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Importance of ground refuges for the biodiversity in agricultural hedgerows

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ABSTRACT

In most agro-ecosystems, hedgerows provide important habitat for many species. Unfortunately, large scale destruction of hedges has stripped this structure from many landscapes. Replanting programs have attempted to restore hedgerow habitats, but the methods employed often fail to replace the unique micro-habitats (complex matrix of stones, logs and roots found along the base of the hedge) that provided key refuges to an array of animal species. We examined the influence of ground refuges on animal diversity in an agricultural landscape. We used non-lethal rapid biodiversity assessments to sample invertebrate and vertebrate taxa in 69 hedges having different levels of herbaceous cover, tree cover, and refuge availability. Co-inertia analyses compared hedge characteristics with the animal biodiversity sampled. We also used a functional index (accounting for body mass, trophic level, and metabolic mode of the species sampled) to compare hedges. In addition, large sedentary predators (e.g. snakes) were used as indicators of shelter presence/quality and as bio-indicators of food web structures. Finally we used unbiased Chao-estimates to evaluate species richness. All results were convergent and show that complexity of the base of the hedge (e.g., bank size and stone abundance) positively influenced biodiversity and predator abundance. Guidelines to restore hedgerows should integrate refuges that can be constructed by retaining the materials that are extracted during the planting of the hedges.

1. Introduction

Hedges are the major elements that sustain biodiversity in many agro-ecosystems (Baudry et al., 2000). Primary used to delimit properties, to protect crops and to contain livestock, hedges play important additional roles. They provide various services (e.g. they supply fodder, fruits, wood, etc.), shelter a wide range of species, and act as corridors for dispersal (Millán de la Peña et al., 2003; Le Viol et al., 2008; Batary et al., 2010). Dense networks of hedgerows have been carefully managed by farmers for thousands of years in Europe, and they have been the focus of many studies (Baudry et al., 2000; Deckers et al., 2005; Lotfi et al., 2010). During the last 50 years, large scale industrialization and intensification of agronomy, especially cereal farming, led to the destruction of immense quantities of hedgerows associated with a strong homogenization of agro-ecosystems (Le Coeur et al., 2002; Baudry and Jouin, 2003; Schäfer et al., 2007; Woodhouse, 2010; van der Zanden et al., 2013). For example in France, more than 1,000,000 km of hedges have been destroyed in less than 50 years (Pointereau et al., 2001). The destruction of hedge habitats is one of the important causes of the massive biodiversity loss associated with agriculture mediated land use changes in Western Europe (Stoate et al., 2001; Sklenicka et al., 2009; Burel et al., 2013).

The impact of habitat changes in agricultural landscapes is well documented for several animal taxa (either pests or allies; Kromp, 1999; Donald et al., 2001; Aviron et al., 2005). These studies indicate that biodiversity, population declines of various species, or pest outbreaks are influenced by the composition of the plant community (trees, shrubs and herbaceous strips) and by the spatial structuration of the hedgerows (Millán de la Peña et al., 2003; Aviron et al., 2005; Michel et al., 2006; Butet et al., 2010). Current guidelines to restore networks of hedgerows take into account these factors, notably to promote biodiversity, ecosystem functioning and the associated ecological services (Burel et al., 2013).

Hedgerows provide other benefits to animals in the form of the complex structures found at the base of the hedge and formed from roots, stones, logs, and other features that often combine to provide a variety of microhabitats. Many animal species depend on the presence of appropriate refuge structures, notably cryptic organisms that remain sheltered most of the time (Lampo, 1994;

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Murdoch et al., 1996). The various microhabitats found at the base of hedgerows offer types of shelters that can be exclusive for many species. These microhabitats are of greater importance to sedentary organisms, especially those that cannot easily emigrate during harsh climatic periods (e.g., drought, cold winter). To our knowledge, the possible importance of these microhabitats and of ground shelter availability on animal biodiversity in agro-ecosystems has not been investigated. Considering hedgerow destruction rates, assessing the influence of ground refuge availability on animal biodiversity in agro-ecosystems is timely and represents the main objective of this study.

Using a wide range of taxa is preferable over biodiversity estimates based on a single taxon (Van Jaarsveld et al., 1998); but performing multiple surveys poses important methodological and logistic difficulties and thus are rarely carried out. In order to take into account a wide range of taxa, we used a specifically developed approach: non-lethal rapid biodiversity assessments (NL-RBA; Lecq et al., 2015). This approach is derived from rapid biodiversity assessments (RBA; Hammond, 1992; Oliver and Beattie, 1993, 1996a,b) where identification of morphospecies relaxes the logistical constraints associated with classical trap-surveys (e.g. species-level identification in the laboratory). Although taxonomically less precise, RBA are useful tools to estimate local biodiversity (Oliver and Beattie, 1993, 1996a; Obrist and Duelli, 2010). NL-RBA amplifies the advantages of RBA because it does not rely on capturing (and killing) individuals but on immediate identification in the field. Thus, NL-RBA is similar to point counts routinely used for surveying bird species. The identification error rate is low at the morphospecies level (<1%, thereby limiting observer bias) and multiple count sessions can be performed because studied populations are not impacted by removing individuals (Lecq et al., 2015).

Importantly, NL-RBA allows the sampling of a wide taxonomic diversity, including protected species that cannot be easily collected (Haila and Margules, 1996; Van Jaarsveld et al., 1998; Schmeller, 2008). Overall, the lack of taxonomic accuracy for certain taxa (e.g. spiders) is offset by practical and ethical advantages.

The influence of habitat type on functional biodiversity needs also to be examined through ecological features such as life-history traits and trophic relationships (Swift et al., 1996; Folke et al., 2004; Cardinale et al., 2006; Moonen and Bàrberi, 2008). For example, because rate of biomass conversion across trophic chains is slow, sustaining apex predators are energetically demanding and thus the status of predator community depends on the status of the underlying trophic levels (Duffy, 2003; Duffy et al., 2007). Top predators are thus often viewed as indicators for the ecological health of the ecosystem (Sergio et al., 2008). Body size and metabolic mode are also important traits to take into account: large endothermic species require much greater absolute amounts of resources compared to small ectothermic animals (Pough, 1980; Woodward et al., 2005). A hedge occupied by a diversity of vertebrate and invertebrate predators is likely sustained by a rich underlying diversity of prey species. Therefore, to assess the influence of ground refuges on hedge biodiversity we incorporated into our analyses the trophic level, metabolic mode and body size of the detected morphospecies. Finally, we also adopted a specific focus on snakes and lizards (i.e. squamates) as indicators of shelter availability, and as food web bio-indicators of the hedges for several reasons. First, being obligate carnivores, most squamates are typically at or near the apex of the hedgerow trophic webs; they depend on the functioning of the underlying trophic levels. Second, they are relatively sedentary and they remain sheltered most of the time, thereby providing accurate spatial information. Furthermore, ophidian populations have declined in agricultural landscapes (Reading et al., 2010) where the network of hedgerows has been severely reduced, suggesting that these predators are sensitive to hedge characteristics (Reading and Jofré, 2009).

By examining terrestrial refuges and cryptic terrestrial species, our main goal was to provide complementary data about the importance of hedges for biodiversity. We predict that the presence of hedges that comprise abundant ground refuges within an agricultural landscape will result in higher biodiversity and more complex trophic webs at those sites. We also aimed to propose practical actions that promote conservation and restoration of these critical habitats.

2. Material & methods

2.1. Study areas

The two study areas are situated in western central France, in an agricultural landscape that has lost the majority of its hedgerow features. Previously characterized by a network of hedgerows (i.e. 'bocage'), more than 80% of the hedges have been removed from the area during the past 50 years. Traditional farming (e.g. market gardening) has been replaced by intensive industrial cereal farming (e.g. maize, sunflower; Meeus, 1993). Despite this, small patches of densely spaced hedgerows persist in several locations.

We selected 69 field hedgerows in the Deux-Sevres-79 (N = 61 hedges, Chizé; 46°06′58.4N, 0°20′59″3W) and Charente-17 districts (N = 8 hedges, Dompierre-Sur-Mer near the Ocean; 46°10′36.9″N, 1°03′12.3″W). The range of hedgerows selected is representative of the gradient of destruction. Several hedgerows were intact (i.e. traditionally managed over decades; Appendix A) and were notably covered by well-developed trees; others were relictual (i.e. most trees have been removed). Our selection of sites also encompassed a diversity of structures at the base of the hedgerows: either with or without large banks, sometimes with small walls made of stones.

The cultivated fields bordered by the hedgerows were characterised by different crops (meadow, fallow, corn, etc.), different agricultural practices, or connectivity (e.g. dense network of connected hedges *versus* isolated hedge). These environmental factors likely influence the biodiversity associated with a particular hedgerow. As such, we limited the influence of these factors by haphazardly selecting different types of hedges (e.g., intact *versus* relictual) across our spatial scale. Moreover, rotating of cultures during the two years of the study (2011–2012) further distributed a possible crop effect across the hedges surveyed. Each species living in a hedge may respond in a particular way to the modifications of agricultural practices in surrounding fields (e.g. differential perturbation caused by pesticides, noise exposure). Implementing all these factors and interactions into the analyses was out of scope of the current study. Therefore, we focused on the availability of ground shelters on a wide range of morphospecies.

2.2. Hedge characteristics

We characterized each hedge using two primary features: 1) vegetative cover and 2) base of the hedge that determines ground refuge availability (Appendix B). For each hedge, we measured height and width of the trees and shrubs using a flexible measuring tape. The size of trees >3 m in height was estimated visually. Plants were identified to the lowest possible taxonomic level (e.g., Family or species), and the relative proportion of ground surface covered by vegetation was recorded. This latter measurement included the proportion of the bank covered by grass (e.g., Poace), bramble/shrubs (e.g., *Rubus fruticosus*), and trees (e.g., *Acer campestris*).

For each hedge, we described the bank and other ground refuges. Banks are often made of earth and stones and are generally associated with one or two ditches and a bordering herbaceous strip (Appendix A). Unless the feature was absent from a particular hedge, the characteristics of the bank (height, width), ditch (height,