Ecological Indicators 67 (2016) 297–305

Contents lists available at ScienceDirect

Ecological Indicators

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

Testing the effectiveness of surrogates for assessing biological diversity of arthropods in cereal agricultural landscapes

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ARTICLE INFO

Article history:
Received 7 August 2015
Received in revised form 28 January 2016
Accepted 16 February 2016
Available online 25 April 2016

Keywords:
Arthropod biodiversity
Cereal pseudo-steppes
Mediterranean landscape
Species richness
Surrogate taxa
Wheat

ABSTRACT

Agricultural intensification is altering biodiversity patterns worldwide. Rapid and effective methods are needed to monitor these changes in farmland biodiversity, but it becomes both a cost- and time-prohibitive task, particularly for hyper-diverse groups such as arthropods. We evaluated the effectiveness of surrogates in irrigated and rainfed wheat fields in a Mediterranean farmland in NW Spain in order to get a rapid tool to assess arthropod biodiversity. We studied six groups with different ecological needs (i.e. Aphididae, Aphidiinae, Coccinellidae, Formicidae, Heteroptera and Syrphidae) at species level (147 species), genus (105), family (10, only Heteroptera) and order (19) level. Higher taxa, cross-taxa and subset-taxa or total richness approaches were tested as well as the correlation in composition between levels for the selected groups, and the influence of farming regime. Genus richness was a good surrogate of species richness in all six groups studied (R^2 = 0.38–0.60), like family and order were for Heteroptera (R^2 = 0.37 and 0.29, respectively). Cross-taxa analyses showed that Aphididae and Aphidiinae genera (R^2 = 0.19 and 0.30, respectively) and species (R^2 = 0.20 and 0.28, respectively) were good surrogates for Aphidiinae and Aphididae species respectively. Coccinellidae genera (R^2 = 0.26) and species (R^2 = 0.25) were good surrogates for Heteroptera species. Finally, Aphididae and Coccinellidae both at genera (R^2 = 0.14 and 0.20, respectively) and at species levels (R^2 = 0.12–0.22, respectively) were good surrogates for total species richness of all groups. Genera composition was the best surrogate for the species composition within each group. Farming regime had no influence on the relationships between surrogates and species patterns in most cases. Our results suggest that genera level is a useful surrogate for all the studied groups and family is appropriate for Heteroptera. Genus level provided a saving of 15% of identification time in Aphidae and 80% for Coccinellidae. This proves its usefulness to asses and monitor biodiversity in wheat croplands and the possibility to reduce costs.

1. Introduction

Agricultural intensification can increase crop production but causes biodiversity loss worldwide (Robinson and Sutherland, 2002; Tilman et al., 2002; Benton et al., 2003; Kleijn and Sutherland, 2003; Green et al., 2005; Wilson et al., 2010). Irrigation is commonly carried out to enhance agricultural production (van der Velde et al., 2010) but at the cost of converting vast areas of dry extensive cereal agroecosystems into irrigated areas (e.g., in Spain; MAGRAMA, 2013). Irrigation negatively affects birds (Tella and Forero, 2000; Brotons et al., 2004; Laiolo, 2005; De Frutos and Olea, 2008), but its effects on other important agricultural fauna such as arthropods are little known (but see González-Estébanez et al., 2011 for butterflies; Pérez-Fuertes et al., 2015 for other arthropods).

Arthropods are apparently declining even faster than vertebrates and plants (Thomas et al., 2004), urging to find rapid methods to assess and monitor arthropod biodiversity in agricultural systems specially now with the new Common Agricultural Policy 2014–2020 (CAP 2014–2020; Official Journal of the European Unión, 2013). Arthropods are essential for ecosystem functioning of agro-ecosystems, providing valuable services such as pollination, pest control, plant productivity, nutrient recycling and a food source for other animals (Daily et al., 1997; Wilson et al., 1999). They are considered also useful indicators of biodiversity loss

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http://dx.doi.org/10.1016/j.ecolind.2016.02.041
1470-160X/

(McGeoch, 1998; Marshall et al., 2003; Biaggini et al., 2007) and can reflect the environmental changes caused by agricultural intensification (Schläpfer and Schmid, 1999; Steffan-Dewenter et al., 2002; Weibull and Östman, 2003; Hole et al., 2005; Knop et al., 2006; Ockinger and Smith, 2007). However, studying overall invertebrate richness is almost unachievable as trapping, manipulation and identification efforts are highly time-consuming and expensive (Nielsen and West, 1994; Gardner et al., 2008). There are three main factors that influence biodiversity monitoring: monetary cost, time investment and the availability of technical expertise (Gardner et al., 2008). Invertebrates are laboratory time-consuming (sampling, sorting and taxonomical identification) and requires the use of expert taxonomists to obtain species-level identification, which increases laboratory costs (Gardner et al., 2008). Qi et al. (2008) stated that laboratory time expenses are 2.5 higher than field time, and that is the reason why invertebrate studies are more expensive. Moreover, the main reason for the high cost in invertebrate studies is the requirement to identify specimens to species level in order to assess effects on species diversity (Qi et al., 2008). Reducing the costs of biodiversity assessments would allow researchers and resource managers to carry out a closer and more frequent surveillance of the ecosystem.

Several alternatives have been proposed to rapidly evaluate the diversity of a given area avoiding the difficulties of a full species inventory: (i) using richness of indicator groups (e.g. McGeoch, 1998; Cardoso et al., 2004a; Finch and Löffler, 2010), (ii) inferring diversity from environmental variables (e.g. Brennan et al., 2006; Dalleau et al., 2010), (iii) identifying morphospecies (species identification just by morphology) (Oliver and Beattie, 1996; Derraik et al., 2002) or (iv) using functional groups (Takada et al., 2008; Noordijk et al., 2010). However, the most popular alternative has been the use of higher-taxa as surrogates (Gaston and Williams, 1993; Williams, 1993; Balmford et al., 1996a,b; Mandelik et al., 2007; Shokri and Gladstone, 2009). Several studies have shown that the number of species in a given area can be predicted from genus and family levels (Gaston and Williams, 1993; Williams, 1993; Williams and Gaston, 1994; Gaston and Blackburn, 1995; Roy et al., 1996) and even from order (Biaggini et al., 2007).

Surrogate taxa may be the most broadly tested option to reduce costs when exploring biodiversity, assessing the impact of human activities and guiding management decisions (Gaston and Spicer, 2004). Surrogates can cut the budget considerably. Balmford et al. (1996b) estimated that identifying Sri Lankan forest woody plants to genus or family level respectively saved at least 60% and 85% of the total budget compared to identifying individuals to species level. The use of taxa surrogates has been effective for community description of both marine and freshwater benthic fauna (Bailey et al., 2001; Thompson et al., 2003; Heino and Soininen, 2007; Shokri and Gladstone, 2009), to evaluate the effects of pollution on soil macrofauna (Migliorini et al., 2004; Nahmani et al., 2006) and monitor biodiversity of various arthropod and other invertebrate groups in agroecosystems (Biaggini et al., 2007; Cardoso et al., 2004a,b; Anderson et al., 2011). In terms of terrestrial arthropods, genus has been shown to be a suitable surrogate for species richness in Australian ant fauna (Andersen, 1995) and Mediterranean spiders (Cardoso et al., 2004a), whereas family richness was used as a surrogate for species richness in Hungarian coleopteran, dipteran and acari assemblages (Báldi, 2003). Biaggini et al. (2007) even showed that order level is a suitable surrogate for species richness in agricultural arthropod assemblages in wheat fields under intensive and organic farming. Thus, this higher taxon/species approach can be highly predictive, particularly when analyses are restricted to ecologically homogeneous regions (Balmford et al., 1996b; Roy et al., 1996; Vanderklift et al., 1998; Prinzing et al., 2003; Villaseñor et al., 2005).

A good surrogate must have a good correlation between the higher taxa richness and the species richness (Williams and Gaston, 1994) although the correlation usually drops sharply when increasing the taxonomic level of the surrogate (e.g. family, order; Balmford et al., 1996a). One group can fail as surrogate, but this can be solved using several groups with different ecological needs, which is called multi-taxa approach (Ricketts et al., 1999). Several factors can influence the relationship between groups (Gaston and Williams, 1993; Andersen, 1995), such as spatial scale (Reyers et al., 2002; Favreau et al., 2006), sampling effort (Andersen, 1995; Cardoso et al., 2004b), geographical location (Lewandowski et al., 2010), and habitat perturbations and management (Perfecto et al., 2003; Kleijn et al., 2004). However, the major limitation of surrogate use is that the taxonomic level needed to get reliable results for diversity studies depends on the focus group and the study area. This occurs both in cross-taxa surrogacy (Ricketts et al., 2002; Bilton et al., 2006) and when using higher-taxa as surrogates (Villaseñor et al., 2005; Bertrand et al., 2006; Rosser and Eggleton, 2012). There are some studies that use species composition instead of species richness to analyze changes in biodiversity, but the results are not conclusive (Negi and Gadgil, 2002; Su et al., 2004). Thus, more studies combining taxa richness and composition of several groups would improve the surrogate approach and the understanding of the agroecosystem.

In this paper, we tested the utility of higher taxa surrogates to assess arthropod diversity and composition patterns in Mediterranean agricultural landscapes. We analyze if farming regime (dry (i.e. rainfed) vs. irrigated) influences the correlations between surrogates and target groups. We studied aphids (Aphididae), parasitoid wasps (Aphidiinae), ladybirds (Coccinellidae), ants (Formicidae), true bugs (Heteroptera) and hoverflies (Syrphidae) at species level. We tried genus, family – only Heteroptera – and order as surrogates for species richness and composition. We also tested if genus and species richness of any group served as surrogates for other taxa and overall species richness. This paper is to our knowledge the first attempt to analyze the use of three surrogate approaches (higher-taxa (within the same group), cross-taxa (between groups) and subset-taxa (one group vs. overall species richness)) with potential pests as aphids and their predators, parasitoids and mutualists in wheat fields in an agricultural Mediterranean area.

We tested: (i) what taxonomical levels correlate better (surrogates) with species richness; (ii) whether genus and species richness of Aphididae (trophically related to the other groups) could be a good surrogate for other taxa and overall species richness; (iii) whether farming regime influences the relationship between surrogate and species patterns.

2. Material and methods

2.1. Study area

The study area (Fig. 1) covers an extension of 1500 km^2 in the south-east of León province, north-west Spain (centred on 42°33 N, 5°31 W). It is included in the supra-Mediterranean bioclimatic level of the Mediterranean region, with annual average precipitations between 436 and 515 mm and temperatures between 8 and 13 °C (Penas et al., 1995). Agriculture is the main land-use in the study area (85% of total surface). We classified the farmland of the study area into two categories according to the main agricultural regimes (see Table 1 for details; Fig. 1): (i) dry sub-area (Dry) and (ii) irrigated sub-area (Irrigated). The dry sub-area covers an extension of almost 130,000 ha under dry (i.e. rainfed) extensive farming system. Cereals are the most widespread crop (65%), dominated by winter wheat (*Triticum* spp., 21%) and oat (*Avena sativa* L., 20%).