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Road network in an agrarian landscape: Potential habitat, corridor or barrier for small mammals?

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ABSTRACT

If the negative effects of road networks on biodiversity are now recognized, their role as barriers, habitats or corridors remain to be clarified in human altered landscapes in which road verges often constitute the few semi-natural habitats where a part of biodiversity important for ecosystem functioning may maintain. In human-dominated landscape, their roles are crucial to precise in comparison to other habitats for small mammal species considered as major natural actors (pests (voles) or biological control agents (shrew)).

We studied these roles through the comparison of small mammal abundance captured (418 individuals belonging to 8 species) using non-attractive pitfall traps (n = 813) in 176 sampled sites distributed in marginal zones of road and crop, in natural areas and in fields. We examined the effect of roadside width and isolation of sites.

We found the higher small mammal abundances in roadside verges and an effect of width margins for shrews. The significant effect of the distance to the next adjacent natural habitat at the same side of the road on the relative abundance of *Sorex coronatus*, and the absence of a significant effect of distance to the next natural habitat at the opposite side of road, suggest that highway and road verges could be used as corridor for their dispersal, but have also a barrier effect for shrews. Our results show that in intensive agricultural landscapes roadside and highway verges may often serve as refuge, habitat and corridor for small mammals depending on species and margin characteristics.

1. Introduction

Road networks have strongly expanded over large areas with human population growth (Watts et al., 2007) so that the majority of the total area for the more developed countries is under their influence (Reijnen et al., 1995; Forman 2000; Selva et al., 2011). Unfortunately, roads are known to have major negative impacts on species and ecosystem dynamics, modifying landscape structure, through habitat destruction, alteration and fragmentation (Forman and Alexander, 1998; Sauvajo et al., 1998; Trombulak and Frissell, 2000; Liu et al., 2008). One major impact identified is the reduction of populations size of a wide variety of species (Fahrig and Rytwinski, 2009; Benítez-López et al., 2010; Rytwinski and Fahrig, 2012) through increase in mortality by collision (Shuttleworth, 2001), fragmentation of home ranges, habitat destruction, disturbance of foraging and reproductive behaviours (Siemers and Schaub, 2011) and barriers to movements which decrease landscape connectivity (Rico et al., 2007a,b). This fragmentation may result in the ultimate division of the population adjacent to roads into smaller isolated subpopulation involving a decrease in the genetic diversity of such isolated population (Rico et al., 2009). However, the potential biological value of road verges in anthropogenic altered landscape has also long been recognized (Way, 1977). Sides of linear transport structures, i.e. linear areas of semi-natural vegetation, may provide refuges and/or corridors (Davies and Pullin, 2007) to a large number of taxa (Hansen and Jensen, 1972; Bennett, 1990; Merriam et al., 1990; Hodkinson and Thompson, 1997; Penone et al., 2012). In some cases, they are

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known to significantly contribute to the conservation of indigenous flora (Spooner et al., 2004; O'Farrell and Milton, 2006) and fauna (Meunier et al., 2000; Ries et al., 2001).

Actually, their role as refuges may depend on their surrounding landscape: in natural habitats, generally supporting a high species diversity, road verges do not provide particular habitat to threatened local species (O'Farrell and Milton, 2006). Ranta (2008) showed that the usual extensive management techniques were not sustainable for the survival of endangered species on a roadside site. Roads network even can have negative effects, especially in favouring invasion by exotic species (Hansen and Clevenger, 2005; Brown et al., 2006). By contrast, in human dominated areas such as intensive agricultural landscapes, where non-agricultural habitats (e.g. edges) are sparse and critical to the conservation of biological diversity and ecological processes (Burel, 1996), road verges should play a crucial role as a refuge and ecological corridors (Dawson, 1994, 2002; Tikka et al., 2001; Le Viol et al., 2008, 2012; Penone et al., 2012).

Hence, there is a crucial need to assess the roles of road verges as refuges, corridors or barriers, and more particularly for small mammals in agrarian landscapes that are supposed to take an important place in the ecosystem functioning. Small mammals are indeed known to be major natural actors of agrarian ecosystems: some of them are considered as pests (Sullivan et al., 1998) while others strongly regulate invertebrate populations in fields and grasslands (Churchfield et al., 1991). These are crucial to ensure good agricultural production (Schoener, 1988; Spiller and Schoener, 1990; Dial and Roughgarden, 1995) because they control for low pest species abundances (Maisonneuve and Rioux, 2001). However, while small mammals are regularly observed or trapped in field margins of agrarian landscapes, the role of road verges as refuge or corridor in comparison to other habitats at the landscape scale has rarely been assessed and results are still scarce and often contradictory. In some studies, small mammals have been observed to spread tens of kilometres along highway roadsides (Getz et al., 1978). Roadsides are thus considered as effective corridors for them (Suckling, 1984; Bennett, 1990; Verkaar, 1990). Other studies showed that roads could be a significant barrier to dispersal of many animals (Rico et al., 2007a,b), particularly in the case of high traffic rates (Harris and Silva-Lopez, 1992). Given the high potential impact of these animals on local agricultural economies, it is important to better understand the role of roadsides among other habitats on the population dynamics of small mammals. In this way, according to the results on the ecological importance of road verges in agricultural landscapes, it will be possible to determine how much roadside management should take into account populations of small mammals.

The aim of the present study is to assess the role of road verges as habitats, corridors or barriers for small mammal species in an intensive agricultural ecosystem. First, their role as habitat was evaluated by comparing the relative abundance of small mammals in road verges, according to their characteristics (width …) and compared to their abundance in other habitats such as fields, field margins and woods. Second, in order to evaluate their potential corridor effect, we investigated the relationship between small mammal abundances in portions of verges and their distance to the closest adjacent (= connected) natural habitats (such as woods or meadows). Finally, we attempted to identify barrier effects by defining the relationships between small mammal abundance in portion of verges and their distance to the nearest natural habitat adjacent to the verge of the other side of the road and compare it to the relationship with distance to the natural habitats of the same side of the road.

2. Materials and methods

2.1. Study area

The study area is an intensive agricultural plain located in the region Ile-de-France in the surroundings of Paris (48° 51′ North - 2° 21′ East, Fig. 1). It is thus mainly composed of urban areas covering 18.2% of the global area and of agricultural fields used for intensive cropping, especially wheat, sugar beet and rapeseed covering 49.0%). The main "natural" habitat is woodland representing about 23.7% of land cover (see Appendix A). In the study area, the road network is 38,906 km long, *i.e.* 3.23 km of highways and roads per km^2. Road network verges (highway or roadside) and field margins are herbaceous strip mowed once or twice each year, differing mainly by their width (15.7 ± 6.6 m [10.0 − 21.5] for highway verges, *HV*, 7.2 ± 3.4 m [4.3 − 14.6] for road verges, *RV*, and 4.0 ± 0.4 m for [2.0−10.0] for field margin, *FM*). The average height of grass strips is less than 1 m in June while five plant species dominate this communities (*Dactylis glomerata, Festuca ssp, Heracleum sphondylium, Galium ssp, Plantago lanceolata have an occurrence exceeding 50%*). All sampled sites (highway, roads and fields) are close to crops typical of intensive agrarian landscape (wheat and rape totalized 81% of crops in the sampling, with no obvious bias among site types: Fisher's exact test, $P = 0.31$). We also verified that studied highway verges and road verges have similar distance ranges to woods (490 ± 83 m [10 − 2100] for highway verges, *HV*, and 973 ± 118 m for [80−4450] for road verges, *RV*). Verges of this road network represent 1.6% of the total area of the region (highway verges: 0.4%, road verges: 1.2%) and field margins (margins comprised between two adjacent agricultural fields), 1.5% of the territory.

2.2. Sampling design

To examine the habitat, corridor and barrier roles of road verges, we sampled the two types of road verges: we studied 31 sites along highways (noted *HV*) and 48 sites along roads (noted *RV*). A site consisted of 5 traps placed linearly every 20 m along the way in the middle of the verges (for more details see Le Viol et al., 2008; Redon (de) et al., 2009).

To assess the relative importance of verges for small mammals in the landscape, we also sampled the main habitat present in this area: fields, $n = 65$ sites and wood, $n = 32$. Fields margins and inside field were sampled (Fig. 1) as following: margins (65 fields, noted *FM*) each consisting of three traps placed around the field separated from each other by at least 100 m; inside fields at 25 m from the hedges (65 fields, noted *F25*, consisting of two traps with a distance of 20 m), and inside filed at 50 m from the hedges (56 fields, noted *F50*, consisting of two traps with a distance of 20 m). Woods (32 sites, noted *WD*) were sampled with one trap randomly placed in each studied wood (Fig. 1). A total of 864 traps were thus installed in the 176 sites, but 813 traps installed were recovered (Table 1). Most traps destroyed during the sampling period were located within or around the fields: in field margins (*FM*: 4% of traps destroyed), fields-25 m (*F25*: 15%) and fields-50 m (*F50*: 21%).

2.3. Small mammals capture and determination

The number of caught individuals was used as a proxy to estimate their relative abundance in the sites. Sampling was carried out simultaneously in 2006 from May the 2nd to June the 4th, (i.e. 31 nights of trapping for each site). For more technical details see Appendix B and Le Viol et al., 2008; Redon (de) et al., 2009; Vergnes et al., 2013). Each animal was dissected and identified mainly using its morphological cranial characteristics, such as teeth, according to Chaline et al. (1974).