Agriculture, Ecosystems and Environment 165 (2013) 60–67

Contents lists available at SciVerse ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Crop, field boundary, productivity and disturbance influences on ground beetles (Coleoptera, Carabidae) in the agroecosystem

M.D. Eyre[a,*], M.L. Luff[b], C. Leifert[a]

[a] Nafferton Ecological Farming Group, University of Newcastle upon Tyne, Nafferton Farm, Stocksfield, Northumberland, NE43 7XD, UK
[b] School of Biology, Ridley Building, University of Newcastle upon Tyne, Newcastle upon Tyne, NE1 7RU, UK

ARTICLE INFO

Article history:
Received 18 July 2012
Received in revised form
12 December 2012
Accepted 13 December 2012
Available online 19 January 2013

Keywords:
Invertebrates
Arable
Grasslands
Organic farming
Conventional farming
Ecosystem services

ABSTRACT

Ground beetles were sampled in nine crops and four field boundary types on a split conventional/organic farm in northern England in the five years 2005–2009. Multivariate analyses indicated that a combination of crop type, management and boundary type influenced ground beetle species and group activity. Short vegetation boundaries with bare ground had similar activity, mainly of small species, to that in organic arable crops, contrasting with activity in conventional arable and more densely vegetated boundaries. Large, medium-sized, herbivorous and Collembola feeding species all had considerable activity in oilseed rape and activity was generally greatest in conventional arable crops but least in conventional grass. Disturbance and productivity estimations provided basic insights into ground beetle activity. Most small and medium-sized species were found in areas with low productivity but high and low disturbance, respectively. Large and Collembola feeding species were most active in highly productive areas with medium and low disturbance whilst most herbivorous species preferred medium values of both drivers. In crops, species richness was greatest in organic beans and conventional oilseed rape and lowest in conventional grass. There were more species in short vegetation boundaries than in more densely vegetated field edges. There may be potential for the use of productivity and disturbance estimations in the provision of ecosystem services, especially in assessing the conditions required to optimise ground beetle activity for pest control.

1. Introduction

Ground beetles (Carabidae) are an invertebrate group of mainly generalist predators, abundant throughout most agroecosystems (Holland et al., 2005) and thought to be an important group of beneficial insects contributing to restricting pest activity (Symondson et al., 2002), an attribute especially relevant in organic and low-input systems (Landis et al., 2000). Agricultural management intensity has been shown to have had a considerable influence on the distribution of ground beetle species assemblages (Cole et al., 2002), brought about by differences in physical and chemical inputs, in the crops grown and because of environmental enhancement.

Crop diversity is greater in organic systems than in conventional (Norton et al., 2009), and crop type influences both ground beetle assemblage distribution and species activity (Hummel et al., 2002), with Weibull and Östman (2003) reporting greater activity differences between cereal and grass fields than between different cereals. Increased weed cover in organic crops has been shown to influence ground beetle activity (Navntoft et al., 2006) whilst the extent and type of non-crop habitat, together with wider landscape variation, have been shown to influence both activity and species richness in the agroecosystem (Schweiger et al., 2005). The provision of ecosystem services by ground beetles has become one of the potential advantages of agri-environment schemes (Whittingham, 2011) with, generally, the provision of appropriate non-crop habitat, including beetle banks (MacLeod et al., 2004), especially relevant in organic systems (Landis et al., 2005). Early comparisons of ground beetles in organic and conventional management systems, generally in wheat, reported more activity in organic crops (Mäder et al., 2002) but further work showed few differences (Purtauf et al., 2005). Bengtsson et al. (2005) concluded that, in general, predatory insects react positively to organic farming but Hole et al. (2005), investigating the effects of organic farming on biodiversity, found that methodological problems and differences in approach made attempting any definitive conclusions concerning invertebrates difficult.

Agricultural management intensity influences ground beetle species distributions, with species of intensively managed areas differing in size, dispersal ability and life history from those found in less managed landscapes (Ribera et al., 2001). These traits are examples of adaptations to a product of disturbance and productivity

* Corresponding author. Tel.: +44 1661 830222; fax: +44 1661 831006.
E-mail addresses: M.D.Eyre@ncl.ac.uk, mickeyre@blueyonder.co.uk (M.D. Eyre).

0167-8809/$ – see front matter
http://dx.doi.org/10.1016/j.agee.2012.12.009

and have been used in habitat templates (templets), delineated by environmental conditions and biotic interactions (Korfiatis and Stamou, 1999). Management differences between organic and conventional farming, such as the crops grown and different sowing times, are likely to influence both basic drivers. Half of Nafferton Farm, in northern England was converted to organic status between 2001 and 2004 and provides a situation within which to compare how management differences and non-crop habitat influence invertebrate distribution and activity in a landscape dominated by conventional farming. Ground beetle species data were generated in the five years between 2005 and 2009 and since ground beetle size has been related to agricultural management intensity, the numbers of large, medium-sized and small species, as well as herbivorous and Collembola feeding species, together with species richness, was also calculated. These data were used to assess the effects of crops and non-crop cover on species activity, as well any relationships between cropped and field boundary areas. Ground beetle distribution in the wider environment is influenced by site productivity and disturbance (Eyre, 2006). Indices reflecting these basic drivers were generated for the sample sites on the split management farm surveyed to investigate an overall approach contrasting with the more usual work where effort is concentrated on assessing limited and specific effects on ground beetles.

2. Methods

Nafferton Farm in south Northumberland, managed by the University of Newcastle upon Tyne, was a typical mixed commercial conventional farm in northern England with a dairy herd and mixed cropping of arable and grassland until 2001, when conversion to organic farming of 160 ha of the 320 ha farm commenced. Half of the farm was fully organic in late 2004. The crop rotation on the conventional half of the farm was limited to winter wheat, winter barley, oilseed rape and grass with more variation on the organic half. Beans were used to improve soil fertility, generally before spring wheat or potatoes. Spring barley on the organic half was undersown with grass/clover and all grass and grass/clover fields were used for silage production. All arable crops on the conventional half were sown in the autumn of the previous year with those on the organic half sown in spring of the harvest year. Inorganic fertiliser was applied to conventional crops, compost and slurry to organic. Herbicides and fungicides were used on conventional arable crops but no sprays were used on organic crops. More details on the fields, crops, sprays and fertilisers are given by Eyre and Leifert (2011).

2.1. Sampling and data generation

Pairs of sampling points were used in crops, one in the edge at 5 m from the boundary, into the field, and one in the centre of the field. The field boundary nearest to the crop edge sampling points was also sampled at the same time. At each sample point (in crops and boundaries), lines of 10 pitfall traps (8.5 cm diameter, 10 cm deep), 0.5 m apart and part-filled with saturated salt (NaCl) solution containing a small amount of strong detergent as a preservative, were used. In crops, there were 42 sampling points in 2005, 60 in 2006, 64 in both 2007 and 2008 and 72 in 2009, a total of 302. Fifty-four sampling points were in grass/clover in the five years, 38 in spring wheat, 20 in spring barley, 34 in beans, 20 in potato, 32 in conventional grass, 48 in winter wheat, 32 in winter barley and 24 in oilseed rape.

The field boundary covers were short herbaceous vegetation (usually grassy with forbs, such as dandelion *Taraxacum*, to a height of 0.5 m), tall herbaceous vegetation (generally 1–1.5 m high with tall grasses and forbs, mainly nettles *Urtica* and thistles *Cirsium*), hedges (mainly hawthorn *Crataegus*) and woodland (mainly coniferous). A number of field boundaries were shared between fields and there were a total of 32 sampling points in short herbaceous vegetation boundaries, 24 in tall herbaceous vegetation boundaries, 26 in hedge boundaries and 48 in woodland boundaries, a total of 130.

The traps were set in the first week of May in all years and five monthly samples were generated. The pitfall trap samples were sorted in the laboratory and ground beetles kept in 70% industrial methylated spirit and then identified to species. Nomenclature followed Luff (2007). Species richness was used as a measure of diversity since indices such as that of Shannon have proved to be of questionable use in agricultural studies (Eyre and Leifert, 2012). The numbers in the genera *Amara*, *Curtonotus* and *Harpalus*, known to eat seeds (Luff, 2007), were summed to provide a herbivorous group. Species in the genera *Loricera* and *Notiophilus* were also summed to provide a Collembola feeding group. Previous studies reported that body size of ground beetle species body was correlated with agricultural activity and so the remaining species were split into three size groups, based on length, for analyses. These were small (5 mm and less), mainly in the genera *Bembidion* and *Trechus*, medium-sized (5–10 mm), mostly comprising species in the genera *Agonum*, *Anchomenus*, *Leistus* and *Pterostichus strenuus* and large (>10 mm), made up mainly of the other species of *Pterostichus* and *Nebria brevicollis*.

To generate a representative idea of the field boundary structure nearest to sampling points, the area of four cover types was used. The area of each boundary cover (short herbaceous, tall herbaceous, hedges, woodland) 25 m from the middle of the boundary sampling point, to either side and behind, was calculated. Weather parameters on the farm were monitored using a Delta-T Weather Station (Type WS01) situated near the centre of the farm. Daily measurements were used to generate mean air temperature values and to ascertain total rainfall for each sampling period in each year.

2.2. Productivity and disturbance indices

Ground beetle distributions are known to be affected by basic influences, related to productivity and disturbance (Eyre, 2006). It was assumed that the most productive areas on the farm were the conventional fields, with regular application of readily available nutrients, especially nitrogen, as inorganic fertiliser. Organic crop yields tend to be approximately one-half to two-thirds that of conventional crops (Leifert et al., 2007) since the compost and slurry applications to organic fields provide fewer available nutrients (Garratt et al., 2011). Soil samples from each sampling point were dried at 105 °C for 24 h and nitrogen content determined using a micro-Kjeldahl procedure. The nitrogen content (mg kg^{-1}) of each conventional field sample was multiplied by three and each organic sample by two, given the differences in nutrient availability, whilst the values for the boundary sites were not adjusted. These values provided a productivity index within the landscape, ranging from the unproductive field boundaries to the most productive conventionally fertilised fields.

Disturbance on the farm was assumed to be related to crop and management effects on vegetation cover and structure. The areas of bare ground and of vegetation cover less that 1 m in height, between 1 and 2 m and over 2 m was estimated to the nearest 10% in an area of 10 m surrounding each sampling point in the first week of May, June and July in each sampling year. These data were then ordinated using detrended correspondence analysis (DCA) and the sampling point scores on axis 1 of the ordination were used a disturbance index, ranging from woodland field boundaries to some of the organically managed fields.