COHNECS-IT Can linear transportation infrastructure verges constitute a habitat and/or a corridor for biodiversity and in which context?

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I. INTRODUCTION

Linear transportation infrastructures (LTIs) have negative impacts on biodiversity, in particular because of the habitat loss and the landscape fragmentation that they generate. Over the last decades, these impacts have been widely studied. Recently, a new question raised among scientists: in parallel to these negative impacts, can LTIs verges act positively on biodiversity?

Indeed, LTIs are generally made up of a transportation lane (road, railway, pipeline, powerline, river or canal) and of **verges** (road and railway embankments, strips of grass under power lines or above buried pipelines, or waterway banks, etc.). A verge is a strip along, between, above or below the carriageway(s), inside the LTI boundaries, not directly used for transportation and managed by the LTI owner. In most cases, verges are covered by vegetation and may potentially constitute semi-natural habitats. It is thus of interest to assess whether, despite their fragmenting effect, LTI verges could contribute longitudinally to an ecological network and thus to biodiversity conservation through any **habitat and/or corridor effect(s)**. More precisely, if a positive effect was effective, for which species, in which landscape and with which management can it be assessed? In the context of such biodiversity losses and because the LTI network is very dense in France, LTI managers might significantly contribute to biodiversity conservation.

At first sight, the few studies that have considered this topic seem to have provided contrasted results and there is thus no consensus in the scientific community. For this reason, a call was developed in France through a research incentive program relative to transportation ecology, named "Infrastructures de Transport Terrestre, Écosystèmes et Paysage" (ITTECOP), with the help of the French LTIs managers (named "Club des Infrastructures Linéaires & Biodiversité" (CILB)) and the "Fondation pour la Recherche sur la Biodiversité" (FRB).

The "Muséum national d'Histoire naturelle" (MNHN) was then chosen to steer a project, named **COHNECS-IT** (See box B1). Its purpose was to product a **systematic review** (See box B2) on this topic, taking into account all accessible studies about the habitat and corridor effects of verges on biodiversity. This document summarize the method and the main results obtained up to 2017.

The review team COHNECS-IT (B1)

COHNECS-IT is a project led by the "Museum national d'Histoire naturelle" (MNHN) with several partners as the "Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture" (Irstea), the "Université de Pierre et Marie Curie" (UPMC), the "Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement" (Cerema) and of the "Institut national de la recherche agronomique" (Inra). Then, the team is composed by researchers and experts in ecology, librarians and biostatisticians. The interdisciplinary coordination was provided by the MNHN.

For further information: http://cohnecsit.mnhn.fr

II. METHOD AND APPROACH

The initial question presented above was divided in **six sub-questions** (See Table p.3) to distinguish, at first, the habitat/corridor effects of LTIs and, secondly, the influence of the management (intervention in the verge) or the context (landscape crossed by the LTI). The study focused on the **temperate climatic zone** and on **five types of LTIs**: road/highway, railway, pipeline, power line and waterway. Up to now, we only considered insects regarding the roads/highways and the waterways, due to the very important volume of documents published on this topic.

We used the frame of a systematic review, which aims making a knowledge synthesis, as proposed by the **Collaboration for Environmental Evidence** (See box B2). The specific method used by COHNECS-IT has been published in the Environmental Evidence Journal (Jeusset *et al.*, 2016).

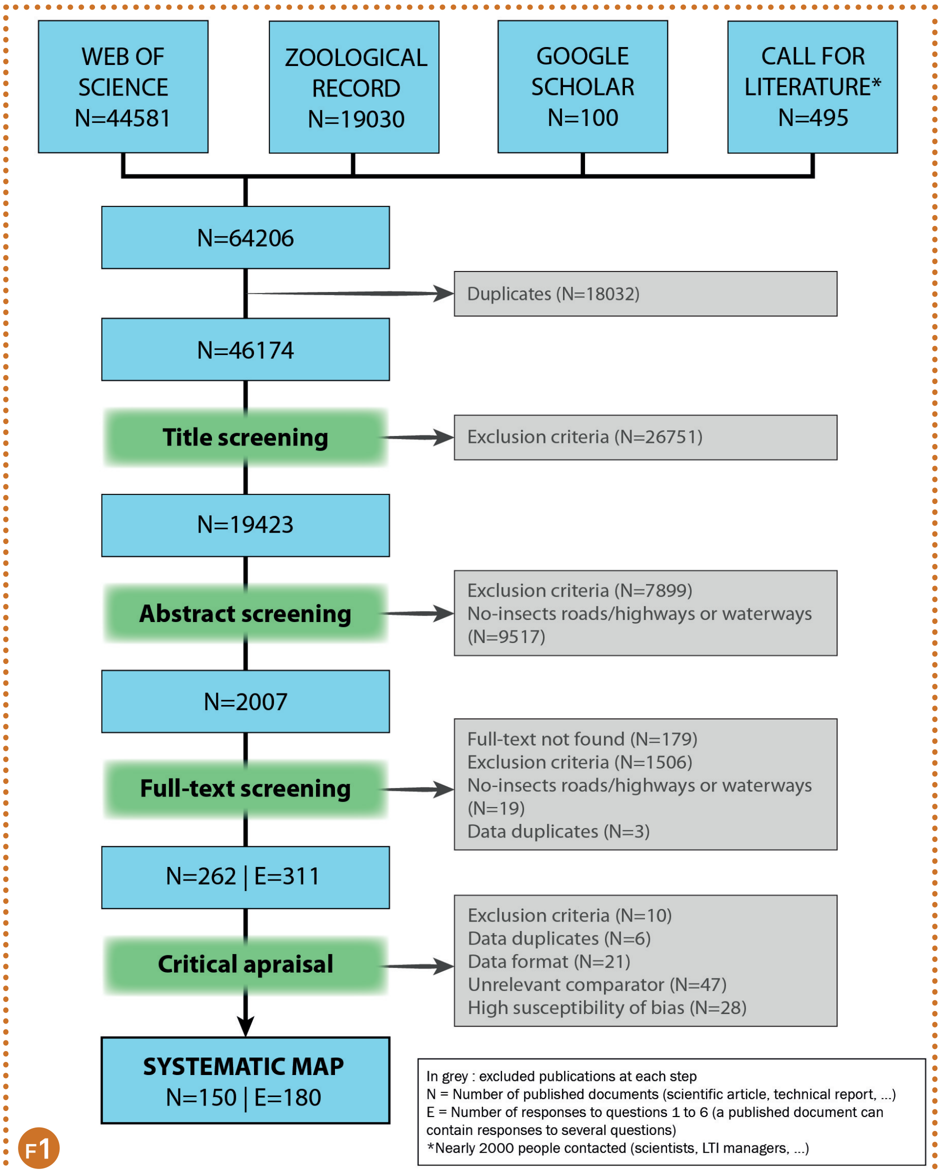
What is a systematic review ? B2

A systematic review is an exercise of evidence synthesis based on published knowledge from researchers and experts in order to inform decision makers. The goal of this exercise is to answer a practical question, by carrying out a knowledge synthesis, understandable of all and robust to possible criticisms. A systematic review is based not only on scientific publications but also on grey literature and follows a standardized and internationally approved protocol. In the environmental field, the international institution giving its seal of approval to systematic reviews is the Collaboration for Environmental Evidence. In France, application of this method is very recent, moreover about biodiversity conservation. Since 2016, the FRB is designated as the official french representative center of the CEE.

For further information: http://www.environmentalevidence.org and http://www.fondationbiodiversite.fr

The main steps of the COHNECS-IT project were (See figure F1):

1. We collected the **scientific literature as well as the grey one**. For this, two online databases were consulted (Web of Science Core Collection and Zoological Records). Additionally, we contacted by e-mail national and international experts of transportation ecology (nearly 2,000 people) and we performed internet searches using Google Scholar.



F1

2. We assessed the relevance of the collected publications for their inclusion, at **three successive levels**: first on titles, second on abstracts and third on full-texts.

3. We developed a **critical appraisal** with several criteria to assess the relevance and the susceptibility to bias of the articles included following the full-text screening.

4. We mapped in a database the studies included after critical appraisal, i.e. the publications that had a low or a medium level of susceptibility to bias. This **systematic map** allows to have a view on the state of the literature regarding our topic. This map is freely accessible and easily searchable.

5. Qualitative and quantitative data were extracted from publications included in the systematic map, respectively to write **narrative syntheses** and to assess the opportunity of a meta-analysis.

6. We performed **meta-analyses** for the specific sub-question Q2 (that deals with the habitat effect of the LTIs verges, See Table p.3) that gathered enough homogeneous studies with the required statistics on insects (See box B3).

A systematic review that deals with habitat and corridor effects of LTIs verges on insects was submitted to EEJ (Villemey *et al.*, 2017).

This document summarizes the main results obtained for the six sub-questions, for the five LTIs and for all biological groups (excepted for roads/highways and waterways: only insects have been considered for the moment for these LTIs).

INFLUENCE/ FUNCTION	HABITAT	CORRIDOR
INTERVENTION	Q1 = Which LTI verge management practices increase, decrease or have no effect on insect biodiversity?	Q3 = Which LTI verge management practices increase, decrease or have no effect on insect dispersal?
EXPOSITION	Q2 = Is the insect biodiversity of LTI verges higher, lower or equal thano the biodiversity of habitats away from the LTIs?	Q4 = Is insect dispersal on LTI verges higher, lower or equal to their dispersal in habitats away from the LTI?
CONTEXT	Q5 = Is the insect biodiversity of LTI verges dependent on the surrounding landscape?	Q6 = Is insect dispersal on LTI verges dependent on the surrounding landscape?

Six sub-questions specifying the initial question asked

III. RESULTS

1. Roads / Highways (insects only)

Only 43 of the 71 studies on the roads (See figure F2), provided statistical results relevant to our questions. **Q1.** The effect of mowing is very difficult to appreciate because the results vary according to the groups of insects and the mowing modalities (frequency, date, removal or not of cutting, etc.). **Q2.** From 30 studies, we can observe an overall lack of difference between road edges and other environments in terms of abundance and / or number of insect species. Pollinators (bees, bumble bees and butterflies), ants and «undesirable» species (parasites, invasives) appear to be favored along roadsides. The observed differences in the results of the studies about Coleoptera could be explained by the species' characteristics (habitat preference, type of feeding) and the compared environments. **Q4.** The two studies comparing dispersal of roadside insects with that in other environments appear discordant: the movement of a moth species is favored by the roadside while the movement of a carabid species is stronger? in other settings.

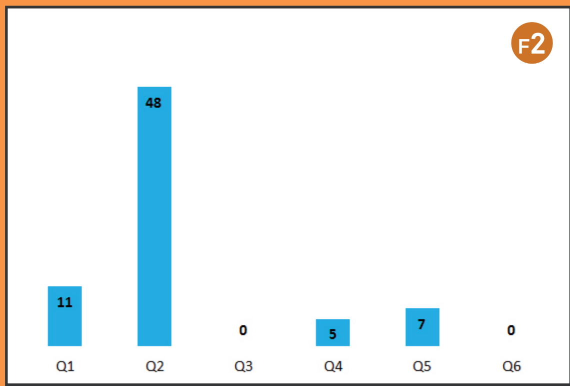
2. Railways

Among the 27 studies of railways (See figure F3), only 15 provided statistical results for our purposes. **Q2.** In many cases, the biodiversity of railways verges appears to be similar to that of other habitat as observed for rodents, foxes, hoverflies, Japanese Knotweed (an invasive plant) and rue-leaved saxifrage. **Q4.** In the two studies that deal with dispersal, foxes are not influenced by railways, whereas stations or bridges / walkways reduce dispersal of plant species along the tracks. **Q5.** The proportion of surrounding forests influences positively the number of species of butterflies, bees and hoverflies of railways' verges. The urbanization of the landscape negatively impacts Orthoptera in one study. In another study, it does not influence plant-specific richness but increases the frequency of invasive plants.

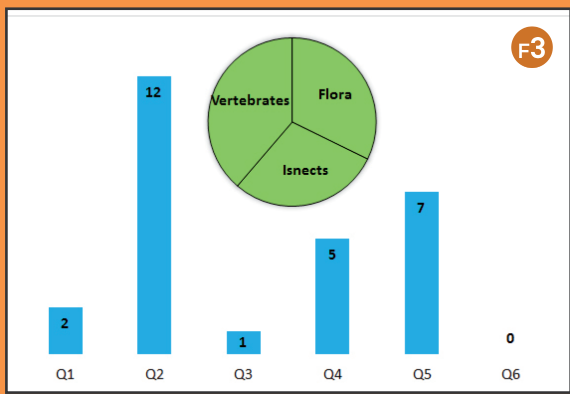
3. Pipelines

Seven studies relate to the gas pipelines (See figure F4). **Q1.** A study demonstrates a positive effect of grazing and vegetation restoration through hay transfer (a method of vegetation restoration by importing hay whose seeds will sow the disturbed environment) on the number of plant species of the verge. **Q2.** The same study showed that the vegetation of the pipeline concerned was less diverse and abundant than in the undisturbed adjacent environment. Another ar-

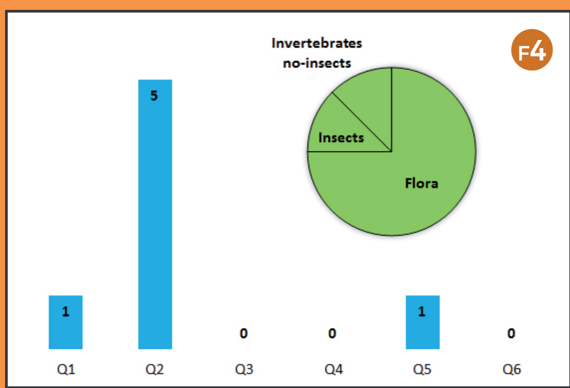
NUMBER OF STUDIES INCLUDED IN THE SYSTEMATIC MAP FOR EACH TYPE OF LTI



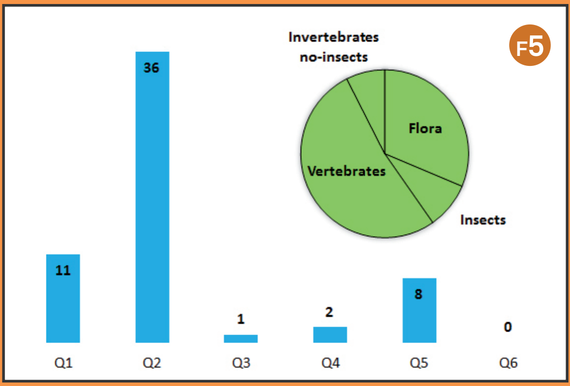
Roads/highways



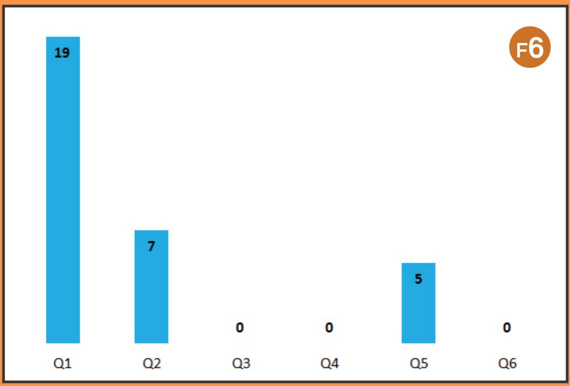
Railways



Pipelines



Powerlines



Waterways

ticle highlights a higher proportion of invasive alien plants for some gas pipelines. An article highlights contrasting responses between carabids' species: some preferring the pipeline, others avoiding it. In another article, crustaceans and molluscs composition was diffent between a gas pipeline and the original habitat, depending on the species and the sites studied. **Q5.** The only article dealing with the influence of the landscape does not highlight any effect of the context of the pipeline on its plants.

4. Power lines

Of the 58 studies involving power lines (See figure F5), 47 provided statistical results usable in our study. **Q1.** The frequency and intensity of vegetation management of power lines dependencies appear decreasing the abundance of certain rodents and the reproductive success of birds. The shares of woody plant species and those associated with shrub and forest environments also diminished with the frequency and intensity of vegetation management. **Q2.** As might be expected, the flora under the power lines can sometimes be distinguished from adjacent forests, by a greater coverage of herbaceous or shrub open environments characteristics species. Five articles show that some mammals (cervids, rodents) may benefit from power line dependencies, especially for their feeding, but the responses vary according to season and species. In four articles, the birds' response is also variable, but their reproductive success is similar between the verges and the compared environment (according to four other articles). Concerning the insects, a synthesis of the studies looks difficult as the results differ according to the groups or the season. **Q4.** Two studies indicate an equivalent dispersal of rodents between the verges and the adjacent forest but the presence of luminous structures in the dependence does not influence this dispersal. **Q5.** In many cases, the tested landscape variables do not influence the biodiversity under power lines. Nevertheless, it can be noted that in two articles urbanization and agriculture reduce the abundance of birds and increase the abundance of an invasive species, the American black cherry.

5. Waterways (insects only)

From the 31 studies dealing waterways (See figure F6), 15 provided usable statistics. **Q1.** Overall, the management of riverbank vegetation does not seem to impact insects. Only two articles show a benefit in the case of effective eradications of exotic plant species. In one paper, riverbank mineralization by riprap reduces the number of Coleoptera species on the banks. The same article shows that at the same time it increases the frequency of invasive Coleoptera (when compared to vegetated or mixed banks). **Q2.** Three articles compare the insect communities along the waterways to those of other habitats. The results differ according to the groups and species studied and the environment type medium used for comparison, hence a difficulty in identifying any trend. **Q5.** The surrounding landscape would not always influence the insect communities of the banks. Nevertheless, urbanization and agriculture development would be detrimental to them while the presence of forests and surrounding natural areas would be beneficial.

IV. IMPLICATIONS AND RECOMMENDATIONS

A. For managers of LTI verges

Given the literature state (strong heterogeneity of outcomes depending on study species and sites, numerous studies without statistical results...), it is difficult to generalise the results of the studies and to make precise recommendations for the management of LTI verges. However, three important conclusions can be:

1- LTI verges **are not "deserts"**. They can host similar to higher levels of insect biodiversity than surrounding habitats.

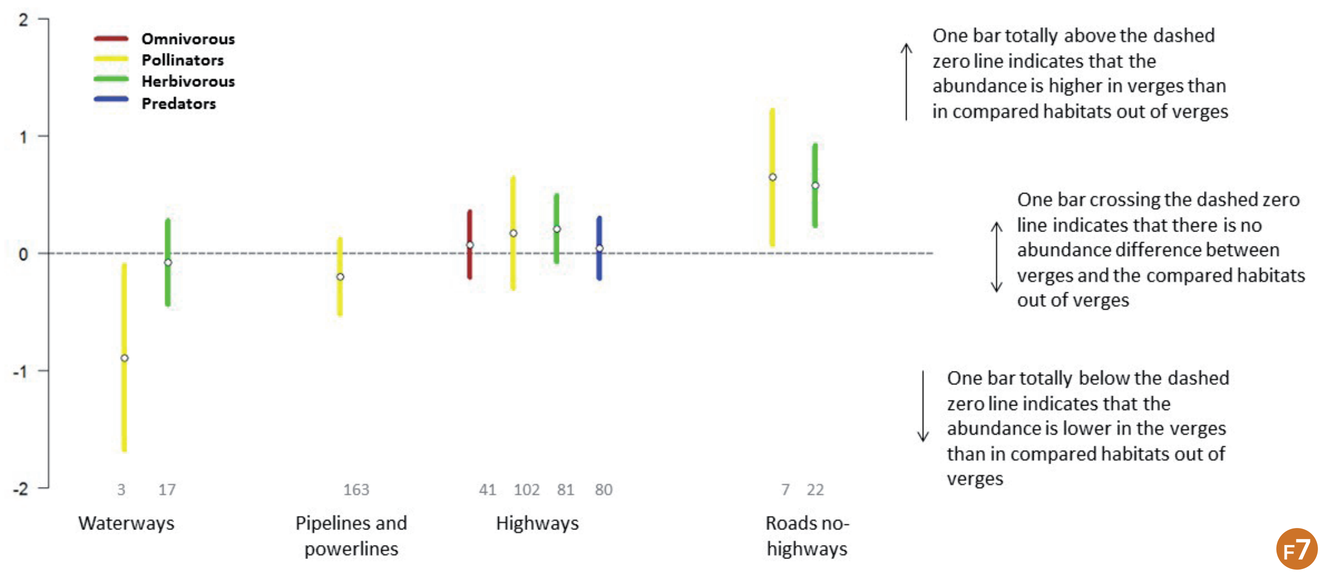
2- The "**naturalness**" of LTI verges seems to have a positive effect on the abundance and diversity of insects. For example, using natural materials (especially for waterway banks and retention ponds) and favouring indigenous vegetation in verges were shown as beneficial for biodiversity.

3- The state of the biodiversity in LTI verges depends on **the surrounding landscape**. It looks like LTI verges are richer in preserved environments ("natural" landscapes) than in urbanised or agricultural landscapes. This is because the surrounding landscape influences the source panel of species which can potentially settle in LTI verges.

A meta-analysis on the effect of habitat on LTI verges for insects

B3

A meta-analysis allows combining the results of several studies. 709 quantitative data on insects were extracted from 34 studies investigating question 2. Among these data, 48 are comparisons of the number of species (specific richness) and 661 are abundance comparisons (number of individuals per species or per taxonomic group), between LTI verges and other types of environments.
Over all LTIs and species, there is no difference between verges and other types of environments, regarding species number or abundance. However, the results are slightly different when accounting for the type of LTI and species characteristics. In most cases, abundance and species number remain similar. However, for roads other than highways, pollinators and herbivorous insects are more abundant in LTI verges than in similar habitats outside from LTI verges (See figure F7). The appearing lower abundance of pollinators in waterway banks (figure F7) being based on only 3 studies, this result is not reliable and should be confirmed by further studies.



Results of the meta-analysis on insects abundance.
Pipelines and powerlines were combined. There is no result for railways because the number of studies was insufficient. For the same reason, results are available only for some insect groups (herbivorous, predators...). Numbers in grey show the number of data for each type of LTI and insect group.

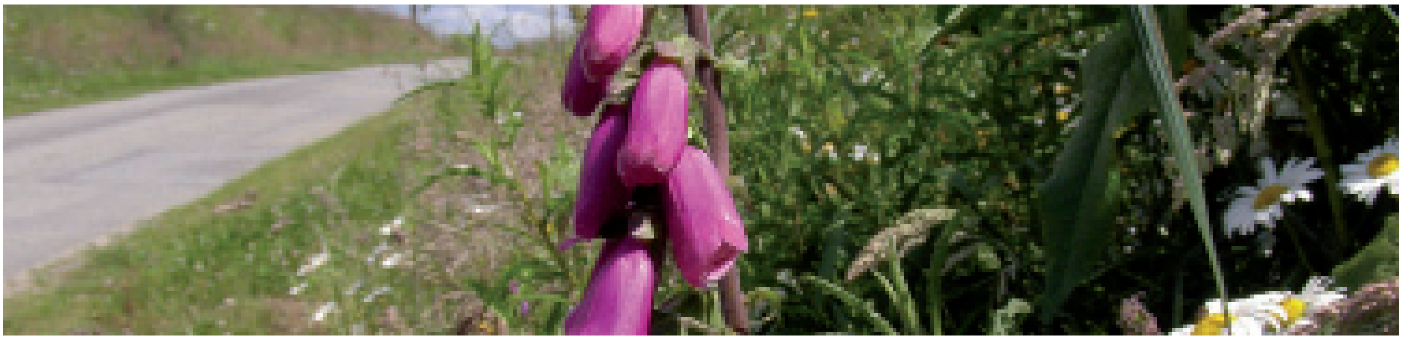
B. For future projects of applied research

Our systematic review allows drawing several recommendations for future research projects:

- There is a strong **lack of knowledge** on the role of verges as corridors. Often, the publications supposed (according to their title) to deal with this question actually only look at potential corridor effects based on habitat contiguity only. LTI-related movements of insects have been investigated, but those studies have almost exclusively focused on transversal movements (i.e. on the barrier effect of LTIs). It is hence essential to run studies on longitudinal flows in LTI verges, using approaches such as landscape genetics, telemetry (VHF, GPS, ...) or capture-mark-recapture.

- A strong **disequilibrium among LTI types** was observed in the literature, with an over-representation of studies on roads. Even though roads are the main LTIs in France, it would be useful to improve our knowledge on the other types of LTIs, especially railways (another major type of LTI).

- It is necessary to dig dipper into the question of the contribution of LTI verges for biodiversity at **the landscape scale** (for ex: in a given area, which proportion of species can be found in LTI verges?), a question very little investigated so far.



- We recommend to favour **experimental studies**, which would allow revealing links between causes and effects (e.g. impact of a type of management on biodiversity), contrary to observational studies which, at the best, provide correlations. Different criteria then need to be respected to insure the quality of the experimental design (See box B4).

A few quality criteria for an experimental study in ecology

B4

• Use a relevant control site to which LTI verges will be compared. The choice of the control site depends on the question:

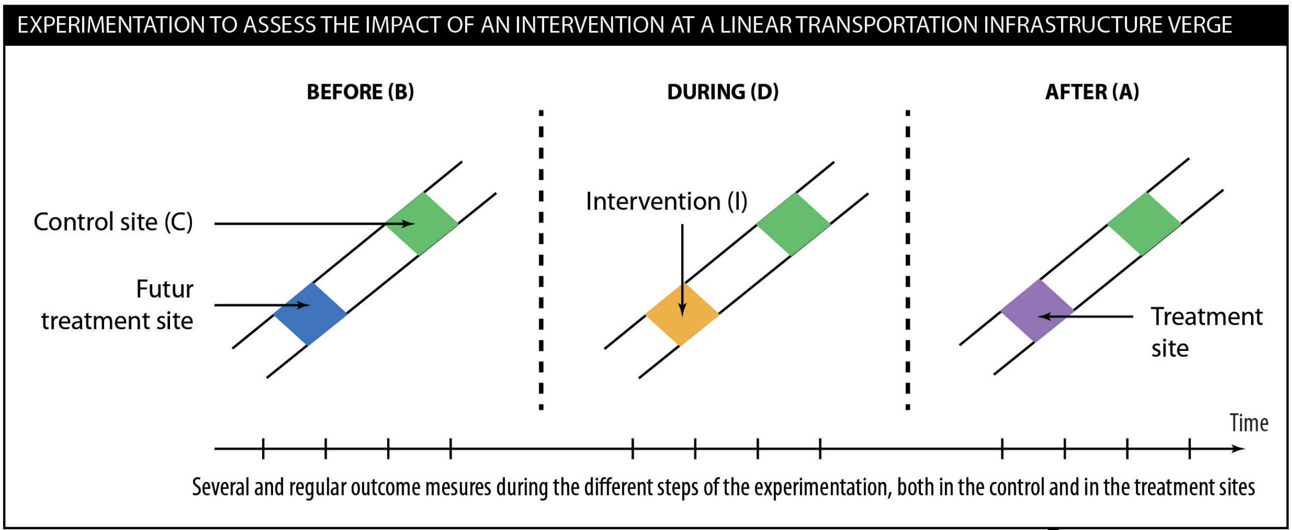
  * Questions 1 and 3: LTI verge either unmanaged or managed in a different way
  * Questions 2 and 4: site outside an LTI verge, “natural” and with a similar type of habitats
  * Questions 5 and 6: LTI verge in another type of surrounding landscape

• Repeat the study in several sites (both for LTI verges and control sites) according to a “real” replication (e.g. several portions of several LTIs)

• Select the study sites according to a relevant sample minimising biases (e.g. random sampling)

• Run long-term studies and if possible replicate them in time

• In the cases where an intervention is studied (e.g. a type of management), favour the “BACI”-type designs, i.e. those with measures both before and after the intervention, and both in the LTI verge and in a control site (See figure F8)



Type of protocol	Abbreviation	Robustness
Before-During-After-Control-Intervention	BDACI	+++
Before-After-Control-Intervention	BACI	+++
Before-After-Intervention	BAI	++
Control-Intervention	CI	+

The hole experiment has to be repeated many times in the space and in the time (=**real replication**)

F8

For further information

VILLEMEY, A., JEUSSET, A., VARGAC, M., BERTHEAU, Y., COULON, A., TOUROULT, J., VANPEENE, S., WITTÉ, I., JACTEL, H., DENIAUD, N., FLAMERIE DE LACHAPELLE, F., JASLIER, E., ROY, V., GUINARD, E., LE MITOUARD, E., RAUEL, V. & SORDELLO, R. 2017. Can linear transportation infrastructure verges constitute a habitat and/or a corridor for insects in temperate landscapes? A map and a systematic review. *Environmental Evidence*....

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