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Hand collection as a method for assessing the community structure of carabid beetles

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ABSTRACT

Pitfall trapping is widely used to estimate population density in carabid beetle communities, but overestimates densities of large bodied species relative to smaller ones because large species move more around. The aim of the study was to test whether abundance estimates from hand collection (collection without area fixing and washing of the substratum) is less subject to such body size-related bias. This was addressed by comparing slopes of size-abundance relationships using data from hand collection with slopes estimated from pitfall trapping data. The material consisted of 246 carabid species and more than 63,000 individuals sampled in 11 habitat types. For epigean carnivores, size-abundance slopes based on hand collection data were significantly more negative than those based on pitfall trapping. This shows that population density estimates from hand collection is less subject to the size-related bias associated with pitfall trapping for this group. Hand collection slopes for epigean carnivores were also similar to slopes found using quadrate sampling in a habitat type where this method had been performed. They were also not different from the theoretical value of −0.75 predicted from the energetic equivalence rule in 5 of the 11 habitat types sampled. This suggests that epigean carnivore population density estimates from hand collection may indeed be unbiased regarding body size in many habitat types. Further studies are needed to clarify how extensively this applies. The analyses also show that hand collection underestimates densities of fossorial carnivores regardless of habitat type and overestimates densities of large bodied epigean carnivores in habitat types where large hiding objects are abundant. For phytophages, no significant differences were found between the performance of hand collection and pitfall trapping.

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1. Introduction

Pitfall trapping has been widely used to assess the abundance of species in beetle communities (Thiele, 1977; Arneberg and Andersen, 2003). With pitfall traps, individuals are captured by actively moving into them. The approach has been criticized because it tends to overestimate the abundance of active species relative to that of less active ones (Arneberg and Andersen, 2003; Hancock and Legg, 2012). Due to low costs and ease of use, pitfall traps are, however, still widely used to estimate relative population abundance in interspecific studies of beetle communities. For example, based on pitfall trap data, Ulrich et al. (2005) claimed that the relationship between body weight and population abundance in carabid communities is actually positive, despite clear evidence that such findings are indeed sampling artefacts caused by overestimation of abundance of large bodied species (Arneberg and Andersen, 2003). Other recent examples include the use of pitfall trap data to estimate ground beetle species biomasses as part of environmental monitoring (de los Santos Gómez et al., 2014) and to identify common species for further studies of influence of forest management practices on carabid beetle communities (Iglay et al., 2012).

Quadrate sampling as performed by e.g. Andersen (1995) does not suffer from the bias associated with pitfall trapping, as to a fair approximation all adult individuals in a given area are registered. However, quadrate sampling is cumbersome and alternative methods are therefore also needed. Here, we evaluate the use of a method based on hand collection for estimating carabid beetle abundance. The method is performed by collecting all beetles

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found within arbitrarily defined areas, and requires substantially less effort and resources than quadrate sampling and other area based methods.

Because activity can generally be expected to correlate positively with body size (see discussion in Hancock and Legg, 2012), we base the evaluation on analyses of relationships between body size and abundance. A positive correlation between activity and body size means that there will be a tendency for density of large bodied species to be overestimated compared with smaller ones when pitfall traps are used (Gaston, 1988; Spence and Niemelä, 1994; Andersen, 1995). Indeed, Hancock and Legg (2012) found that variation among species in body mass accounted for 78% of variation in sampling bias in arthropod abundance from pitfall traps. Such size related bias will lead to estimation of too positive slopes of the relationships between size and abundance when using data from pitfall traps. As expected from this, Arneberg and Andersen (2003) found that in carabid communities, slopes were significantly more positive when using data from pitfall traps compared with slopes estimated using data from quadrate sampling.

Thus, to assess whether hand collection is less subject to the size related bias associated with pitfall trapping, we test whether slopes of size-abundance relationships are more negative when based on data from hand collection than from pitfall trapping. Hand collection is also to some extent compared with results from quadrate sampling. The analyses are based on a large database collected by the first author over more than four decades, covering a range of habitat types and representing collection of more than 63,000 individuals from a total of 246 species.

In addition to testing for differences between the two sampling methods in slopes of size-abundance relationships, the theoretical value expected from the energetic equivalence rule is also considered. According to this rule, population density will be related to body mass with a slope of −0.75 on logarithmic scales if the rate of population energy use is independent of species body mass (Damuth, 1981). From the large number of studies that have been performed in various animal species assemblages, it appears that slopes often fall around −0.75 (e.g. Damuth, 1981, 1987, 2007; Arneberg et al., 1998), in particular when a common resource base is shared (Jennings and Mackinson, 2003; Hechinger et al., 2011). In agreement with this, Arneberg and Andersen (2003) found that slopes did not deviate from −0.75 on log- log scales in local carabid beetle communities when they were estimated by using quadrate sampling data, but were significantly more positive when using data from pitfall traps. Thus, here we assess whether density estimates from hand collection indeed appear to be unbiased with respect to body size by comparing slopes of size-abundance relationships with the value of −0.75. When doing this, we acknowledge that real slopes of size-abundance relationships may differ from −0.75 in a community type if important factors favour either small or large bodied species or if a common resource base is not shared by the species considered. We thus pay notice to whether such factors may operate in any of the community types sampled.

There are great differences in behaviour, habitat selection and other aspects of ecology among carabid species (Thiele, 1977; Lindroth, 1985, 1986). We acknowledge that hand collection is not expected to perform equally well across all this variation. In particular, densities of hypogean/fossorial species are expected to be underestimated relative to surface active ones because no complete examinations of the substratum are made when hand collection is performed. In addition, in habitat types where large objects such as stones are frequent, abundance estimates of species that typically aggregate under such objects may be biased. To identify limitations of the method, these issues are addressed in the analyses of the data.

2. Materials and methods

2.1. Study areas and habitats

The study comprises 210 sites in a total of 130 localities situated in Scandinavia between Ebeltoft in Denmark (56.2°N) and Alta in Finnmark county, Northern Norway (70.0°N). Two localities and three sites in Cascais (38.7°N) in Portugal were also included. The climate varies much with place and the localities cover most of the vegetational zones of Europe: The mediterranean (evergreen) forest zone (Portugal), the nemoral zone (Denmark and parts of the

Table 1
Characteristics of the investigated habitats. Vegetation coverage is according to the scale of Hult-Sernander. Information about ecological requirements of plants is according to Lid and Lid (2005) and Mossberg and Stenberg (2007).

Habitat	Soil type	Moisture	Vegetation coverage, height	Notes
A. Exposed freshwater (rivers, stagnant water) shores	Solid, mineral soil	Wet–mesic	1–5, mostly low	Subdivided according to substratum and vegetation coverage
B. Exposed, stagnant fresh water shores, reeds in water	Organic soil, soft, muddy or peaty	Watery–moist	2–5, mostly low	Eutrophic-mesotrophic Without large objects.[d] Hydrophytes
C. Sea shores	Clayish/silty or sandy	Wet–moist	1–3, low medium	Salt- brackish water, partly submerged by high tide. Without large objects.[d] Halo- phytes
D. Forests. Deciduous[a], mixed, coniferous				
(1)	Mull or podzol	Mesic–dry	1–4, variable	Without large objects[d]
(2)	Mull or podzol	Wet–moist	1–3, variable	Without large objects[d]
(3)	Mull or podzol	Moist–mesic	1–4, variable	With large objects[d]
E. Supralittoral dunes, heaths[b], garigue. Close to sea	Sand	Very dry	2–4, low medium	Natural, seminatural. Large objects[d] scarce or absent.[c] Xeric vegetation
F. Meadows, screes	Thin humus over small stones, gravel and sand	Very dry	2–5, variable	Naturally open, or open due to grazing. Large stones often abundant. Xeric vegetation.
G. Open, anthropogenic habitats (fallow fields arable land, sand pits)				
(1)	Sand, silt, clay	Dry	1–5, variable	Large stones often abundant. Ruderal plants frequent
(2)	Sand, silt, clay	Mesic	1–5, variable	Large stones frequent in some sites
(3)	Sand, silt, clay	Wet–moist	1–3, mostly low	Large objects[d] scarce. Hygrophilous plants dominate.

[a] Evergreen in Portugal.
[b] Dominated by *Calluna vulgaris*.
[c] On garigue in Portugal locally abundant.
[d] Larger stones, pieces of wood or bark etc.

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