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Ecology and conservation of heathland Carabidae in eastern England

Mark G. Telfer & Brian C. Eversham

Telfer, M. G., School of Environmental Sciences, University of East Anglia, Norwich, NR4 7NE, UK
Eversham, B. C., Biological Records Centre, Environmental Information Centre, ITE Monks Wood, Abbots Ripton, Huntingdon, PE17 2LS, UK

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The history, ecology and conservation of three distinctive areas of heathland in eastern England are discussed: the Humberhead Levels, the Lincolnshire cover-sand heaths, and the East Anglian Breckland. The biogeographic and habitat affinities of the carabid faunas of the three areas are examined. Breckland is identified as a stronghold for a characteristic and declining carabid fauna. Analysis of the biotope preferences of these carabids reveals the importance of a previously unrecognised and currently unprotected 'traditional arable' biotope. Effective carabid conservation, at least in heathlands, must begin with baseline survey for carabids, independent of any pre-existing botanically-defined protected area system.

1. Introduction

Britain's heathlands are of international conservation significance, comprising about 18% of Europe's lowland heaths, yet they have suffered severe declines during the last 150 years (Farrell 1989, Webb 1986), through a variety of causes. Some of the losses have been due to the cessation of traditional management practices such as cutting, grazing and burning. This has lead to *Betula* scrub encroachment and ultimately succession to woodland. A high proportion of lowland heaths, especially in eastern England, have been afforested with non-native conifer species. A few areas, especially the cover-sand heaths of north Lincolnshire, have been lost to urban and industrial development. The habitat is recognised as a priority for conservation in the Annexes of the European Union's Directive on Habitats and Species. Despite this recognition, heathlands are often cited as examples of species-poor habitats which will become more diverse (but of lower conservation value) when damaged or degraded by human activity, including pollution. While this perception may be justified from a botanical perspective (Rodwell 1991), it is less true of invertebrates, for which heaths are notably important (e.g. Kirby 1993), and especially for carabids, which have a distinctive and comparatively species-rich fauna on most types of both dry and wet heathland (Webb 1986, Vermeulen 1993).

In this paper we aim to explore the conservation status of British lowland heathland carabids in eastern England. The results of an extensive baseline survey of heathland carabids, covering both a wide geographic range and a wide range of biotopes will

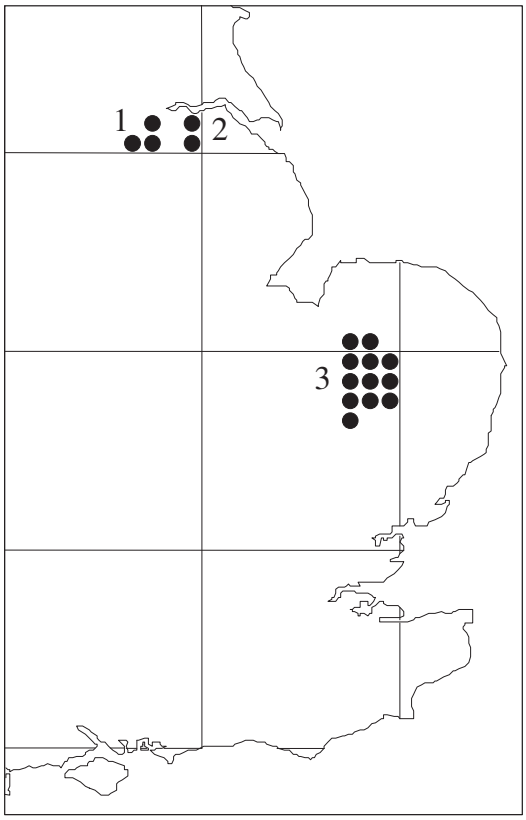

Fig. 1. The three areas of heathland studied in 10-kilometre squares of the national grid. 1 = Humberhead Levels, 2 = Lincolnshire cover-sand heaths, 3 = Breckland.

be used to assess the impacts of current conservation policy and practice upon them.

2. Biogeographic and habitat affinities of the eastern English heaths

Three components may be distinguished within the carabid fauna of British heaths: (a) lowland heathland, (b) upland moorland, (c) sand dune. Species have been assigned to habitats from the literature (Lindroth 1974, Turin *et al.* 1991) and field studies.

The lowland heath fauna, typical of areas of ericaceous scrub (*Calluna vulgaris* and *Erica* species) on sandy or peaty soils, is well represented in the heaths of southern England, especially Dorset, Hampshire and Surrey, and the mid-altitude moorland of North Yorkshire and the Pennines, and includes *Amara infima*, *Anisodactylus nemorivagus*, *Cicindela sylvatica* and *Pterostichus kugelanni*, with *Agonum sexpunctatum* in the wetter parts. One species, *Cymindis macularis*, is found only on the heaths of Breckland.

The upland moorland fauna, associated with *Calluna, Erica, Arctostaphylos*, and *Empetrum* is widespread throughout Scotland, and in the montane areas of England and Wales. It includes *Agonum ericeti*, *Bembidion nigricorne*, *Bradycellus collaris, Pterostichus adstrictus* and *Trichocellus cognatus*. There is also a boreo-montane group, including *Amara alpina*, *Leistus montanus*, *Nebria nivalis*, and *Patrobus septentrionis,* absent from eastern England; and two species associated with glacial moraine, *Miscodera arctica* and *Cymindis vaporariorum*, which are predominantly upland but occur in the Humberhead Levels (the latter so far only as a Bronze Age sub-fossil).

Several species, e.g. *Bradycellus ruficollis*, *Carabus arvensis*, *Carabus nitens*, and *Pterostichus lepidus*, are found equally in both lowland and upland heathland types.

British sand dunes support many heathland species, but also have a distinctive fauna including *Amara lucida*, *Amara spreta*, *Broscus cephalotes*, *Calathus mollis*, *Demetrias monostigma* and *Harpalus servus*.

3. The heathland study areas

We examine the fate of three areas of heathland in eastern England (Fig. 1). The Humberhead peatlands of Thorne and Hatfield Moors and the Lincolnshire cover-sand heaths are geographically adjacent, 17 km apart, but differ greatly in character. The Breckland of East Anglia is a larger region further south and east, which resembles the cover-sand heaths. All three areas support a rich and characteristic fauna and flora, with many nationally rare or scarce species (Perring & Farrell 1983, Hyman 1992).

The Humberhead Levels (area 1 in Fig. 1) is a low-lying (maximum altitude 3 m above sea level) area of river floodplain, dominated by acidic peatlands since the Bronze Age. The extent of these lowland raised mires has been reduced by drainage, peat cutting and agriculture over the past 500 years (Eversham 1992). The fauna and flora of the area has been thoroughly surveyed, beginning in the early 19th century, and changes through time can thus be assessed (Woodruffe-Peacock 1920–1921, Skidmore 1970, Skidmore *et al.* 1987). Much of the c. 3 000 ha of acidic peat which remains is partially drained, and now supports a heathland fauna, as well as species typical of raised mire (Eversham *et al.* 1995).

The cover-sands of North Lincolnshire (area 2 in Fig. 1) are periglacial windblown sands, which originally supported extensive areas of inland dunes and heathland. In the past 50 years, almost all of the heath has been lost to industrial development or conifer plantations. Several small fragments survive as nature reserves, and the largest area, Risby Warren, 170 ha, has more limited protection.

Breckland (area 3 in Fig. 1) comprises 940 km^2 characterised by light, usually sandy, freely-draining, infertile soils, and a semi-continental climate (low rainfall, high summer and low winter temperatures). Historical and pollen records indicate that most of this area was probably heathland from the arrival of early Neolithic settlers about 5 000 years ago (Dolman & Sutherland 1991). During the past century, much of the heathland has been converted to forestry and intensive, permanent arable agriculture; the remaining patches of heathland are fragmented and largely confined to protected areas. Habitat quality within intact seminatural habitats appears to have declined due to increased nutrient inputs, reduction in grazing, scrub and bracken encroachment, succession from *Calluna* to *Deschampsia flexuosa*, and reduction in soil disturbance; declines and local extinctions of populations of plants and birds are well-documented (Dolman & Sutherland 1992).

The three study areas contain all three biogeographic elements of the heathland carabid fauna. The Humberhead Levels in particular are noted for the co-occurrence of northern and southern elements in the British insect fauna (Skidmore *et al.* 1987); *Agonum ericeti* coexists with *A. sexpunctatum*, *Trichocellus cognatus* and *Bradycellus collaris* with *Bembidion humerale*, and *Miscodera arctica* with *Broscus cephalotes*.

4. Breckland: a case study

4.1. The Breckland carabid fauna and its affinities

The limits of Breckland in Fig. 1 encompass the area defined by soil type (Eversham & Telfer 1994). The area has been comparatively well recorded for several decades. The regional fauna is very well known, and a total of 167 carabid species have been recorded, from a British fauna of c. 350. Our recent more intensive sampling has added only a few species to the regional fauna, but these include two nationally rare species, *Amara fusca* and *Bembidion octomaculatum* (Telfer & Eversham 1994ab).

A high proportion of Breckland species are seed-eaters: *Amara*, *Harpalus* and *Bradycellus* species. This probably reflects the original character of the region, its light, sandy soils and perpetual disturbance favouring an annual or ephemeral flora, with a high seed production.

The Breckland carabid fauna has similarities with the faunas of coastal dunes, and other areas of inland lowland heaths, and with the areas of Cretaceous chalk in southern England. This highlights a distinctive feature of Breckland, although regarded as heathland, much of the soil is base-rich. Hence, the fauna includes calciphile carabids such as *Licinus depressus* and *Panagaeus bipustulatus*. The link appears to be thermophily and/or xerophily, though a few species, notably *L. depressus*, may be more dependent on calcareous soils to provide high densities of snails, its main food.

4.2. Changing status and biotope preferences of Breckland species

Historical data on carabids over much of Britain is relatively poor, but there is unpublished evidence for a decline in area of occupancy, and a contraction of ranges towards a core area in Breckland, in some species. Many of the most characteristic Breckland species appear also to be those suffering the greatest declines, both locally and nationally. Of the regional fauna of 167 species, 4 are Red Data species, and 30 are nationally scarce (Hyman 1992, Eversham & Telfer 1994, Telfer & Eversham 1994ab, and unpublished data).

Data on biotope preferences of Breckland carabids comes from a number of sources, chiefly our own surveys of a range of protected heathland sites (Sites of Special Scientific Interest), farmland sites, open areas of clear-felled conifer forestry and other sites within the Breckland landscape. Sampling has been carried out in 1993, 1994 and 1995, mainly from April to October, with limited survey work during the winter. Pitfall trapping, sweeping (which has been particularly productive at night) and direct searching, both by day and by night, have been used. In addition, data on particular sites has come from unpublished survey reports.

Using this information, we allocated the species of the Breckland fauna to 8 categories based on their biotope preferences, as follows: grass heath (Watt 1940, 1971), *Calluna* heath: in Breckland, a particularly dry, sandy facies with high percentage cover of lichens and bryophytes, sand dune: vegetated dunes are still visible on one site; blowing sands and mobile dunes once covered a large area of Breckland (Dolman & Sutherland 1991), 'traditional arable', modern arable, coniferous forestry plantation, wetlands, eurytopes.

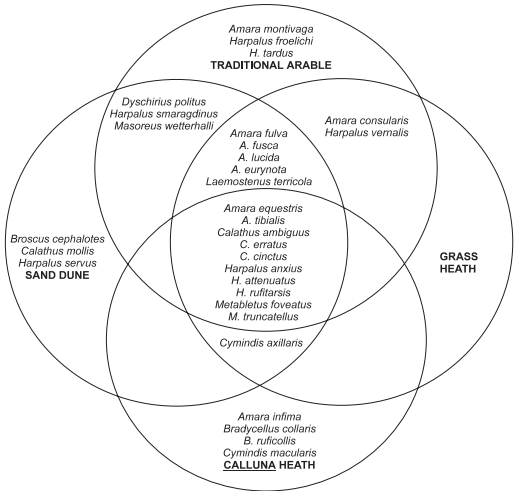

Fig. 2. Venn diagram showing habitat occupancy of the Breckland carabid fauna.

Because they are not relevant to this paper, wetland species are excluded from the analyses. A further set of species remains unclassified due to insufficient information.

Grass heath, *Calluna* heath and sand dune are familiar biotopes, which have figured in discussion of Breckland for the past 50 years. However, 'traditional arable' is previously unrecognised. Our sites in this category support a faunal assemblage which is not found together in the other classes of site, but the sites are not characterised in terms of altitude, soil moisture or soil pH. There are important differences in disturbance, soil temperatures, percentage of bare ground, and (unusually for carabids) vegetation composition. 'Traditional arable' sites are mechanically disturbed every year, they have low, usually sparse vegetation, a high proportion of bare ground, and a southern aspect, and so warm up rapidly in Spring. The flora is characterised by a succession of short-lived prolifically seeding annual plants; the flora as a whole produces a continuous supply of seeds of a range of sizes from early April until mid November each year. These characteristics we associate with features once typical of arable land before the advent of modern intensive farming practices: hence 'traditional arable'.

4.3. Geographic variation in biotope preferences

The biotope preferences of certain species in Britain are considerably narrower than those documented elsewhere. For example, *Calathus mollis* and *Broscus cephalotes* are found only on dunes, and are almost exclusively coastal in Britain, but occur more widely in dry sandy locations inland in Europe (Turin *et al*. 1991). This restriction in ecological amplitude toward the edge of a species' range has been widely documented but has been quantified in only a few species, mostly butterflies (Thomas 1991). It may be a more general example of the restriction of species to thermophilous microhabitats toward their northern range edge (Thomas 1993). However, for most species, the physical and vegetation characteristics of their habitats in Breckland agree closely with those summarised by Turin *et al*. (1991), and with individual studies elsewhere in Europe (e.g. Vermeulen (1993) in The Netherlands, Desender *et al*. (1987) in Belgium, and Kubach *et al*. (unpubl. data) in South-West Germany).

4.4. Conservation of the Breckland fauna

As discussed elsewhere (Eversham *et al*. 1996), species associated with modern arable land and with commercial forestry, and eurytopes, need no conservation. In the modern, radically-altered Breckland landscape, a few patches of heath remain. Most of these heaths are protected for their conservation value, and their management has been the subject of considerable research. While these reserves are undoubtedly representative of the predominant Breckland landscape of recent centuries, they do not support a rich, characteristic or threatened assemblage of carabids.

Few carabid species are exclusively associated with any one of the four seminatural biotopes of conservation value. Using presence/absence data, the overlapping biotope occupancies can be represented in a Venn diagram (Fig. 2). Sand dune species are of regional biogeographical interest as inland occurrences of these species are unusual. Unbroken or nearly complete grass swards, which include most of the heathland nature reserves and protected sites, are unproductive habitats for the carabidologist. No species is solely or predominantly found on grass heath, despite its greater areal extent and the intensity of recording effort it has received.

Traditional arable sites have the potential to conserve the majority of the Breckland fauna in these four open ground/heathland biotope categories (excepting only the sand dune and *Calluna* specialists). In addition, there is some evidence from pitfall trap-

ping that many of these species are considerably more abundant on the traditional arable sites than they are on grass heaths. This is not surprising given the difference in seed production between the sites. The use of heavy grazing regimes as management on heathland nature reserves has not been beneficial to carabids. The richest single site found in our survey has over 70 species, including 19 *Amara* and 13 *Harpalus* — probably the richest site for either genus in Britain.

Considerable carabid rarity and diversity is thus concentrated into a very few, small sites, which have so far been entirely unrecognised and consequently neglected by conservationists. In The Netherlands, small sites have been found to have as many species as large sites, but to contain fewer heathland stenotopes (De Vries 1996). Edge effects have also been shown to be significant in determining recorded diversity of the fauna of British heaths (Hopkins & Webb 1984). This is attributed to wanderers from adjacent biotopes that are nearer to the traps than they would be in larger sites. In Breckland, this appears not to be the case. Firstly, some of the richest small sites are several hundred metres from potential sources, and are separated by species-poor modern farmland. Secondly, many of the most stenotopic 'traditional arable' species are believed to breed at the sites, since tenerals and brachypters are found, often in large numbers (Eversham & Telfer 1994).

5. The future of heathland carabids in eastern England

Botanically determined site selection and management criteria do not appear to benefit many of Breckland's carabids: site selection appears to have been based on an expectation that a readily-defined vegetation community such as heathland must be of more value than (equally distinctive) ruderal communities which are outside of many vegetation classifications (e.g. Tansley 1939, Rodwell 1991). The range of habitats on the Lincolnshire cover-sand heaths is similar to Breckland. The richest areas here, with dense populations of scarce stenotopic species such as *Cymindis axillaris* and *Harpalus smaragdinus*, have an impoverished flora dominated by annual and ephemeral plants.

In peatlands, too, the targets for nature reserve selection and management are usually botanical and/or hydrological (Ratcliffe 1977, Joint Nature Conservation Committee 1994). For instance, the key targets at Thorne and Hatfield Moors are currently to increase the cover of *Sphagnum* and *Eriophorum* species, and to reduce or eliminate *Betula* and *Pteridium*. Although this may be ideal for the most stringent bog species, such as *Agonum ericeti*, it would require too high a water table for the survival of *Bembidion humerale* (for which the Humberhead peatlands are the only British sites), and of most of the wet-heath and dry-heath fauna.

The value of botanical criteria in evaluating and monitoring a species-poor habitat such as acid peatlands is debatable: a recent survey of Hatfield Moors found 6 species of vascular plant, and 8 of bryophyte and lichen, in a 4 m^2 quadrat, all of which were nationally common. A single pitfall trap and a water trap in the same quadrat produced 346 species of insects, of which one species was new to Britain, 3 endangered (Red Data Book category 1) and 15 nationally scarce species (P. Skidmore, unpublished), including three rare/scarce carabids (*Bembidion humerale*, *Agonum ericeti* and *Trichocellus cognatus*). Given the impoverished flora of many heathlands and moorlands, it is not surprising if botanical criteria are unable to distinguish between the finer gradations of invertebrate microhabitats.

Baseline invertebrate survey should not be restricted to existing protected areas, which will usually have been selected using botanical criteria. In the heathlands of eastern England, the important vegetation parameters for carabids appear to be the phenology of seed production and seed size diversity. For many carabid assemblages, the important features of the environment are likely to be soil properties and the disturbance regime, rather than the vegetation *per se*.

A comparative assessment of the carabid assemblages of a range of heathland sites in relation to these physico-chemical factors is essential for a more accurate understanding of the environmental requirements of these assemblages. Once such a study has been completed, management prescriptions can be drawn up.

The conservation interest of heathlands for invertebrates is widely recognised, but conservation action targeted at heathland invertebrates is rare. In eastern England, botanically-guided selection and management of heathland conservation sites has failed to protect a significant proportion of the carabid fauna. Just as botanical conservation is of limited

benefit to carabids, carabids cannot necessarily be regarded as a proxy for all invertebrates: they serve to demonstrate the complexities of invertebrate conservation. Conservation of the entire carabid fauna of a heathland landscape will necessitate specific carabid conservation measures.

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