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Manipulating hedgerow quality: Embankment size influences animal biodiversity in a peri-urban context

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ABSTRACT

Hedgerowsare important features within urban, peri-urban, and agricultural habitats because they shelter most of the biodiversity in a landscape dominated by infrastructures or a monoculture. Hedges are characterized by their vegetative cover but also by their base, notably the breadth of the embankment and the various microhabitats made by stones, coarse woody debris, and leaf litter. These features determine the availabilities of arboreal and ground refuges. Their respective roles on biodiversity remain poorly explored. We experimentally manipulated the size of the embankment in newly-constructed hedges in a peri-urban context. We used non-lethal rapid biodiversity assessments and functional indices (accounting for body mass, trophic level, and metabolic mode) to monitor the presence of a wide range of animal taxa. We observed a positive effect of embankment size on animal biodiversity. Various elements of the fauna (e.g. arthropods, reptiles) rapidly colonized newly-constructed hedges provided with an embankment. Guidelines to restore hedgerows should consider embankment size and quality. Both of these features can be improved by simply retaining the materials that are extracted when establishing agricultural plots such that a diversity of microhabitats and ground refuges become available.

1. Introduction

Urban sprawl and transport infrastructure expansion are leading causes of forest fragmentation and habitat alteration, and the concomitant loss of biodiversity (Wilcox and Murphy, 1985; Savard et al., 2000; Seto et al., 2012). Furthermore, conversion of forest habitats to agricultural use has yielded more than 1.5 billion ha that are currently cultivated, representing > 10% of the surface of the planet and more than 36% of the land surface (Bruinsma, 2003). It has been estimated that an additional 2.7 billion ha of forests might be progressively converted for crop production in the coming decades (Van Vliet et al., 2017).

Certain types of anthropogenic modifications of the landscape can be beneficial to the wildlife (Fahrig et al., 2011; Pe'er et al., 2014). Natural or managed forests offer refuges for many organisms in highly altered urban and agricultural landscapes (Savard et al., 2000; Alvey, 2006). Yet the space available is strongly constrained by infrastructures (buildings, roads, etc.). Many urban forests are linear, bordering roads, parks or rivers (Faiers and Bailey, 2005). The benefits of urban forests to wildlife inhabitants depend on the connectivity among patches; corridors shelter more biodiversity compared to isolated parcels (Mörtberg and Wallentinus, 2000). Linear forests provide essential systems of exchange between peri-urban areas and inner zones of cities, especially alongside rivers and railways (Varet et al., 2013). The benefits for biodiversity and human welfare that stem from promoting urban forest networks connected to surrounding habitats are now implemented into urban planning strategies (Goddard et al., 2010).

Hedgerows (i.e. linear forests) shelter most of the biodiversity in agricultural and urban landscapes, and they contribute to spatial and structural heterogeneity (Burel, 1996). Trees are the most salient part of hedgerows, but previous investigations of the value of this habitat also considered bordering herbaceous strips and connectivity with other habitats (Hinsley and Bellamy, 2000; Moonen and Marshall, 2001; Bailey, 2007). Little attention has been paid to the base of the hedges however, especially the embankment: stones, coarse woody debris, tree roots form a complex matrix of burrows and refuges (Lecq et al., 2017). These structures offer microhabitats for a wide range of organisms and substantially contribute to species richness (Lecq et al., 2017). Moreover, complex interactions exist among species and many animals routinely shuttle between ground shelters and the tree cover above (Ctifl, 2000). Unfortunately, the parameters of the embankment are typically not accounted for in planting or management guidelines for

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hedgerows.

We focused on the embankments of hedgerows. Large trees have broad bases that provide abundant ground refuges and, as such, the contributions of tree cover to the biodiversity of a given hedgerow are not easily dissociated from embankment size. For this reason, our experiment manipulated the basal structure of hedges independently from vegetative cover. Hedgerows were installed in a meadow connected to an agricultural landscape and a small city. Three types of embankments were created and we sampled animal biodiversity during two years. To examine the influence of embankment quality on biodiversity, we used a non-lethal survey method to limit the impact of sampling on our dependent variable, both for ethical reasons and to encompass a wide range of taxa (i.e., from small invertebrates to mammals; Lecq et al., 2015).

The primary goal of our study was to examine specific features that can improve hedgerow quality with minimal impacts on managers and farmers in terms of costs and labor. We addressed two questions: (1) Does the presence of an embankment promote animal biodiversity following the installation of a hedgerow? (2) Does embankment size contribute to that measure of diversity?

2. Material and methods

2.1. Study site

The experiment took place in western central France (46°07′21″N, 0°21′24″W) in a typical peri-urban landscape that has been modified extensively in the past several decades (Baudry and Jouin, 2003). Traditional agriculture has been replaced by intensive practices while urbanization developed along with an expanding infrastructure. At the study site, approximately 50% of the hedges have been removed (Fig. 1) and most residential areas were constructed recently (e.g., within the last 25 years; almost all properties containing dwellings that are visible in Fig. 1).

2.2. Experimental design

In February 2011, nine hedges were created in a rectangular grass meadow (115 × 80 m) with the main axis oriented ∼30 °N. The southern margin of the meadow was bordered with a 900 m-long hedge (35 m width) connected to a village in the east and to a forest in the west (600 m distant). The northern margin was adjacent to a working area used for gravel storage and to a road. The two other margins were adjacent to a cultivated meadow (west) and to an athletic field (east). Prior the experiment, the meadow was regularly mowed and no trees or bushes were present.

The nine hedges were oriented west-east in order to present one side to maximal sun exposure. They were regularly spaced (10 m) and each measured 60 m in length. Each hedge was planted with 61 young trees (< 1.5 m in total height) representing species that occur locally (e.g. *Carpinus betulus, Corylus avellana, Prunus spinosa, Crataegus monogyna* in alternation). We constructed each hedge using one of three types of embankment size: minimal, small and large. The minimum base (MB; n = 3 hedges) lacked any sort of embankment; thus, the surface was level with the existing grade. Each tree was planted directly in the ground. Each hedge having a small base (SB; n = 3 hedges) included a small (1.00 m wide, 0.75 m high) embankment constructed using earth and small stones. We planted the trees on the top of the ridge formed by the embankment. Hedges having a large base (LB; n = 3 hedges) differed only in the size of the embankment (1.50 × 1.20 m), and trees were again planted at the top of the embankment ridge. The volume of material used to construct the LB hedgerows was twofold greater than the amount needed for the SB type. In addition, we placed several stones (∼40 × 40 cm) on the south slope in order to cover ∼5% of the ground surface of the LB hedges. The embankments were not compacted. The three types of embankment correspond to the most widespread and traditional basal structures found among the hedgerows in the study area. Overall, we adopted a simple and realistic approach by selecting easily-built structures. In practice, the dimensions of the SB and LB base types corresponded to the amount of material that can be excavated with a backhoe loader during replanting programs. In areas of our study site where the arable soil is relatively thin, the underlying marly-calcareous layers must be broken up before plantation. The three types of hedges were placed in semi-random order, avoiding a configuration that placed two of the same hedge type next to each other (Fig. 2). This design enabled us to focus on the effect of the size of the embankment.

Following the construction of the hedges (February 2011), the area was not managed nor did we monitor the herbaceous vegetation. The purpose was to monitor colonization of the hedges by various animal species. The proximity of the forest, and the connection of the meadow with large hedges, provided a putative means by which non-flying species could colonize the hedges within the meadow (Alignier and Deconchat, 2013). For example, many organisms such as woodlouses, myriapods, cryptic spiders, reptiles or small mammals avoid crossing open areas and follow corridors. To contrast the constructed hedgerows with those bordering the meadow, the former type is hereinafter termed the experimental hedges.

2.3. Biodiversity sampling

Many studies addressing the ecological impacts of agricultural practice have successfully used birds as an index of animal biodiversity (e.g., Pe'er et al., 2014). Others have focused on a particular taxon (e.g., Cole et al., 2002). Approaches that integrate a more accurate examination of biodiversity are preferred, however, because using only a few taxa as surrogates of overall diversity provides unreliable assessment that might not reflect all ecological processes occurring in that habitat (Van Jaarsveld et al., 1998; Andelman and Fagan, 2000; Verissimo et al., 2011). Therefore, we did not focus on a given taxonomic group and instead attempted to sample all macroscopic animals.

The macrofauna was sampled using five complementary versions of a protocol developed to visually identify morphospecies: non-lethal rapid biodiversity assessment (NL-RBA; Lecq et al., 2015; Książkiewicz-Parulska and Gołdyn, 2017). Individuals were not collected, but directly identified and/or photographed in the field. Precise species identification was not always possible; instead observed specimens were assigned to different taxonomic categories, from the species- (fine resolution) to the order-level (coarse resolution; Oliver and Beattie, 1996). To limit observer bias, pictures of common and difficult species were used as "reference specimens;" moreover pictures were taken randomly or when the observer was uncertain. This limitation of the NL-RBA approach was offset by the absence of environmental or ethical concerns, the ability to sample a wide range of taxa, and a high cost/efficiency ratio that enabled us to accumulate a large data set (Lecq et al., 2015).

Three versions of the NL-RBA protocol (rapid visual transect, slow visual transect and focal observation) were relatively similar as they relied on visual searching of the fauna using different walking speeds. The two other versions (active searching and cover objects [five corrugated slabs of cement were placed along each experimental hedge]) targeted cryptic fauna that typically associate with ground refuges. Natural shelters such as stones, leaf litter, or artificial shelters were lifted during these survey variations (see Lecq et al. (2015) for details on each version of the protocol). These two last survey methods attempted to detect hidden animals and, as such, could produce an encounter even at times outside of the activity period for a given species. By combining the different versions of the NL-RBA, the methods were designed to include the relatively cryptic species that depend on the availability of ground refuges (e.g. arthropods, mollusks, reptiles). Yet, many individuals belonging to not-cryptic species were also counted (e.g., a pair of wagtails successfully nested in one experimental hedge).