LIFE NATUR' ADAPT

# SOME **CASE STUDIES** ON THE EFFECTIVENESS OF **TERRESTRIAL CORRIDORS** IN EUROPE


## Summary :

A literature review on the effectiveness of corridors for European vertebrates was carried out as part of the LIFE Natur'Adapt project, following the precepts of systematic reviews.

Despite the importance of the theme of ecological networks in the academic sphere, our study highlighted knowledge gaps in the literature on corridors.Indeed, restricting ourselves to the terrestrial vertebrate group and the European continent, we obtained only a very small number of studies that rigorously compared measurements obtained for patches connected by a corridor, with those obtained for patches with similar properties but isolated within the landscape matrix. Two previous syntheses on the effectiveness of corridors had, however, managed to identify more studies due to a large number of works carried out in America (Resasco 2018; *Gilbert- Norton et al., 2010*). In the case of the present review, the few empirical results identified show a positive influence of the presence of corridors on the populations studied (assessed essentially by their effects on abundance and species richness), in line with the existing literature. However, the heterogeneity of the publications makes it difficult to summarize the reported effects, with results that are sometimes contradictory. This summary illustrates the above points through a series of case studies, and concludes with the need to carry out studies specifically on the movement of individuals via corridors, and to integrate the issue of climate disruption to better anticipate future conservation challenges.


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To remember : There is little empirical evidence to rigorously validate the effectiveness of corridors for vertebrates in Europe. However, the few results available point to a positive influence of corridors on vertebrate populations. Further studies are needed to address the actual movement of individuals within corridors and to make the link with climate issues.

# 1. Background to this review

As part of the LIFE Natur'Adapt project, three management measures have been studied through literature reviews (map and systematic review, meta-analysis) in order to better understand how these measures can be used to adapt protected area management to the context of climate change. The creation (or preservation) of corridors is one of the three measures studied.

To survive in the face of climate change, many species will have to adapt their range by migrating to areas with more favorable environmental conditions. However, not all species have the same dispersal capacities. What's more, most of them evolve in environments characterized by a high degree of fragmentation of available habitats. Consequently, the persistence of a population in the landscape may depend to a large extent on the presence of corridors in these fragmented landscapes, connecting different habitat patches together and limiting the movements to be made by individuals within a matrix that may prove increasingly inhospitable. Ensuring a certain degree of landscape connectivity by creating or preserving corridors therefore appears to be a major conservation challenge.

For these reasons, measures targeting habitat connectivity are the most frequently advocated for managing natural areas in the current context *(Prober et al., 2019; Heller & Zavaleta, 2009).* Ecological networks are also being implemented in many countries, notably France, through public policies (green and blue infrastructure) and dedicated conservation strategies.

Despite the clear interest in maintaining ecological corridors, questions remain as to how best to implement them. Indeed, most of the recommendations come from opinion articles and theoretical modelling or simulation work. What's more, while the value of corridors seems obvious in highly constrained environments where travel possibilities are limited, their relevance can be questioned in more rural or even natural locations where a more or less permeable landscape already allows for diffuse travel. The aim of our study was therefore to summarize the scientific literature assessing the importance of corridors and the management practices that optimize their usefulness for biodiversity, in a context of increasing climate change.

# 2. Method

The bibliographic synthesis was based on the systematic review method proposed by the *Collaboration for Environmental Evidence.* To reduce the volume of documents to be processed and match the scope of the synthesis to European protected areas, the problem was restricted to terrestrial vertebrates in Europe. The corpus of bibliographical references was compiled using a keyword search on two databases («Scopus» and «Web Of Science Core collection») and a search engine (Google Scholar). The documents collected were sorted successively by title, summary and full text, to ensure their relevance to the question posed.

In this note, we propose a series of case studies selected from the publications retained at the end of the sorting process. These reflect the heterogeneity of empirical studies available in the scientific literature, address distinct aspects of corridor effectiveness and report results likely to inform management decisions.

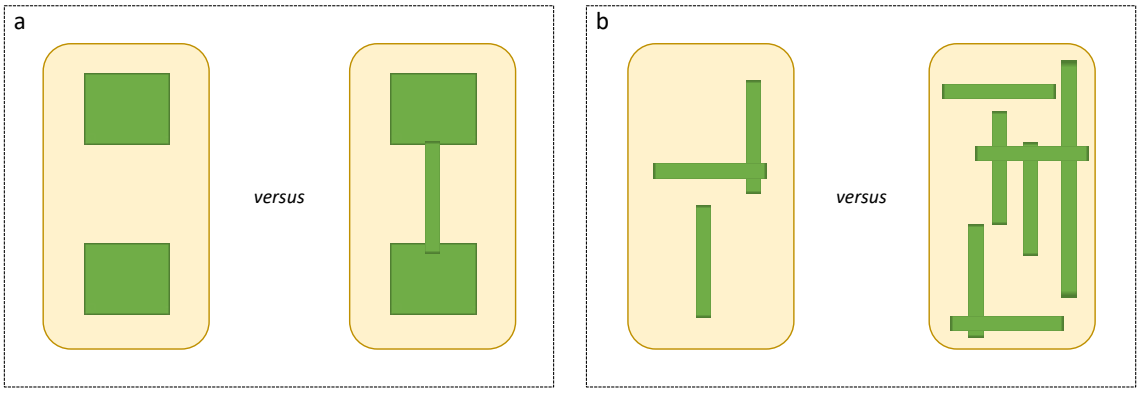
In addition, a meta-analysis was carried out on studies looking at the effect of gradients of linear elements (e.g. hedges, pits, embankments, tree alignments, etc.) on species abundance and richness, which are the most numerous studies in our corpus. We first critically analyzed these studies to assess their level of bias (types of protocols, number of replications, random selection of study sites, etc.). Only studies with low or medium bias were included in the meta-analysis.

# 3. Case studies

## A) COMPARISON OF PATCHES CONNECTED VIA A CORRIDOR VS. UNCONNECTED PATCHES

The ideal configuration for testing the impact of a corridor for a given population is to compare measurements made on habitat patches connected to other patches by a corridor, with those obtained on comparable habitat patches but isolated within the landscape matrix (see Figure 1a). Previous reviews looking at the effectiveness of corridors have indeed relied on this type of experimental design *(Resasco 2018; Gilbert-Norton et al., 2010*).

However, studies reporting such comparisons for vertebrates in Europe represent only a few publications of the final corpus, thus limiting our ability to draw general conclusions on the effectiveness of corridors. The four case studies described in this section nonetheless illustrate the few results obtained using protocols that come closest to this ideal configuration, and offer insights into the type of work that could fill current knowledge gaps.




Assessment of corridor role stricto sensu: Comparison of similar unconnected or connected habitat patches

Assessment of a landscape's overall permeability: Presence/ density of variable linear elements between two landscapes

**Figure 1: Two types of comparison tested to measure the corridor effect more or less directly**

1/ The first case study is a manipulative study carried out at a research station in south-east Norway by *Andreassen & Ims (2001)* on the northern vole, Microtus oeconomus. The experimental design used by the researchers is shown schematically in Figure 2a.

Laboratory-bred individuals were released into three types of habitat configuration: six small patches isolated from each other, six patches of the same size but linked by 1.5m-wide corridors, and two large unconnected patches. In all cases, the habitat patch corresponded to a dense, homogeneous grassland habitat, while the matrix separating the patches was kept inhospitable by weekly mowing.

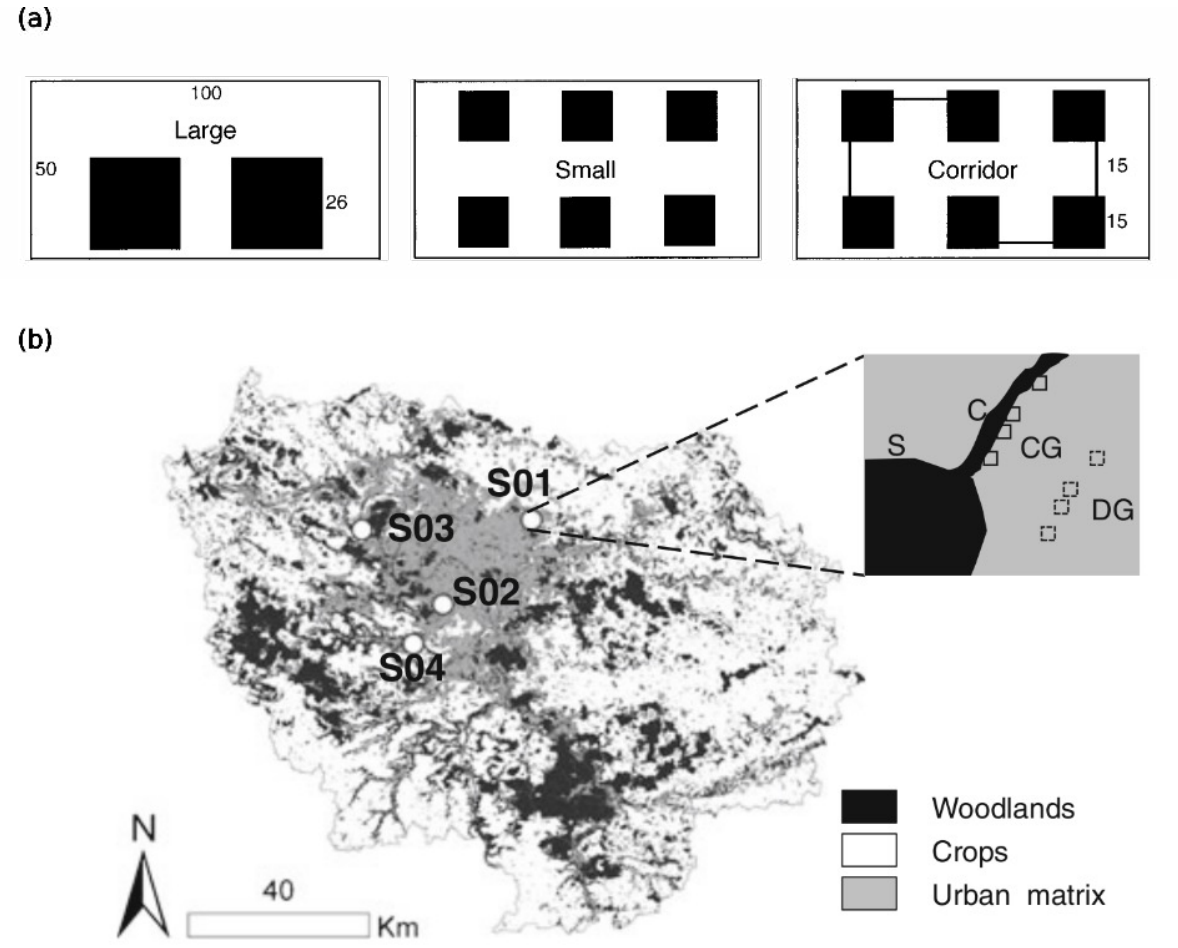



**Figure 2:** Schematic representations of the protocols used by the first two case studies. case stu dies. Adapted from (a) *Andreassen & Ims, 2001; (b) Vergnes et al., 2013.*

Northern vole populations were monitored using traps during the breeding seasons from 1990 to 2001. These surveys highlighted the use of corridors by individuals during dispersal, but did not lead to an increase in the frequency of patch changes at population level (Figure 3).

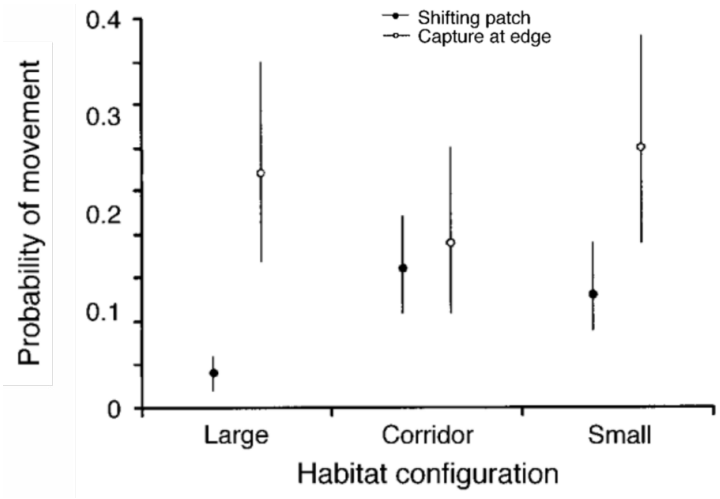



**Figure 3.** Probability associated with transitions between patches and catches at pen edges for different patch configurations. Adapted from Andreassen & Ims, 2001.

2/ Although non-manipulative, the study carried out *by Vergnes et al. (2013)*, in France, is analogous to the previous one in that it is based on a strict sampling protocol (represented schematically in Figure 2b), making it possible to assess fairly rigorously the impact of the presence of a connection by a linear element on the inter-patch distribution of another taxonomic group of small mammals, shrews. Sampling was replicated at four separate sites in Ile-de-France, each with the following configuration:

(i) a single forest remnant or urban park within a 1.5 km radius, (ii) a wooded corridor between 20m-50m wide physically connecting the wooded reservoir to four domestic gardens, (iii) four disconnected domestic gardens located more than 300m from the corridor. Traps were used in each of the three elements to conduct surveys over a two-month period in spring. The occurrence data obtained for three shrew species (*Crocidura russula, Sorex coronatus, Sorex minutus)* show a clear positive effect of the corridor's presence on their probability of occurrence in the domestic gardens, with a more marked effect for *C. russula.*

3-4/ The next two case studies again look at the direct impact of patch connectivity, this time for permanent pools located in an agricultural matrix (Figure 4). The study *by Hartel et al (2010)* in Romania compares the amphibian species richness of relatively isolated ponds in the agricultural matrix with that of ponds connected to an adjacent forest by a corridor (e.g. a grass strip or hedge).

Data from eight years of monitoring show a significantly higher number of amphibian species in ponds directly connected to a patch of forest. The study by *Lewis-Phillips et al (2019)* concerns bird populations in the UK, and also looks at their abundance in addition to species richness. Monitoring ponds over one year showed a positive influence of connectivity, both for bird abundance and species richness.

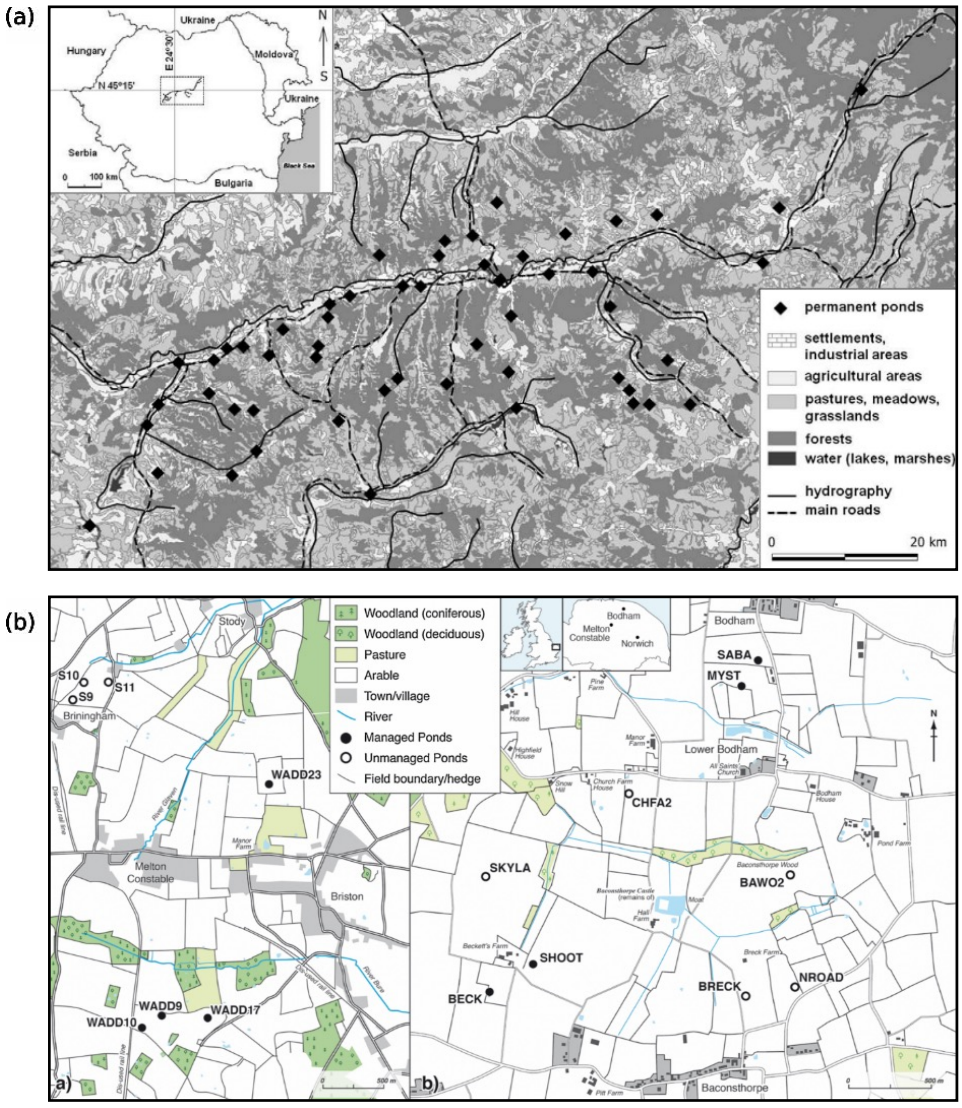



**Figure 4.** Maps illustrating the sampling plans used by the two case studies on the impact of pond connectivity. Adapted from (a) *Hartel et al., 2010; (b) Lewis-Phillips et al., 2019.*

## B) PRESENCE/ABSENCE, GRADIENTS AND STRUCTURAL PROPERTIES OF LINEAR ELEMENTS

The few available studies on European vertebrates assessing the effect of corridors by directly comparing connected habitat patches with unconnected patches thus seem to indicate generally positive effects of corridors on the species richness and abundance of the few taxonomic groups studied. Nevertheless, in order to take into account a wider range of empirical evidence, our study also looked at papers measuring the effect on terrestrial vertebrate populations of gradients in the presence of linear elements around sampling points (without the need for them to physically connect two habitat patches) (Figure 1b).

The study by *Rosalino et al. (2009*) compares sites with and without linear elements that could be used as corridors. Here, the sites correspond to oak woods with or without riparian vegetation, set in a montado-type landscape matrix in south-west Portugal. By comparing these two types of habitat, the researchers showed that the presence of a riparian forest contributed positively to total mammalian species richness, and was associated with an increase in the Shannon-Wiener index for small mammals and in the species richness of carnivorous mammals.

Other studies focus on gradients in the presence of linear elements. This is the case of the study by *Lewis-Phillips et al. (2019*) presented above on the abundance and species richness of birds at the edge of permanent ponds in the UK. Indeed, in addition to pond connectivity, the authors also measured hedgerow lineage within a 500m radius of the sampling point. In contrast to connectivity, hedgerow length, regardless of size, was not significantly associated with bird abundance or species richness.

The next three case studies add to the quantification of a gradient in linear elements and its effects, the influence of properties of these linear elements such as its width and height, or the frequency and area occupied by openings along a hedgerow. The study by *Carlier et al. (2019)*, for example, looks at the impact of a planned greenway along the route of an abandoned former railroad line in Ireland, on the activity and number of bat species observed at the site. In particular, the authors measured the density of linear elements (in km/site) in circular sites 320m in diameter containing hedges or rows of trees, as well as the average size and width over the site, and the percentage of openings greater than 5m that fragment hedges. Based on bat inventories carried out according to a stratified random sampling plan, they were able to demonstrate a positive association between the presence of openings in the hedgerow and bat species diversity, and the same for *Pipistrellus pipistrellus activity*. In addition, the data also show a higher presence of *Myotis daubentonii*, *Myotis mystacinus* and *Pipistrellus pipistrellus* where the density of linear elements is higher, while a negative relationship was found for *Nyctalus leisleri.*

*Boughey et al (2011)* carried out a similar study in the UK, also on bats as part of a national monitoring program. The data obtained highlighted that the presence of *Pipistrellus pipistrellus* and *Pipistrellus pygmaeus* was more likely in areas adjacent to a linear feature (Figure 5a-b), while no association was found for *Nyctalus noctula* and Eptesicus serotinus. On the other hand, there was no impact of the width of the linear elements.

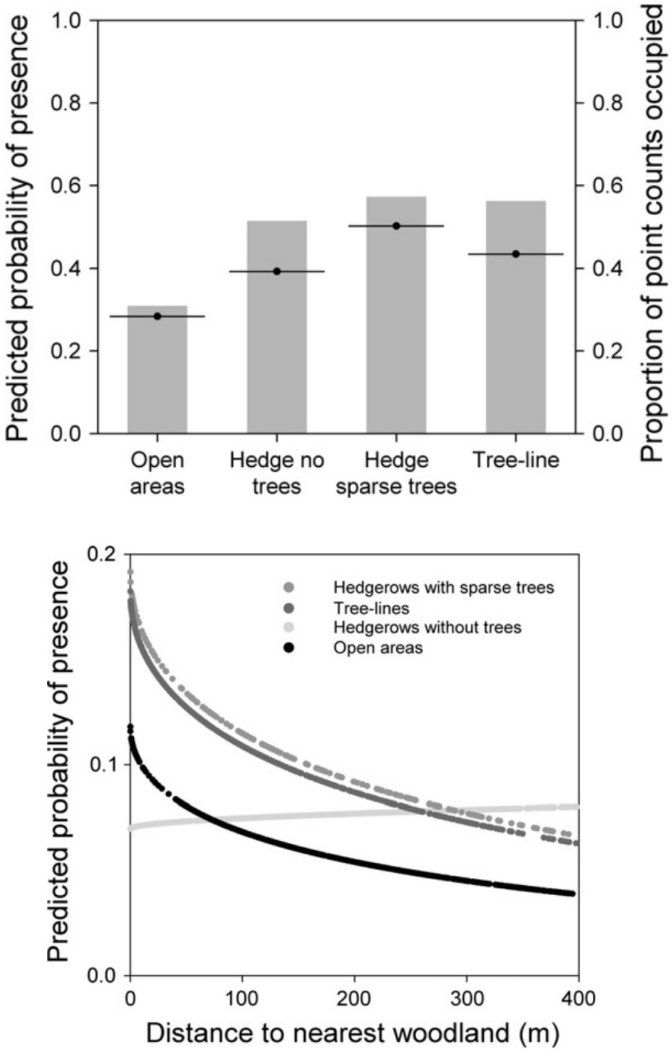



**Figure 5.** Estimated probabilities of occurrence as a function of presence and type of linear element (a) for Pipistrellus pipistrellus, (b) for *Pipistrellus pygmaeus. Based on Boughey et al., 2011.*

The third study by *Dondina et al. (2016)* in Italy is similar to the previous two, but compares the effects of hedgerow structure on two species with different traits: the European badger (*Meles meles*) and the muscardin (*Muscardinus avellanarius*). By sampling 55 hedgerows with varying characteristics (width, continuity, type of plant cover, etc.), the researchers showed that badger presence was more likely in wider hedgerows with reduced herbaceous cover (Figure 6a-b).

For the muscardin, the major factors influencing both probability of presence and abundance were the presence of a continuous hedgerow nearby, and hedgerows with well-developed shrub cover (Figure 6c-e). These results suggest that, in order to improve landscape connectivity for both species, it is desirable to maintain wide, continuous hedges, while at the same time ensuring significant bush cover.

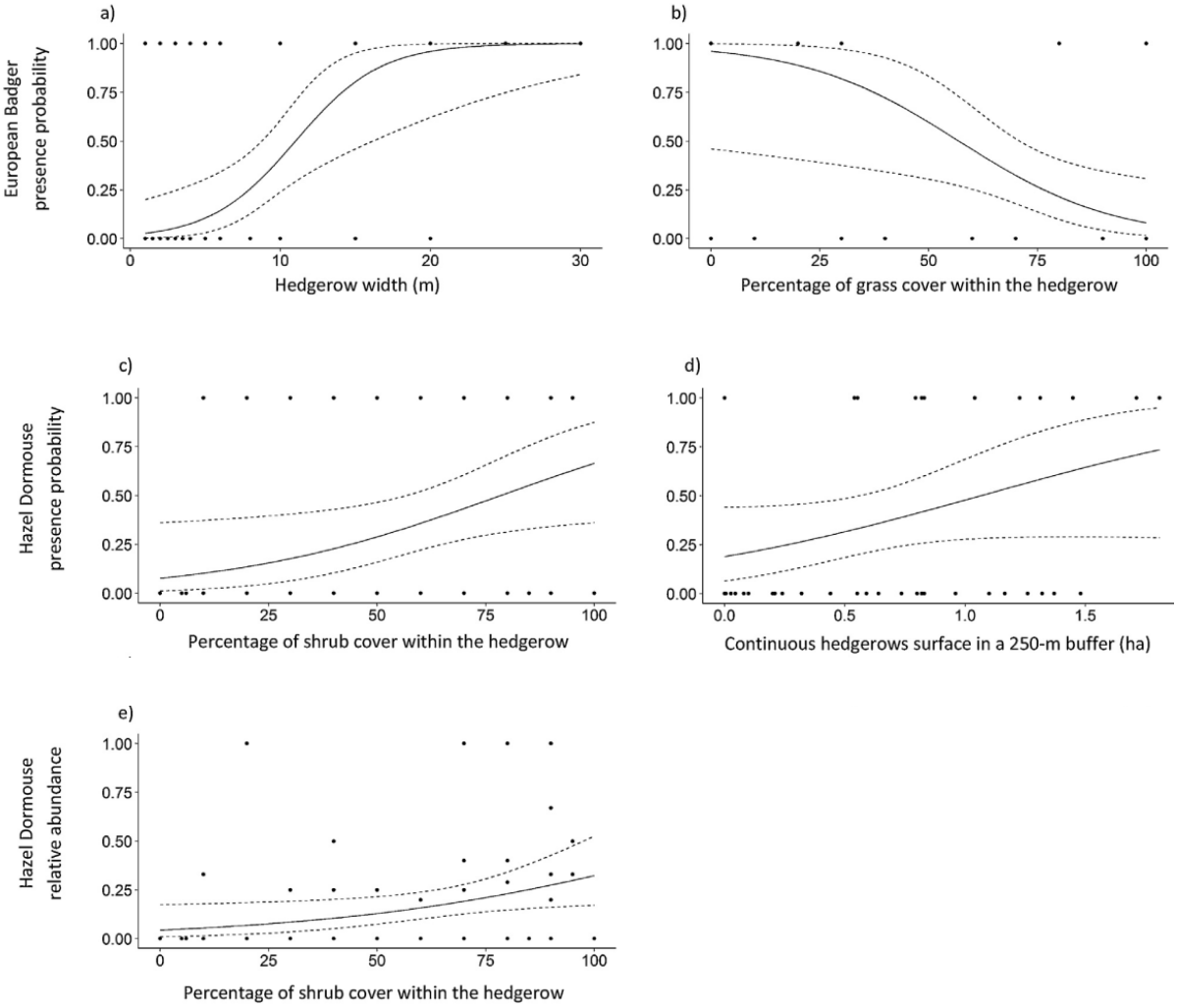



**Figure 6.** Relationships between probability of presence (badger, a and b) and relative abundance *(muscardin, c-e*) and the structural properties of the hedges sampled. Adapted from *Dondina et al., 2016.*

Finally, the last case study by *Batary et al. (2012)* takes into account an additional parameter: whether the hedgerow is connected to a habitat patch or isolated in the landscape matrix. The authors investigated the influence of this factor in Germany by carrying out ornithological surveys either at six hedgerows connected to the forest, or at six hedgerows isolated in the agricultural landscape. The data obtained showed no significant differences between forest-connected hedgerows and isolated hedgerows, either in terms of abundance or species richness. Nevertheless, the two types of site hosted distinct bird communities. No effect of hedge height or width was observed.

# 4. Meta-analysis

The meta-analyses we have carried out show no significant overall effect of the presence of linear elements in the landscape, either on species richness or vertebrate abundance. However, in the case of species richness, 13 out of 22 effects (59%) show a positive average effect of the presence of linear elements (Figure 7), in line with existing international literature on the subject. The influence of linear elements in the landscape appears to be highly species-dependent, probably linked to the biology and behaviour of individual species or even individuals, making global analyses of this subject difficult.

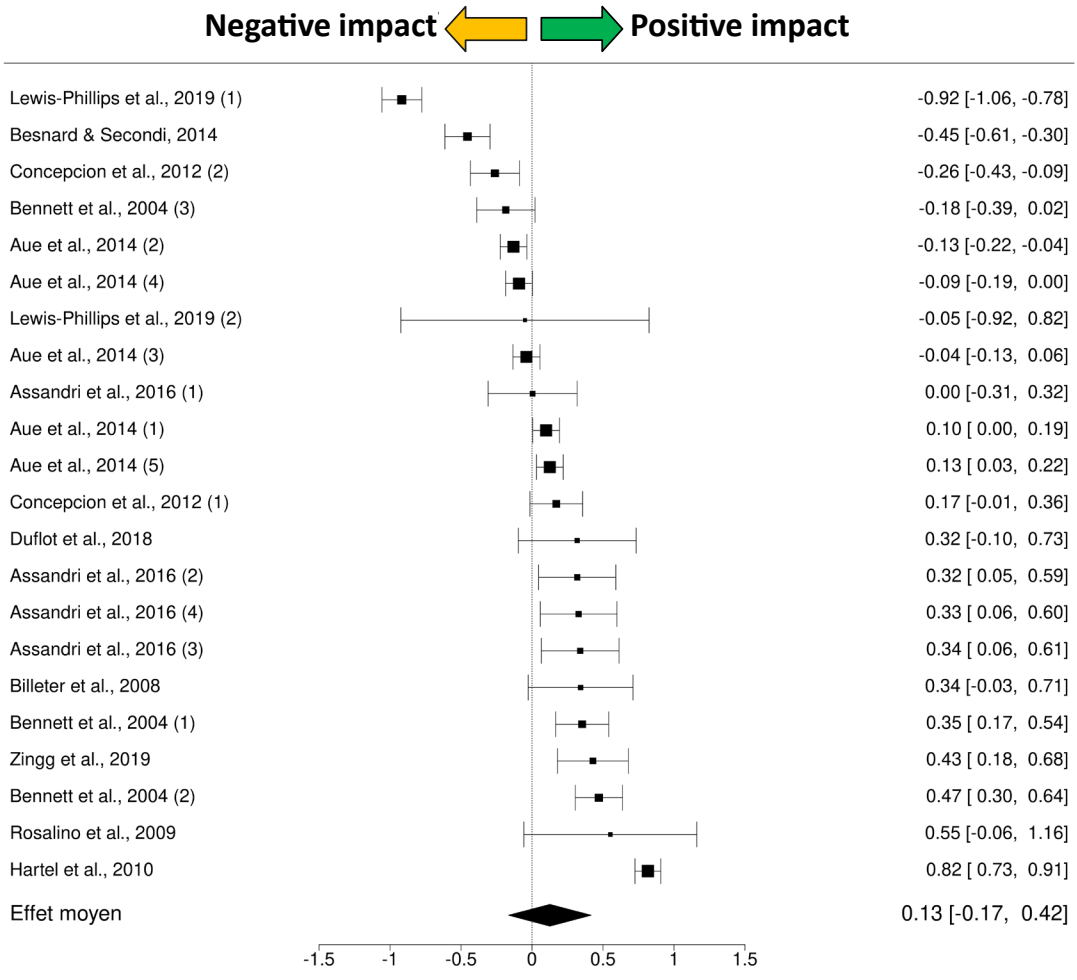



**Figure 7.** Effect on species richness. The further the mean deviates from the dotted line, the greater the effect is (positively or negatively).

## 5. Limits and prospects

Although some studies caught our attention, overall we noted a lack of available scientific knowledge concerning the role of corridors for vertebrates in Europe, particularly via manipulative studies. More studies exist on American vertebrates, demonstrating the effectiveness of corridors even if the contexts, landscapes and species are not necessarily transposable to Europe (*Resasco 2018; Gilbert-Norton et al., 2010*). However, these summaries highlight the scarcity of robust movement data for testing the corridor function, and also fail to integrate the issue of adaptation to climate change. Despite these limitations, this does not call into question the value of pursuing policies aimed at setting up ecological networks; maintaining a landscape dense with habitats and free from anthropogenic barriers would appear to be a common-sense, low-cost (and therefore no-regrets) measure for ensuring that ecosystems function properly, and all the more so in the face of climate change.

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