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Urban, industrial and other manmade sites as analogues of natural habitats for Carabidae

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Human activity has destroyed or fragmented seminatural habitats, yet some carabid species have maintained, or even extended, their range. This can partly be explained by their colonisation of manmade habitats. A range of manmade analogues for seminatural habitats exists, which supports rare and threatened carabids. The fauna of manmade sites may be partitioned into ubiquitous and eurytopic species, and habitat specialists. The conservation evaluation of manmade sites is discussed; a method based on the proportion of the regional species-pool of habitat specialists present is proposed. The habitats and management of manmade sites are compared with those of nature reserves.

1. Changes in landscape and carabid species composition in Britain

The British landscape is almost all man-modified. Intensive agriculture dominates the lowlands, seminatural habitats surviving as fragments in an agricultural matrix (Barr *et al.* 1993). It has been argued that farming pre-dates many forms of management on which seminatural habitats now depend for their maintenance, such as grazing regimes of grassland and coppicing of woodland (Stoate 1995). This explains the existence of stenotopic and threatened farmland species, such as weeds (Firbank *et al.* 1994), and the 'traditional arable' component of the British carabid fauna (Telfer & Eversham 1996). However, over the past fifty years, intensive application of herbicides and insecticides, and other changes in farming practice, have removed all but a few species from the modern agricultural matrix, and many 'traditional arable' species are now endangered (Wilson 1992, Telfer & Eversham 1996). Apart from these farmland relics, most stenotopic species are confined to increasingly fragmented remnants of seminatural habitats, of value to nature conservation (e.g. Ratcliffe 1977). In the face of landscape simplification (Hengeveld 1994), how have carabid species responded? This study aims to explore the role of anthropogenic sites in carabid survival.

Species may be categorised according to their geographical and habitat range as follows: (a) ubiquitous species are geographically wide-ranging, (b) eurytopic species are found in a wide range of habitats,(c) stenotopic species are specific to one

or a few habitats. Ubiquitous species may have a wide or a narrow habitat range; the majority in Britain today are eurytopic.

These categories may be defined for carabids in Britain as follows: (a) *ubiquitous species*: present in a majority of sites/mapping units within the area of study, (b) *eurytopic species*: found in many habitats; occurring in 5 or more of the 22 major biotopes used to define habitat-specificity (Eversham & Roy 1996), (c) *habitat-specific species*: classified from literature (Lindroth 1974, 1985, 1986, Turin *et al*. 1991) and field studies; species have been allocated to up to 4 categories (which will usually be ecologically related, e.g. sand dune, dry sandy grassland, dry heathland), but most are placed in only 1–2 similar habitats.

Eurytopic species of carabids appear to have maintained their distribution and abundance in Britain, and some may be increasing. This trend has been demonstrated for other groups, e.g. butterflies (Pollard & Eversham 1994), and vascular plants (Eversham & Roy 1996). The most intensive agricultural land is characterised by eurytopic species: Table 1 shows that the most frequently recorded species in farmland in lowland Britain, such as *Bembidion lampros*, *Harpalus aeneus*, *Amara aenea*, *Notiophilus biguttatus* and *Harpalus rufipes*, tend to be both eurytopic and ubiquitous. These species occupy the agricultural 'matrix' of the modern lowland landscape, although also occurring in seminatural habitats. They may be more abundant than in the past, as has been suggested for certain farmland butterflies (Pollard & Eversham 1995), and for those dragonflies which have colonised manmade wetlands (Merritt *et al*. 1996).

Habitat-specific species occur in the fragments of seminatural habitat embedded in the agricultural matrix, and become locally extinct when a fragment is destroyed or degraded (Pollard & Eversham 1994, Prendergast & Eversham 1995). The survival of habitat-specific species is thus the most appropriate focus of conservation efforts: the ubiquitous and eurytopic species should survive without conservation, provided that their range of habitats remains common.

Studies of other taxa suggest that habitat-specific species in Britain are in decline, their ranges contracting, and their areas of occupancy (*sensu* Gaston 1991) reducing (Eversham & Roy unpublished data). This is evident among the carabids: most

Table 1. Carabidae on agricultural land. The occurrence of carabid species on farmland, based on data from nine arable sites in eastern England sampled by the authors between 1980 and 1990. Sites are described and analysed by Telfer and Eversham (1996). Eurytopic species (E) are defined as occurring in five or more major biotopes. Ubiquitous species (U) are geographically very widespread.

Species	No. of sites	Eurytopic?	Ubiquitous?
Bembidion lampros	9	E	U
Harpalus aeneus	8	E	U
Amara aenea	7	E	U
Notiophilus biguttatus	7	E	U
Agonum dorsale	6		U
Demetrias atricapillus	6	E	U
Harpalus rufipes	6	E	U
Amara familiaris	5	E	U
Calathus fuscipes	5	E	U
Nebria brevicollis	5	E	U
Pterostichus madidus	5	E	U
Amara apricaria	4	E	
Badister bipustulatus	4	E	U
Bembidion guttula	4	E	U
Bembidion obtusum	4	E	
Dromius linearis	4	E	U
Pterostichus niger	4	E	U
Trechus quadristriatus	4	E	U
Agonum muelleri	3		U
Amara aulica	3	E	
Bradycellus harpalinus	3	E	U
Bradycellus verbasci	3	E	
Notiophilus substriatus	3	E	
Pterostichus cupreus	3	E	
Pterostichus melanarius	3	E	U
Trechus obtusus	3	E	U
Calathus erratus	2	E	
Abax parallelepipedus	2		U
Amara bifrons	2		
Amara plebeja	2	E	U
Bembidion mannerheimi	2	E	
Clivina fossor	2		U
Harpalus anxius	2		
Harpalus latus	2	E	
Harpalus rufibarbis	2		
Harpalus tardus	2		
Leistus spinibarbis	2	E	
Nebria salina	2	E	U
Pterostichus versicolor	2	E	

A further 20 species were each recorded at one site: *Agonum moestum, Amara anthobia, Amara consularis, Amara convexior, Amara convexiuscula, Amara lunicollis, Asaphidion stierlini, Bembidion properans, Bembidion tetracolum, Calathus ambiguus, Calathus cinctus, Calathus piceus, Carabus problematicus, Carabus violaceus, Leistus fulvibarbis, Loricera pilicornis, Metabletus truncatellus, Microlestes maurus, Microlestes* cf. *minutulus, Synuchus nivalis.*

stenotopic species have declined in Britain, as shown by the Red Data Book (Shirt 1987) and more recent national conservation review (Hyman & Parsons 1992). Similar patterns have been found in Denmark, The Netherlands, Belgium and Luxembourg (Desender & Turin 1989). But some stenotopic species of carabid have survived, or even extended their geographic range, in recent decades. For some species, we suggest this is due to the colonisation of artificial habitats by species assemblages previously confined to natural sites.

2. Role of manmade sites in nature conservation

If eurytopic ubiquitous species are not in need of conservation, the value of an area for conservation depends on its ability to maintain populations of stenotopic species. Such species generally characterise seminatural ecosystems, and are assumed to fit into the habitat framework within which mainstream nature conservation operates (e.g. Ratcliffe, 1977, 1993, Ball 1995). Hence also our reference to manmade sites as *analogues of seminatural habitats*.

2.1. A national overview

Table 2 shows a range of habitats which are represented in manmade sites, from wetland to xeric habitats such as dry grassland and bare rock. The definition of 'manmade' used here, which distinguishes these sites from heavily man-modified farmland for instance, is that the soil type is either unknown in nature (e.g. pulverised fuel ash) or would not occur in the area without human, usually industrial, activity.

A small and specialised fauna which is partly or wholly synanthropic or peridomestic in Britain (e.g. *Laemostenus complanata*, *L. terricola*) also occurs free-living in caves, and in the burrows of rabbits, badgers and other large mammals, which is their main habitat in the south of Europe. At least one additional species, *Sphodrus leucophthalmus*, formerly occurred in cellars and outhouses but appears now to be very scarce or extinct in Britain and much of northern Europe.

Table 3 summarises the relative importance of the more frequent manmade habitats for conservation. Over 35% of the rare and scarce carabids in Britain have been recorded from manmade habitats. Some of these, especially sand and gravel pits, support a diverse fauna characterised by uncommon carabids, and a few species are confined to this habitat: the only British localities for *Omophron limbatum* and *Dyschirius obscurus*, both Red Data Book species, are in gravel pits on the south coast of England (Hyman & Parsons 1992). Similarly, *Omophron* occurs on the Belgian coast only on the frequently-disturbed pools among ballast (M. Lodewyckx, pers. comm.). Several other species have the majority of their British populations in manmade sites.

2.2. Origins of the fauna

Most manmade sites are of comparatively recent origin. They generally support a proportion of the eurytopic species which occur in the surrounding landscape, and a stenotopic component comprising colonists from seminatural habitats. Following principles of island biogeography (MacArthur & Wilson 1967) and metapopulation theory (Gilpin & Hanski 1990), colonisation will depend on: distance from sources, abundance of species within sources, dispersal abilities of species, permeability of the inter-

Table 2. Manmade habitats which function as analogues of natural habitats for carabid assemblages.

Natural habitat	Manmade analogues
salt-marsh	flooded colliery spoil
	salt-pans
fenland	wetlands on pulverised fuel ash from power stations
	flooded sand quarries
calcareous grassland	lagoons of dried river dredgings
	dry colliery spoil
	lime kiln waste
	Leblanc process waste
heathland	abandoned sand/gravel pits
sand-dune	active sand/gravel pits
	perpetually disturbed road-verges on sandy soil
inland cliffs and scree	hard-rock quarries
	demolition sites
	industrial installations
	railways
open woodland	hedgerows
caves, mammal burrows	cellars, stables

vening matrix, establishment and survival within manmade sites.

The most widespread and abundant seminatural habitats will provide the greatest source of potential colonists: in lowland Britain, these are mesotrophic grassland and broad-leaved woodland (Roy, D. B., Eversham, B. C. & Harding, P. T. unpubl. data). Dry grassland is also frequent in eastern England. Conversely, habitats such as sand dunes are very restricted, and saltmarsh is confined to estuaries and low-lying coasts.

The few quantified studies of dispersal in field conditions suggest that it is hard to generalise about the dispersal abilities of the carabid fauna. That of broad-leaved woodland might be expected to be composed largely of poorly dispersing species (Terrell-Nield 1990, Warren & Key 1991), although in Britain it is arguable that few carabids are woodland specialists (Eyre & Luff 1994). Many grassland species, especially the seed-eating species associated with disturbed ground and early-successional stages ('traditional arable' as discussed by Telfer & Eversham 1996), would be expected to be effective dispersers: disturbed ground represents an 'r-selective' component of landscape (Warren 1993). And indeed, most species of *Amara* and *Harpalus* are fully-winged. However, some species with no obvious means of dispersal, such as *Broscus cephalotes*, which in Britain is almost entirely confined to coastal sand dunes, have colonised gravel pits (e.g. Hatfield Lings, Table 4).

Survival of species once they have reached manmade sites will depend on how closely the site matches the environmental conditions of the seminatural equivalent. The dry, free-draining soils of sand and gravel pits may be too arid for some of the eurytopic species which flourish in the agricultural landscape: such species as *Demetrias atricapillus* and *Pterostichus* species are often absent from such sites. However, these conditions favour a thermophilous element in the fauna, and manmade sites may permit a northward extension of range for some species, such as *Harpalus puncticeps* at Thorne colliery. The role of human activity in extending or maintaining the geographic range of thermophilous species in the post-glacial period has been postulated by Thomas (1993).

The saltmarsh fauna of an inland lagoon created by mining activity in the 1920s, Bell's Pond, in southern Yorkshire, provides a further example, suggestive of a continuous process of colonisation. Detailed surveys in the 1960s and 1970s failed to find *Bembidion iricolor* or *B. minimum* at the site, although *Dromius longiceps* and *Amara convexiuscula* were present (along with a species-rich halophilic Diptera assemblage (Skidmore *et al.* 1987)). *B. minimum* was first seen in 1992, and *B. iricolor* in 1994. (The halophyte, *Salicornia*, first appeared at Bell's Pond in 1995). In Britain, these species are almost always associated with saline biotopes (the water at Bell's Pond contains c. 4.5% sodium chloride). The other saltmarsh or intertidal carabids, such as *B. laterale*, *Aepus* and *Dyschirius* species, may be more reliant

Table 3. The numbers of rare and scarce Carabidae listed as occurring in a range of manmade habitats. Some species occur in two or more biotope categories, thus the totals are not simply the sums of the figures in the columns above. Conservation categories are: End = (Endangered), Vul = (Vulnerable) and Rar = (Rare) (Shirt 1987); Na = Nationally Notable, grade A (thought to occur in fewer than 30 10-km squares in Britain) and grade B (thought to occur in 31–100 10-km squares in Britain). (Data have been extracted from Hyman and Parsons (1992); associations derived from additional fieldwork by the authors are given in brackets).

	End	Vul	Rar	Na	Nb	Total
Total in category	26	4	19	41	79	169
Sand & gravel quarries	3	1	3	5	26 (2)	38 (2)
Chalk & limestone quarries	1	–	–	1	7 (1)	9 (1)
Roadsides & railways	(1)	(1)	–	1 (1)	2 (9)	2 (12)
Cultivated land	2	1	–	1 (1)	6	10 (1)
Reservoirs	1	–	–	–	6	7
Total in manmade habitats	6 (2)	2	4	9 (2)	38 (3)	59 (7)

on regular inundation with saline water, so are unlikely to establish even if they were to arrive.

3. Conservation evaluation of individual manmade sites

Several previous studies have found interesting assemblages of carabids in manmade sites (Lazenby 1983, 1988, Harding *et al*. 1988, Eversham 1992, Eversham & Telfer 1994, Lott & Daws 1994, Eyre & Luff 1994). Eyre and Luff (1994) have found scarce species (Notable B — see legend to Table 3) such as *Amara praetermissa* at their sites, but few studies have attempted an objective evaluation. Table 4 shows the eight manmade sites which we have surveyed, and the sampling period and methods used.

3.1. Previous methods of evaluation

In evaluating such a disparate range of sites, several methods are available, but most current approaches have serious drawbacks. Diversity indices or simple measures of species-richness have been proposed as objective criteria for evaluation (Disney 1986), but the significance of different levels of diversity is not clear (Eyre & Rushton 1989). Attention needs to be paid to the actual species composition of the fauna (Desender 1996).

Species Quality Indices, SQI (Foster 1987, Foster *et al*. 1989), with or without additional weighting for rarity (Eyre & Rushton 1989), have the advantage of objectivity (Eyre *et al*. 1996). Since SQI is based on the proportions of rare and scarce species on the site list, it will vary between habitats (just as the proportion of rare and scarce species in Table 3 varies between manmade habitats). SQI may also vary geographically: in Britain, there is a strong south-north gradient in species-richness, with higher species-richness in most taxa in the south (Eversham 1983, Lawton *et al*. 1994), and a higher proportion of rare species. In southern England, Red Data and nationally scarce species comprise 20–24% of the fauna in most taxa, whereas in northern England the figure is 13–17% (Eversham 1983). Thus, SQI for

Table 4. Industrial sites considered to serve as analogues of natural habitats. Grid: Ordnance Survey national grid reference. Habitats: only the main habitat types at each site are listed. Dry grass = species associated with dry, usually sandy, grassland; calc grass = found mainly on calcareous grassland; arable = species found in modern arable farmland; dune = found mainly in coastal sand dunes; trad arable = found mainly in 'traditional arable' and other early successional habitats (discussed by Telfer and Eversham (1996)). Sampling: date period during which data have been gathered. All sites have been sampled by direct searching and pitfall trapping except Hatfield Lings (direct searching only).

Site name/Grid Site type	Habitats	Sampling
Thorne colliery SE71 spoil heap	dry grass, arable	1978–95
Barking TQ48 pulverised fuel ash	saltmarsh	1989–94
Hatfield Lings SE60 sand quarry	heath, dune, dry grass	1994–95
Doncaster SE50 limestone quarries	calcareous grass	1980–90
Durham NZ33 limestone quarries	calcareous grass	1980–86
Rainham TQ58 silt lagoons	saltmarsh, calcareous grass	1990–93
Bell's Pond SE71 saline lagoon	fen, saltmarsh	1978–95
Wangford TL78 roadside	dune, dry grass, trad arable	1993–95

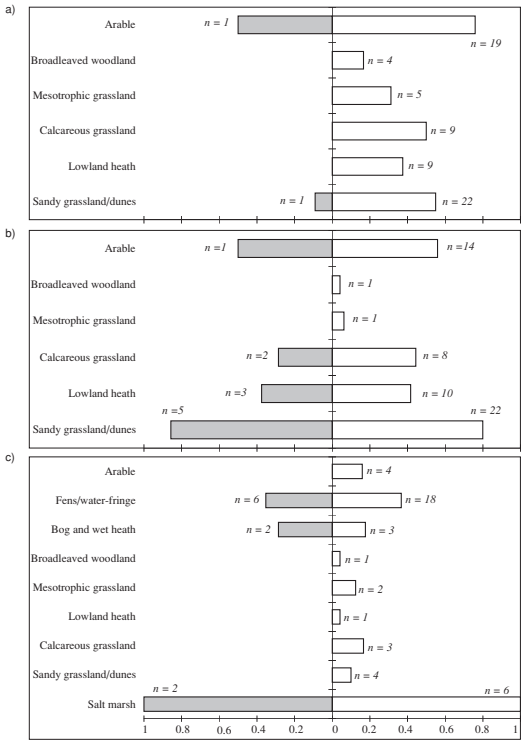

Fig. 1. Proportions of regional species-pool for each major habitat (open bars to the right), and proportion of the scarce and threatened species found within each habitat within the region (filled bars, to the left), for three manmade sites in southern Yorkshire. The total number of species (n) found in the habitat within the site is given on the right, and the total number of scarce and threatened species (n) in the habitat within the site on the left (zero unless stated otherwise). Data are presented for a selection of biotopes, based on species' recorded habitat occupancy. Site a) = Thorne Colliery, b) = Hatfield Lings, c) = Bell's Pond.

equivalent sites would be higher in the south. However, although their originators intended that these scores be applied only after an analysis of different assemblages has been undertaken on a regional basis, other users have applied them much more widely.

An alternative approach to site evaluation, proposed for Carabidae by Heijerman and Turin (1994), is similar to methods used increasingly by plant ecologists. Assemblages of species characteristic of each major habitat are identified from multivariate analyses of large data-sets. The diagnostic species of each habitat then comprise an 'expected' composition. The quality of a site depends on the goodness-of-fit to this expected composition which typifies the habitat. Although useful at a local or regional scale, this method also suffers from the effects of gradients in species-richness within most habitats. Manmade sites seldom fit well to assemblages defined from typical seminatural habitats; this is one reason why manmade sites tend to have been ignored by conservationists. Assemblages in manmade sites will often contain disparate elements from several seminatural habitats, e.g. silt lagoons beside the River Thames at Rainham in east London support a xerophilic assemblage typified by *Brachinus crepitans* and several *Harpalus* and *Amara* species, coexisting with a wetland fauna of *Demetrias imperialis*, *Agonum*, *Badister* and *Bembidion* species. This site was a desiccating slightly saline lagoon, the vegetation dominated by *Bolboschoenus (= Scirpus) maritimus*, *Anthriscus caucalis* and chenopods. As such, it does not conform to the botanist's expectations for a seminatural vegetation type, nor the carabidologist's fit to a named assemblage.

3.2. Habitat-specialists and the regional species-pool

A third approach, which we advocate, is that of the *regional species-pool*. The concept is included within the framework of Penev (1996). In this study, we define the region as a 110 km square centred on a study site. A site is compared with all the stenotopic species occurring in this area, the species being first categorised by their habitat occupancy (Eversham & Roy 1996). This approach overcomes the difficulty of geographic gradients in species- and rarity-richness, by focusing on a smaller region, and is able to assess a site which combines elements of several habitats by taking into account the whole fauna. At the same time, it avoids weighting rarities unduly, and is not influenced by the co-occurrence of large numbers of eurytopic species (the eurytopic and ubiquitous having been excluded before the habitat classification).

Manmade sites in the same region support very different assemblages, and the completeness of the assemblage varies greatly. Fig. 1 gives more detail of three neighbouring sites in southern Yorkshire, dividing the fauna into narrower habitats, and examining the proportion of rare and scarce species within each habitat group. This shows that the richest assemblage does not always support the greatest

proportion of scarce species; this is in part due to the intrinsic differences between habitats. We consider it more valuable to summarise the species complement of a site in a series of values, as shown, than to reduce it to a single numerical value.

4. Conclusions

Manmade habitats support a rich carabid fauna, including 35% of the rare and scarce species in Britain. They represent one of the few habitats which is increasing in area within Britain. Some, such as roads and railways, have the potential both to divide and fragment seminatural habitats, but also to link them (Vermeulen 1993, Eversham & Telfer 1994). Many sites are currently derelict, and nature conservation would provide an inexpensive afteruse. Some of the habitats which are easily maintained in manmade sites by a low level of disturbance, such as bare ground and early-successional stages, are particularly valuable to carabids. Although their lack of an immediate aesthetic appeal may be an obstacle to acceptance by conservationists and planners (Eyre & Luff 1994), these early successional stages are important because they are generally absent or difficult to maintain within traditional nature reserves. Carabids provide an ideal group to sample for monitoring purposes, and we propose that by comparing a site with the regional species-pool for the major seminatural habitats, manmade sites can be judged fairly and objectively.

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