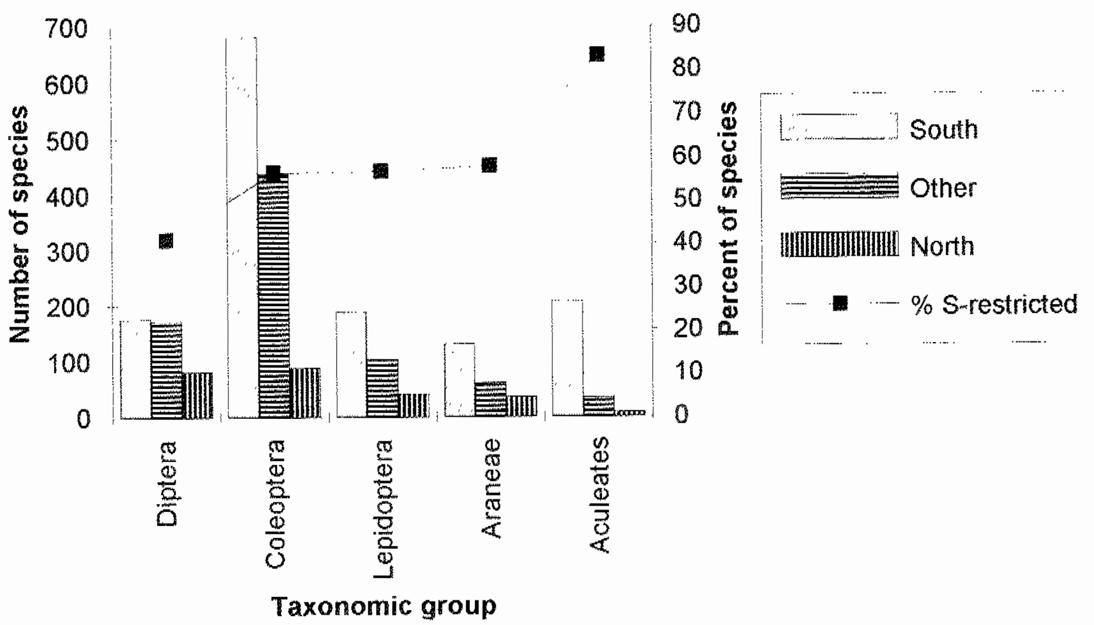


Figure 5: Species in different orders with geographical restrictions



recorded. Since each species may occur in more than one semi-natural habitat, a chi-square value for comparison of these results is only an index, not a formal test, but the size of the difference (chi-square 117, df=6) makes it highly unlikely that this is a chance result.

This is reinforced by the logic of the habitat order shown in Figure 4. The semi-natural habitats whose species do not colonise artificial habitats are those which are in general remote from urban areas and/or support vegetation which both takes a long time to develop and has few of the habitat components quickly mimicked in artificial habitats, i.e. uplands, ancient woodlands and wetlands. The inclusion of wetlands is perhaps surprising, but many scarce wetland invertebrates are associated with mire and other communities which are not easy to replicate in artificial areas. The habitats which do contain scarce invertebrates likely to colonise artificial habitats are the very ones which naturally contain bare ground, ephemeral vegetation and/or develop rapidly and are thus easily mimicked by artificial habitats, i.e. grassland, heathland, coastal habitats and scrub.

The potential importance of artificial, often peri-urban, habitats is thus clearly limited to those semi-natural habitats containing components which can be reproduced there. Preservation of other semi-natural habitats with their invertebrate fauna, such as ancient woodlands, is likely to be a "war of attrition" against the effects of isolation and disturbance restricted to attempts to preserve what is there with little effective contribution from newly created habitats.

4.3 Geographical Limits to Colonising Artificial Habitats

The comparison between BAP and other nationally scarce species above already suggests that artificial habitats may be disproportionately good at preserving species which are scarce because they are on the edge of their range. This is reinforced by an explicit geographical comparison.

First, as reported by Kirby, broad taxonomic groups do differ in the geographical restrictions of their scarce species across Britain (Figure 5). Dividing species into those which are restricted to the extreme south or south and midlands of Britain, those which are restricted to the north, and all other species, shows that aculeate Hymenoptera form the group with the greatest southern restriction of the five with enough numbers for a meaningful comparison. Diptera have the least southern restriction (and conversely the greatest number of Arctic-Alpine specialist species which are present but scarce in northern Britain), and beetles, moths and spiders are intermediate. This difference is significant at below p=0.001 (chi-square=152, df=8).

Further, this difference is reinforced by a greater likelihood of south-restricted species being reported from artificial habitats than any other group (overall chi-square = 21.8, df=2, p<0.01). The state of knowledge at the time of Kirby's review suggests that artificial habitats are disproportionately important for supporting scarce species on the northern edge of their range in Britain, taxonomically biased towards groups such as the aculeate Hymenoptera.

4.4 Taxonomic differences in ability to colonise

This bias in colonisation is directly reflected in broad taxonomy. Figure 6 is ordered by the proportion of the nationally scarce and rare species in each group which had been recorded in artificial habitats up to the time of Kirby's review and incidentally shows that the merely scarce, rather than rare, species are more likely to have been recorded in artificial habitats in general (overall chi-square = 10.42, df=1, 0.01<p<0.001). The difference between groups is immense (and highly significant: chi-square =161, p<<<0.001): an order of magnitude separates the over 50% of scarce aculeates which have been reported from artificial habitats from the less than 5% of comparable Diptera.

This is not an artefact of better recording of some groups than others. Among the Diptera, hoverflies have been exceptionally well studied, and three out of 102 Red Data Book and nationally scarce species were recorded by Kirby (1995) from artificial

Figure 6: Percent rare (R) and scarce (N) species in artificial habitats

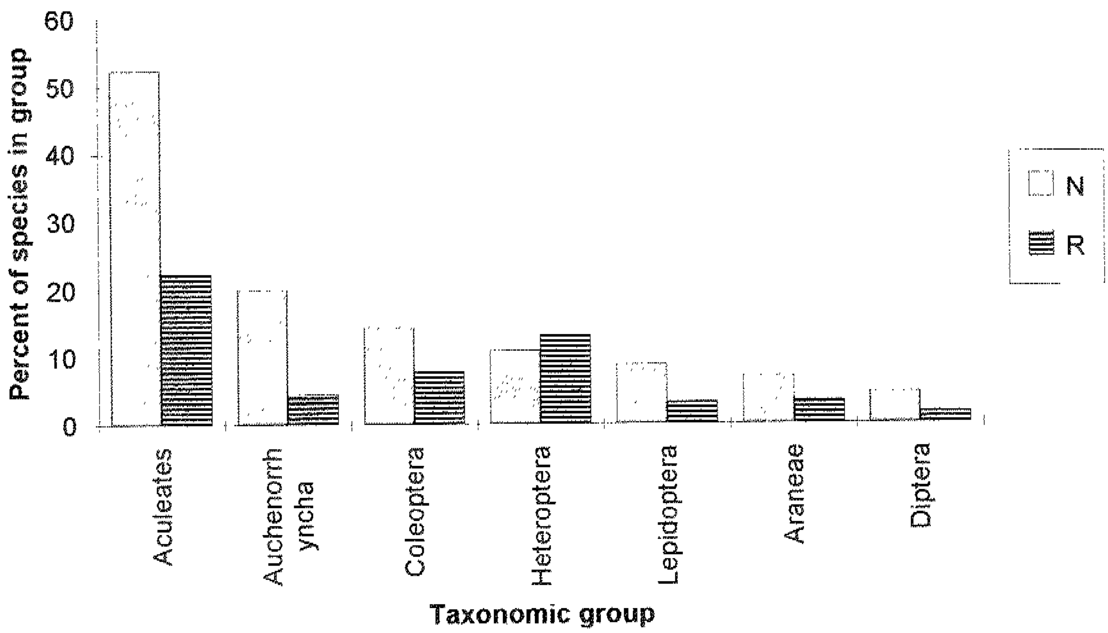
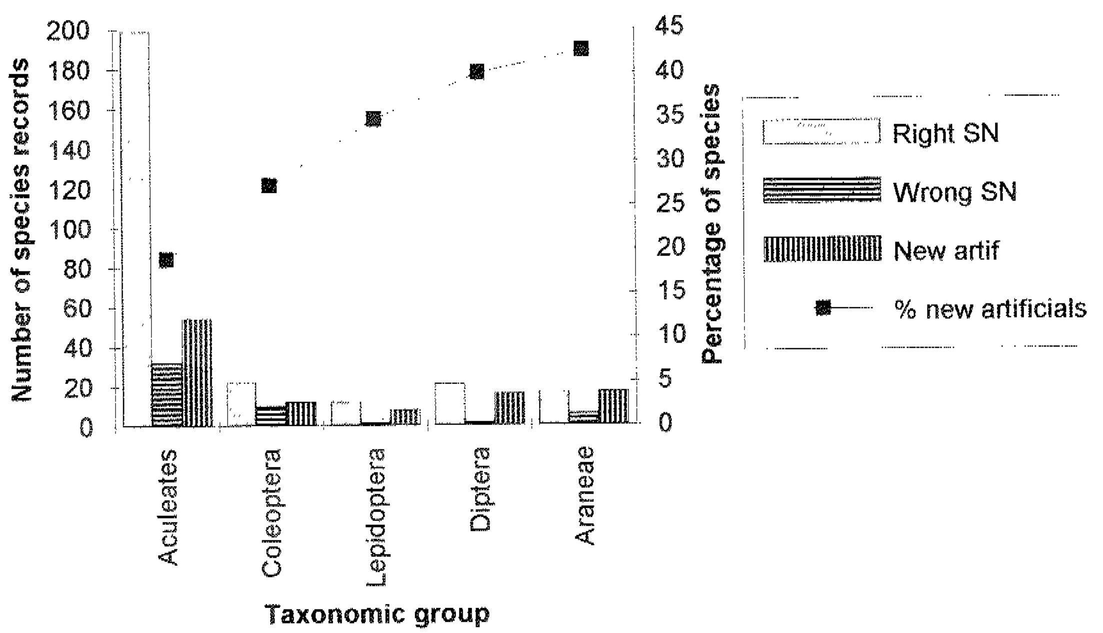


Figure 7: New habitat records compared with past ones



habitats, slightly less than the overall Dipteran average of 5%. Comparably well-recorded groups among the aculeates are the true bees (Apidae), social wasps and ants. Here nine out of 28 scarce and rare species have been recorded from artificial habitats, similarly (35%) slightly less than the overall group average. Any difference probably reflects the fact that the often larger and also taxonomically "easier" families, which become well recorded, may also be more specialised and less able to take advantage of artificial habitats. The patterns between taxonomic orders are however similar whatever the degree of knowledge about distributions.

4.5 Other limits to colonisation

Other restrictions on the scarce species which have succeeded in colonising artificial habitats support intuition. Artificial habitats are less likely to be colonised by species supposed to require large areas of habitat (chi-square = 19.2, df=1, $p<0.01$) and by those which are supposed to be less mobile (chi-square = 55.1, df=1, $p<<0.001$). Indeed, only one species out of 185 scarce species regarded by Kirby as having low mobility was recorded from artificial habitats (the snail *Lauria sempronii* which is only known from old walls - in the countryside, and absent from other apparently suitable walls nearby). Conversely, perceived population structure had no effect on the likelihood of colonisation.

4.6 In conclusion

The conceptual models are thoroughly vindicated in that a substantial proportion of nationally scarce and rare species associated with semi-natural habitats occur also in artificial, often peri-urban habitats. These include species likely to have originated in habitats remote from artificial habitats as well as those likely to have occurred or which still occur in close proximity. However, relatively few species which are globally restricted (as judged by the BAP lists) have succeeded in doing so. There is also a strong bias in that artificial habitats tend to be colonised by species of grassland, coasts, heathlands and scrub, not upland or ancient woodland communities. Artificial habitat species tend to be more mobile, less restricted to large areas, on the northern edge of their range in Britain, and less scarce than the general run of nationally scarce and rare species.

5 HOW MUCH DO WE KNOW?

The above conclusions arise from a "snapshot" of knowledge of a limited but extensive range of invertebrate groups. Such a snapshot is inevitably limited but also allows a test of the state of knowledge, in that new results can be compared with it to see if the patterns are similar or if there is a high proportion of surprises suggesting that our current knowledge is limited.

Geography and the nature of invertebrates further limit such a test because nationally scarce and rare species in Britain are fewer in number further north. Although some taxonomic groups have been covered by the preparation of regionally scarce lists, there needs to be a much greater coverage before the contribution of artificial sites in the north of Britain can be judged fairly. The following remarks are inevitably biased towards sites in southern Britain.

Plant and Harvey (1997) collated data for 28 sites on the Thames gravel fringe, including artificial sites, semi-natural sites and those with a mixture of habitat origins. Their data set contains many scarce and rare species records and provides a useful test by itself, albeit limited to this region of the country.

In addition, a limited number of data sets have been available from other sources, arising from Bioscan studies and elsewhere where there have been sufficient scarce and rare species recorded to form a judgement. The locations range from London to the Suffolk and Norfolk border and Warwickshire. Data sets from further north have also been examined, such as the Center Parcs holiday village at Sherwood Forest in Nottinghamshire, but these contain only few nationally scarce and rare species. Between them these sites include ones completely surrounded by urban development as well as artificial habitats on the urban edge or in the countryside.

The Plant and Harvey data set (Figure 7) underlines the rate at which new knowledge is accumulating. Taxonomic groups in Figure 7 are ordered by the proportion of species records which are from artificial habitats and are of species for which Kirby

(1995) did not report any artificial habitat records (new artificial). The numbers of species records in each taxonomic group recorded from a previously known semi-natural habitat (right SN) and from a previously unrecorded semi-natural habitat (wrong SN) are also shown.

The proportion of "surprises" in artificial habitats is large, ranging from just over 15% of all records in the aculeates (for which a high proportion of scarce species are already recorded from artificial habitats) to over 40% for Araneae. The "surprises" in more natural habitats follow a slightly different pattern, with proportionately fewest in the Lepidoptera and Diptera, and most in the Coleoptera although there were also many new semi-natural habitat (Wrong SN in Figure 7) records for aculeates.

This suggests that, for whatever reason, current estimates of the potential contribution to be made by artificial habitats to the conservation of scarce and rare invertebrates are gross underestimates. The data confirm the habitat conclusions of the above section, in that all "surprises" involved species previously thought to be confined to semi-natural heathlands, grasslands, scrub or coastal habitats, but show that an even greater proportion of species than previously considered can be supported by artificial habitats.

Comparison with other individual sites reinforces this. Proportions of "surprises" did not differ significantly between sites, but ranged from eight out of eleven nationally scarce and rare species at a London site to 13 out of 31 at the Center Parcs holiday village at Elveden Forest in the Suffolk Breckland (omitting species occurring in habitat such as conifer woodland which existed before the village was built) and 23 out of 57 at Chafford Hundred in Essex (Penny Anderson Associates 1997). Even at the northernmost site, Sherwood Forest Center Parcs, one out of four species records was a new one for artificial habitats. Further, new records may be of species for which Britain is important for global populations, such as the case-bearing moth *Coleophora tricolor* recorded at Elveden which is a BAP Middle List species known from few sites in Europe.

Further confirmation comes from the experience of other individuals. Having seen the results presented in a draft of this report, Lott (personal communication) was able to add a total of 52 new species records of scarce and rare species of Coleoptera from artificial habitats from records held by him. These comprised 17 records of freshwater species from long-established artificial habitats, 19 from more recently developed habitats, nine terrestrial species records from quarries and seven from derelict land. The great majority of these records are from the Midlands (mainly Leicestershire), an area which is, from the analysis above, less likely than the south of England to produce such records.

In conclusion, the limits to the potential value of artificial habitats for invertebrate conservation are not yet known. The substantial (12-15%) proportion of nationally scarce and rare species known to occur in such habitats is an underestimate.