Agriculture, Ecosystems and Environment 139 (2010) 500–507

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Influence of agronomic practices, local environment and landscape structure on predatory beetle assemblage

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A R T I C L E   I N F O

Article history:
Received 15 March 2010
Received in revised form 6 September 2010
Accepted 7 September 2010
Available online 14 October 2010

Keywords:
Agronomic practices
Ground and tiger beetles
Landscape structure
Local environment
Non-crop areas
Variation partitioning

A B S T R A C T

In this study, two main hypotheses were tested: (1) whether landscape structure explains a greater part of the variation in predatory beetle assemblage than agronomic practices and local environment; and (2) whether non-crop areas and landscape heterogeneity have a positive effect on predatory beetle abundance and diversity. Ground and tiger beetles were sampled in ditch borders adjacent to 20 cornfields in 2006 and 2007 in Quebec (Canada). For each site, agronomic practices performed in the border and adjacent field, local border characteristics and landscape cartography (at 200 and 500-m radii) were measured. Compared with agronomic practices and the local environment, landscape structure was globally the main factor driving predatory beetle abundance and diversity, explaining 7.9–24.6% of the variation (unique contribution) depending on the variable and year. In most cases, non-crop areas and landscape heterogeneity had a positive influence on predatory beetle abundance and diversity. Our results showed that variables acting at large scales represent an essential factor influencing predatory beetle assemblage and they validate the importance of conserving non-crop areas and landscape heterogeneity in agricultural landscapes.

1. Introduction

In agroecosystems, natural pest control depends on field colonization by natural enemies from non-crop areas (Wissinger, 1997; Tscharntke et al., 2005). Many studies found that ground beetles, rove beetles and spiders are efficient biological control agents that are directly responsible for aphid mortality in fields (Östman, 2004; Schmidt et al., 2004; Van Alebeek et al., 2006). Ground beetles, in particular, consume a large variety of crop pest (Thiele, 1977; Kromp, 1999; Sunderland, 2002) and are often used as bioindicators to assess the impact of farming methods (Kromp, 1990) or environmental disturbances (Luff, 1996; Rainio and Niemelä, 2003).

Several studies have shown that ground beetles are influenced by agronomic practices (Hance and Grégoire-Wibo, 1987; Kromp, 1999; Holland and Luff, 2000), generally with a greater abundance or diversity in less intensive land-use systems or systems with reduced chemical input (Attwood et al., 2008). For instance, ground beetle assemblage is influenced by the farming system (organic versus conventional farm), usually showing greater abundance and diversity in organic farms (Kromp, 1989; Cárcamo et al., 1995; Bengtsson et al., 2005). In addition, ground beetle assemblage can be affected by crop rotation and land use (Booij and Noorlander, 1992; Ellsbury et al., 1998; Dauber et al., 2005), tillage (Cárcamo, 1995; Menalled et al., 2007; Nash et al., 2008), fertilization (Söderström et al., 2001) and the use of pesticides (Ellsbury et al., 1998; Epstein et al., 2001; Nash et al., 2008). Regarding seed characteristics, the effect of genetically modified plants on non-target organisms such as ground beetles is not clear (Floate et al., 2007). However, it has been found that ground beetles are actually exposed to the Bt toxin (Zwahlen and Andow, 2005).

On a local scale, the characteristics of field borders (vegetation composition, richness and width) and border management (mowing and/or fertilization) can explain differences in ground beetle assemblage in the border region (Sotherton, 1985; Woodcock et al., 2005, 2007; Griffiths et al., 2007) as well as in the adjacent field (Lys et al., 1994; Varchola and Dunn, 2001). For instance, Van Alebeek et al. (2006) found twice as many ground beetles in uncut field borders than in bare soils, providing evidence for the need to conserve the vegetation beside fields.

Beyond the local scale, it has been found that ground beetles can be affected by landscape structure independently of farming practices (Purtauf et al., 2005a). Many studies involving landscape have underlined the positive effect of non-crop areas (Purtauf et al., 2005a; Werling and Gratton, 2008; Perovic et al., 2010) and landscape heterogeneity (Weibull and Östman, 2003; Weibull et al., 2003; Ekroos et al., 2010) on ground beetle assemblage. In particular, Dauber et al. (2005) showed that ground beetle richness was positively correlated with the length of forest edges, and Hendrickx

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0167-8809/$ – see front matter
doi:10.1016/j.agee.2010.09.008

et al. (2007) showed that ground beetle diversity increased with the proximity of semi-natural habitat patches, confirming the need to conserve non-crop areas in agricultural landscapes.

Few studies have integrated different factors and scales to understand ground beetle assemblage (Weibull and Östman, 2003; Aviron et al., 2005; Schweiger et al., 2005), and there is still much uncertainty about which of these factors influence the assemblage of ground beetle communities. Moreover, given that most rural landscapes are perturbed by human activities, it is also crucial to quantify the impacts of anthropic variables. Therefore, the aim of this study was to understand the relative effects of agronomic practices, local environment and landscape structure on predatory beetle abundance and diversity (Coleoptera: Carabidae and Cicindelidae). First, we hypothesized that ground and tiger beetle abundance and diversity were more strongly influenced by landscape structure than by agronomic practices and local environment. Second, we wanted to verify whether ground and tiger beetle abundance and diversity were positively related to non-crop areas (fallow, woodland, border, riparian vegetation) and landscape heterogeneity (richness and diversity), as mentioned in previous studies.

2. Methods

2.1. Study area and sampling

The study was conducted in the Vacher creek watershed (Lanaudière, Quebec, Canada), located approximately 40 km northeast from Montreal, covering 69 km^2 and including the town of Saint Jacques (45°56′N, 73°34′O) and Sainte Marie Salomé (45°55′N, 73°29′O) (Domon et al., 2005). The Vacher creek watershed present landscapes with different land use configurations (Ruiz et al., 2008) and as a consequence, sampled sites were positioned throughout the entire watershed so that we could assess the potential effects of these configurations on predatory arthropods. Twenty sites were sampled in the watershed during the summers of 2006 and 2007, each site representing a ditch bordering a cornfield. We considered as field borders any elements that represented a limit between a field and another landscape element (e.g., simple herbaceous field margins, hedgerows, woody borders or ditches).

Ground and tiger beetles were collected weekly from the beginning of June until the end of September in 2006 and 2007, covering a span of 16 weeks over a period of two years. These sampling periods allowed us to collect both autumn-breeding and spring-breeding species, maximizing the representation of ground and tiger beetle abundance and diversity. A total of 80 pitfall traps (four traps per site, 20 sites) were installed each year. Pitfall traps consisted of Multipher I traps (⌀ 12.5 × H 24 cm) used without pheromone. A cover (⌀ 26 cm) was used to avoid water entering the trap and to limit the access to small mammals. Four openings (2.6 cm × 8.4 cm) allowed ground and tiger beetles to fall inside the traps. Traps were buried in the ground so that openings were at the ground level, and they were placed in the edge of the ditch, between the ditch and the field margin. The first trap was placed at approximately 10 m from the beginning of the field, and the other traps were placed every 10 m along a transect parallel to the ditch. A plastic container filled with approximately 100 ml of propylene glycol (car antifreeze with low toxicity) diluted with water (1:1) was placed inside each trap to preserve insects. Due to identification logistics, only ground and tiger beetles sampled every other week were identified to species based on Larochelle (1976), with Agriculture and Agri-food Canada's expert confirmation.

2.2. Agronomic practices

Agronomic descriptors included variables regarding the studied field border (ditch) and the agronomic practices conducted in the field next to it (see Appendix A for details of all the descriptors). Because we focused on ground-dwelling predators, soil characteristics and soil perturbations were considered as well. Border descriptors included soil type (sand, loam-clay, clay) and binary codes describing whether the border was mowed or not during the season. Regarding the cornfield, seed characteristics included corn heat unit (C.H.U.) that serves as a proxy for corn precocity. In order to determine whether genetically modified corn could influence ground and tiger beetles, two variables were taken into account: corn borer resistance (i.e., Bt corn) and herbicide tolerance. We also considered descriptors linked to the agronomic practices performed in the cornfield included crop rotation (i.e., whether or not the field was cultivated with crop other than corn in the previous year), sowing date, sowing rate, soil perturbation which included the type of tillage (superficial vs deep) and hoeing, soil fertilization (organic fertilization, post-emergence fertilization, quantity of nitrogen, potassium and phosphorus applied to the field) and phytosanitary treatment, including the type of herbicide used (amino acid, sulfonylurea, triazine) and the application date. In 2007, three agronomic descriptors were added due to changes in relation to 2006: the practice of direct-sowing (not performed in 2006) involved three categories of variables for tillage instead of two (direct sowing, superficial tillage and deep tillage), the application of pre-sowing mineral fertilizer (pre-sowing fertilization) and the addition of one group of herbicides (other herbicide). In total, 21 agronomic variables were estimated in 2006 and 24 in 2007. Note that no insecticide or fungicide was applied to the fields during the two-year study period.

2.3. Local environment

Local environment included descriptors related to the sampled ditch, the cornfield adjacent to the ditch (=focal field) and the landscape element located on the other site of the ditch (see Appendix B). The following local characteristics were measured regarding the ditch: width, tree presence, creek presence and vegetation richness. Data from the cornfield next to the border included field area and spatial orientation. Finally, the type of landscape element located on the other side of the ditch was characterized (corn, fodder crop, other crop, fallow, woodland or road). In 2007, none of the studied borders was located next to a road, so the road variable was removed from the local descriptors in 2007. Overall, 12 local variables were estimated in 2006 and 11 in 2007.

2.4. Landscape structure

Aerial photos of the Vacher creek watershed, dated from 1998, were obtained from the Minister of Environment du Québec (MDDEP) and were updated using information gathered directly in the field. Circles of 200 and 500-m radii were plotted around each site to delimit landscape descriptors. Only three descriptors were not measured at the 200-m level (see Appendix B) as these variables were based on the entire field which extension expands beyond 200 m. In 2006 and 2007, landscape composition within each circle was determined by field observation. Then, spatial analyses of landscape structure (composition and configuration) were performed using MapInfo (ESRI, 2000) and ArcGIS (ESRI, 2005). Regarding landscape composition, the areas of the different landscape elements were calculated at both scales (200 and 500 m): corn, leguminous crop (soybean or beans = bean), cereal (wheat, barley, oat or mixed cereals), fodder crop (grass, alfalfa, clover or mixed fodder), other crop (potatoes, berries or other vegetable crops), fallow, pasture, woodland, riparian vegetation, water (pool, creek or river), constructed area, road or path and sand pit. Landscape heterogeneity at 200 and 500 m was evaluated by landscape richness, representing the number of different landscape elements