



## FINAL REPORT

### I. Project identification

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**Project title:** BRIDGE

**[FR] Titre du projet:** *Quand corridors routiers, corridors fluviaux et bords de cultures entrent en contact : co-construction paysagère des diversités taxonomiques et fonctionnelles végétales*

**Acronym:** *Building a bridge between river corridors, roadsides and field margins: how landscape interactions modulate taxonomic and functional plant diversity*

**Co-funding organization** (if relevant): ITTECOP

**Principal Investigators:** Eric Tabacchi (CRBE, Université de Toulouse-CNRS-INPT-IRD, Toulouse, FR) & Guillaume Fried (Unité d'entomologie et de botanique, ANSES, Montferrier-sur-Lez, FR).

**Name of the person writing the report** (if not the Principal Investigator):

E-mail of the person who wrote the report:

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**Starting date of the project:** 30 June 2022

**Finishing date of the project:** 30 June 2025

**Scientific summary of project** (maximum of 300 words, spaces included)

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BRIDGE aimed to understand how riparian corridors, road corridors and field crop margins shape both taxonomic and functional plant diversity across agricultural landscapes. We compared such landscape patterns from Spain, France and United Kingdom. The first task was devoted to build a homogenised database including 11,400 samples, more than 3,000 species and related environmental variables and biological traits. In the second task, we first highlighted the ecological effects of road-river intersections (bridges) on plant communities. The alteration of plant diversity is significant at bridges compared to reference sites. However, bridges had no effect on the percentage of native and non-native species, nor were there differences between bridge and reference quadrats in the community-weighted mean (CWM) of invasive versus non-invasive status. The use of specific spatialized models showed that this effect was local and that non-directional (across landscape) factors influenced more plant diversity than directional (within-corridor) ones. Physical disturbance (transverse gradient) played also an important role in shaping diversity. . Then we estimated the importance of the species shared among the three linear habitats and inferred their role in shaping both functional and taxonomic diversity. The three habitats share 30% of the total number of species. Riparian species host the highest number of species (gamma diversity) and the highest proportion of specialists, while roads and field margins shared the highest number of indicator species. Traits related to disturbance, soil moisture and nutrient loads explained the differences in

functional diversity. Hypervolume analysis showed that habitat heterogeneity and near-natural disturbance explain the broader functional space of riparian corridors. A more specific ongoing work is targeting the effects of local and regional factors on introduced species. In a fourth task, we draw some management implications of this project, suggesting that: i) interactions among linear habitats should be included in management strategies and ii) the studied habitats include both good (refugia for threatened or keystone species) and bad (invasion by exotic species) aspects, that should be mitigated, especially in the scope of climate change.

**[FR] Résumé du projet** (maximum de 300 mots, espaces inclus)

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Key words (5): river corridor, road corridor, field crop margin, taxonomic plant diversity, functional plant diversity

**Context and objectives** (around 1,500 characters including spaces)

*This will be used in the 'fiche résultat' for the project. CESAB-FRB reserves the right to modify the text for publication on its platforms. You will be consulted before publication. As these elements are intended for the general public, be sure to write this text in a way that is easy to understand.*

Riparian corridors, road corridors and field margins expand a very substantial importance in agricultural landscapes. They include very diverse ecological attributes and are exposed to contrasted levels of anthropogenic influences. As linear, often interacting structures, they play a major role by hosting and facilitating the spread of plant species. Such habitats can host specialized or threatened species, as well as opportunistic or invasive ones. They share many species, suggesting a partial ecological substitutability among linear entities. In the context of Climate Change, such habitats can facilitate distributional shifts. BRIDGE explored these potential roles considering both taxonomic and functional attributes at landscape-level and local scales along a European gradient from Catalonia to the United Kingdom. We investigated the importance of intersections, proximity, as well as the main ecological drivers (biogeographical settings, disturbance, nutrients, moisture,...) for shaping plant communities along and within these habitats. As an input task, we challenged the construction of a consistent database from heterogeneous data. As an output, we used our results to do recommendations to managers, including conjoint (multi-habitat) perspectives and mitigation between desirable and undesirable elements of plant community development.

**[FR] Contexte et objectifs** (environ 1 500 caractères espaces inclus)

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Les corridors riverains, les corridors routiers et les bordures de champs développent des linéaires très importants dans les paysages agricoles. Ils présentent des caractéristiques écologiques très variées et sont soumis à des niveaux contrastés d'influences anthropiques. En tant que structures linéaires, souvent interconnectées ou voisines, ils jouent un rôle majeur en hébergeant et en facilitant la dispersion des espèces végétales. Ces habitats peuvent accueillir des espèces spécialisées ou menacées, tout comme des espèces opportunistes ou envahissantes. Ils partagent de nombreuses espèces, ce qui suggère une substituabilité écologique partielle entre ces entités linéaires.

Dans le contexte du changement climatique, ces habitats peuvent faciliter les déplacements des espèces. Le projet BRIDGE a exploré ces rôles potentiels en prenant en compte les attributs taxonomiques et fonctionnels, à l'échelle du paysage et à l'échelle locale, le long d'un gradient européen de la Catalogne au Royaume-Uni. Nous avons analysé l'importance des intersections, de la proximité, ainsi que des principaux facteurs écologiques (contextes biogéographiques, perturbations,

nutriments, humidité, etc.) dans la structuration des communautés végétales le long et à l'intérieur de ces habitats.

En amont, nous avons relevé le défi de construire une base de données cohérente à partir de données hétérogènes. En aval, nous avons utilisé nos résultats pour formuler des recommandations à l'intention des gestionnaires, en intégrant une perspective multi-habitats et en proposant des mesures d'arbitrage entre les éléments souhaitables et indésirables du développement des communautés végétales.

## II. Project participants

### List and attendance of project participants

Please indicate if any project participants were unable to attend a meeting, but were active remotely by using an asterisk (\*).

	Name	Affiliation	Country	WS1	WS2	WS 3	WS 4	WS 5
PI 1	Eric Tabacchi	Centre de Recherches en Biodiversité et Environnement, Université de Toulouse, CNRS, INPT, IRD, Toulouse	FR	X	X	X	X	X
PI 2	Guillaume Fried	Laboratoire de la Santé des Végétaux, Unité Entomologie et Botanique, ANSES, Montferrier-sur-Lèz	FR	X	X	X	X	X
Post-doc	Erica rievrs-Borges	FRB-CESAB	BRA/FR	*	X	X	X	X
Post-doc	Aaron Sexton	FRB-CESAB	USA/FR				X	X
1	Marta Carboni	Dipartimento di Scienze, Università Roma TRE	IT	*	X	X	X	X
2	Eduardo Gonzalez-Sargas	Department of Biology, Colorado State University; USGS Arizona Water Science Center, Tucson, Arizona	USA	*	*	*	X	*
3	Alejandro Juarez-Escario	Department of Plant Production and Forest Science, ETSEA, University of Leida	ES	X	*	X	X	X
4	Claude Lavoie	Ecole Supérieure pour l'Aménagement du Territoire, Université Laval, Québec	CA	*	*	*		
5	Lindsay Maskell	Centre for Ecology and Hydrology, Lancaster	UK	*	*	*	*	*
6	Anne-Marie Planty-Tabacchi	Centre de Recherches en Biodiversité et Environnement, Université de Toulouse, CNRS, INPT, IRD, Toulouse	FR	*	*	*	*	*

**Please list any additional invitees similarly, and identify their category: i.e. students, postdocs or visiting experts**

1	Nicolas Cazajus	FRB CESAB	FR	X	X	X	X	X
2	David Bauman	AMAP-IRD	FR				*	
3	Bérenger Bourgeois	Centre de Recherche et d'innovation sur les végétaux, Université Laval, Québec	CA					*

**Comment :**

### III. Activity report

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Describe the main stages of advancement of the project, its main results, and their importance for this particular field of research. Please include some key illustrations and figures (**300dpi, 10 x 10cm minimum with legends and reference in the text**). Approximately 8 to 10 pages, with guidelines for the size of sub-sections. You can add documents as Appendices if necessary.

#### III.1 Description of the work conducted and scientific results obtained: for the scientific reader.

The BRIDGE project gathered eight specialists of plant ecology (landscape ecology, community ecology, functional ecology, biological invasion ecology and biostatistics) originating from six distinct countries. This project investigated how plant community and ecological strategies vary across three types of linear habitats—riversides, roadsides, and field margins—and how their intersections, particularly road–river crossings (bridges), influence these patterns. Linear habitats are widespread in human-modified landscapes and often act simultaneously as corridors, filters, and refuges for plant species. However, they are subject to diverse and intense pressures: hydrological disturbance in riparian zones, mechanical management and pollution along roads, and agricultural spillover in field margins. While these habitats are often treated as functionally similar in conservation and infrastructure planning, we aimed to disentangle the specific ecological roles they play and to identify the distinct and combined effects of anthropogenic structures, especially bridges, on plant diversity and community composition. The studied habitats exhibit various levels of vulnerability when facing recent Global changes, especially Climate changes. An applied objective of BRIDGE is to document how they can interplay as refuges, surrogate habitats, or vectors for climate tracking.

The first task of the BRIDGE project was to build a common database including existing floristic datasets from France, United Kingdom and Spain, totaling about 3,000 plant species observed in 11,400 plots located along roads, rivers and cultivated fields. Once the plant names homogenized, plant trait values and environmental variables (both local and regional scales) were added to the database.

The research by itself was structured around two complementary research actions.

The first one, detailed in Borges et al. (2025), focused simultaneously on on the fine- and broad-scale impacts of road–river intersections. We surveyed vegetation at 19 bridges along the Adour and Garonne river systems in southern France, collecting data from 4,560 quadrats located along both roads and rivers, either adjacent to or at a distance from bridge structures (reference sites). Bridges were sampled from the source to the estuary (cumulated length: 900 Km). As intersections between roads and rivers, bridges are likely to disrupt the spatial biotic continuity along these corridors, especially along rivers where ecological continuums have been identified from the source to the mouth. Also, we expected that specific management practices at bridges create original constraints for the vegetation that limit functional diversity. Due to the corridor structure, we expected a stronger influence of factors shaping biodiversity along the corridors (including internal transverse disturbance gradients) than through the neighbouring landscape. Our basic questions were: i) are the alpha and beta diversities of plant communities affected by bridges; ii) do environmental filters at bridges favor species with similar ecological preferences, leading to trait convergence, compared to plant communities on river and roadsides away from bridges?; iii) are directional spatial processes more important than non-directional spatial processes in structuring riverside and roadside species composition, and do bridges influence the effect of directional spatial predictors on species composition?

Within each type of corridor, we considered the inner edge, the interior area and the outer edge as transverse sampling units. We compared species richness (alpha diversity), compositional dissimilarity (beta diversity), and ecological trait composition (functional diversity) between “bridge” and “reference” locations. Additionally, we analyzed community-level ecological indicator values (e.g., moisture, nutrient preference) and used spatially explicit modelling (Moran’s Eigenvector Maps and Asymmetric Eigenvector Maps) to assess the respective role of directional (e.g., upstream–

downstream) and of non-directional (diffuse, overland) spatial processes in shaping community structure. A specific R package was developed to automatically fill the connectivity matrix among the samples (Casajus et al. 2023).

The second research action used a large-scale (European latitudinal gradient) comparative approach based on 11,000+ vegetation plots from national and regional monitoring schemes in France, the UK, and Spain. This synthesis allowed us to characterize species pools and functional trait spectra in riversides, roadsides, and field margins, and to assess overlap, specialization, and ecological strategies using both taxonomic and trait-based analyses. We paid particular attention to invasive and threatened species, exploring how their distributions vary across habitats and how these patterns relate to habitat structure, disturbance regimes, and connectivity. We addressed more specifically the following questions: (1) To what extent do the species pools of these three habitats overlap taxonomically? (2) How do the functional traits of species pools differ across habitats in terms of ecological strategies (LHS traits), resource requirements, and disturbance responses? (3) What are the implications of these patterns for biodiversity conservation (threatened species) and management (invasive species) in linear habitats? We hypothesized that field margins and roadsides would share a higher proportion of ruderal and disturbance-adapted traits compared to riversides, which would support more hydrophilic and stress-tolerant species and that invasive species will be more prevalent in roadsides and riversides due to their corridor function and frequent disturbances facilitating dispersal and establishment.

To perform the analyses, we selected plant traits related to the Westoby's LHS strategy (SLA, plant height and seed mass) and assessed plant response to physical disturbances by using the Midolo's Disturbance Indicator Values. We used Ellenberg's indicators to assess plant resource (nitrogen, light, moisture) requirements. We used resampling techniques to account for regional sampling biases in the original datasets. We characterised species habitat affinity by using indicator values (IndVal). We calculated and compared functional hypervolumes from all observed species, species specific to a given habitat, and species shared by two or three habitats.

Key findings from the bridge-focused study include:

- We identified 1,446 plant species at the total, with i) 1,057 occurring at bridges and 1,299 at reference sites and ii) with 1,093 species found along rivers and 1,139 along the roads. Roads and rivers shared 786 species. The percentage of non-native species was similar (23%) along rivers and along roads, with slightly more invasives along roads (0.55%) than along rivers (0.35%).
- Surprisingly, the average alpha diversity was significantly higher along roads (13 species/m<sup>2</sup>, 0 to 49 species/m<sup>2</sup>) than along rivers (10 species/m<sup>2</sup>, 0 to 73 species/m<sup>2</sup>). This shows the potential of artificialized system for hosting high levels of diversity. However, the observed difference was due to higher proportions of opportunistic and widely distributed species. In contrast, riparian zones exhibited higher proportions of specialized species, even though a substantial part of the flora also included ruderal and non-native species.
- Species richness and diversity were significantly lower at bridges than at reference sites for both riversides and roadsides. In rivers, richness at bridges was reduced by ~33%; in roadsides by ~16%. Shannon diversity showed similar declines. This reduction was especially pronounced in zones closest to the water or roadway (e.g., frequently flooded areas and berms).
- Beta diversity turnover decreased at bridges, particularly in zones most exposed to disturbance. This suggests a process of biotic homogenization, where bridge-related

environmental filters favor generalist species and reduce compositional variation across space.

- Functional diversity (measured via functional dispersion) was lower at bridges, reflecting convergence in ecological preferences. However, while both rivers and roads showed this trait filtering effect, they did not converge toward the same ecological optima—indicating that bridges act as parallel but distinct filters for the two systems.
- Trait-based community responses revealed that bridges selected for species with specific ecological preferences, such as higher tolerance to heat and low soil moisture in roadsides, and lower soil texture preference in riversides. This highlights how artificial structures impose novel selection pressures distinct from natural gradients.
- Despite strong local effects, bridges did not significantly alter directional spatial structuring in riverine plant communities. Redundancy analyses showed that overland spatial processes (MEMs) explained more variation in species composition than directional watercourse processes (AEMs), and that including bridge connections in spatial models did not significantly improve explanatory power.

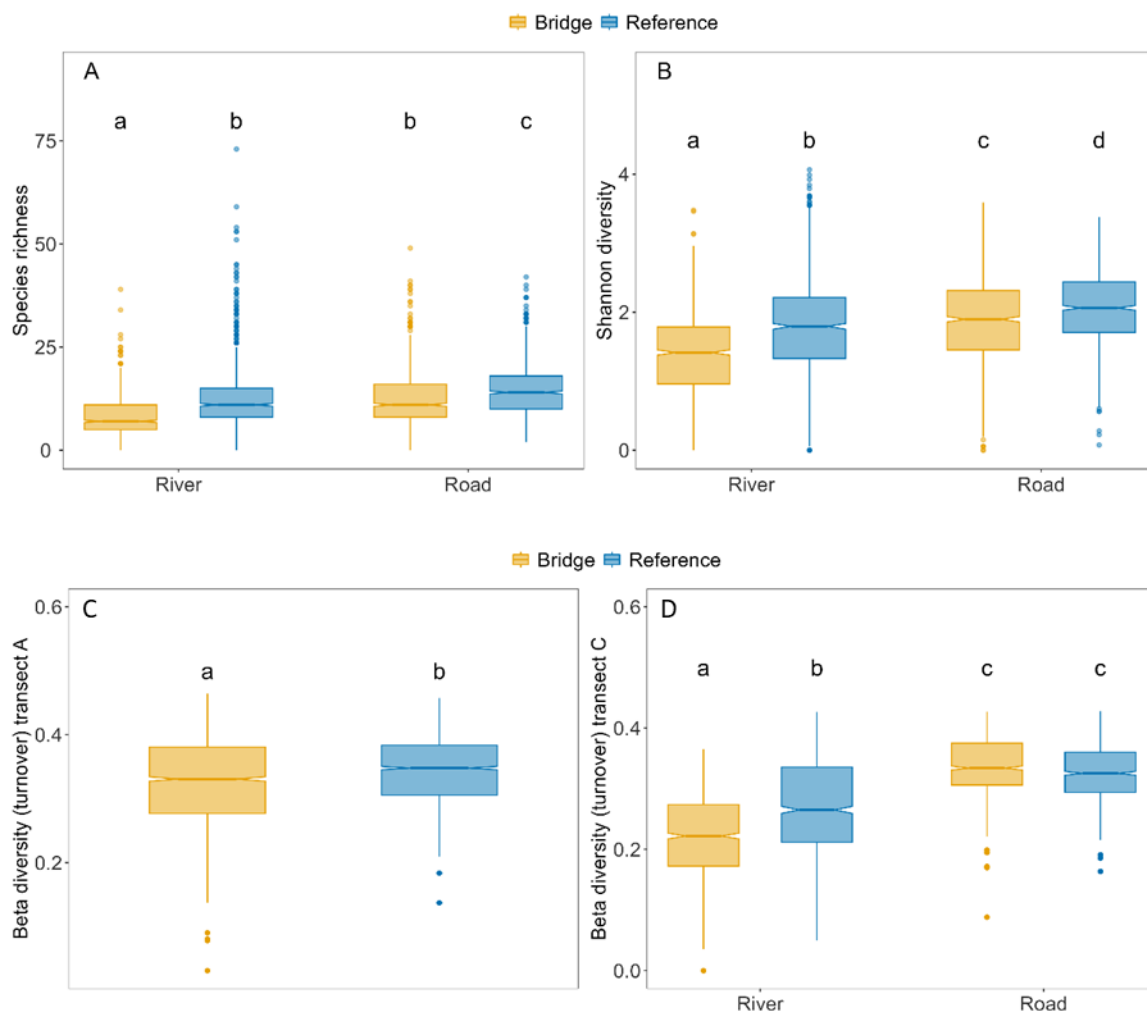


Figure 1. A-B Bridge effect on species richness (A) and Shannon diversity (B) for rivers and roads. The center lines in boxes represent the medians of observed values; box limits indicate the 25th and 75th percentiles; whiskers extend 1.5 times the interquartile range from the 25th and 75th percentiles. Different lowercase letters indicate statistically significant differences in a pairwise comparison of

least-squares means (Tukey HSD). C-D Bridge effect on the replacement component of beta diversity (turnover) per block. The interaction term between treatment (bridge vs reference) and corridor (road vs river) was not significant for transect A (panel C), therefore panel A displays the beta diversity for both roads and river together. The center lines in boxes represent the medians of observed values; box limits indicate the 25th and 75th percentiles; whiskers

From the large-scale comparative analysis across linear habitats, we found that:

- Riparian corridors supported the richest and most functionally diverse plant communities, reflecting greater environmental heterogeneity due to variable flooding regimes, soil moisture, and geomorphic complexity.
- Roadsides had intermediate diversity and were characterized by stress-tolerant perennial species adapted to nutrient-poor soils, exposure to sunlight, and frequent mowing.
- Field margins had the lowest overall species richness but included a high proportion of threatened species, many of which are declining in intensively managed agricultural landscapes. Field margins often function as refugia for these taxa, especially when located near high-intensity agricultural areas where semi-natural habitats are scarce.
- Invasive species were most prevalent in riversides and roadsides, consistent with their function as dispersal corridors. In contrast, threatened species were more habitat-specific, particularly associated with field margins and, to a lesser extent, roadsides.
- Functional hypervolume analyses showed that riparian species pools occupied the largest trait space in terms of ecological strategies (LHS traits) and resource requirements (Ellenberg indicators), while field margin species were highly adapted to disturbance and showed greater trait convergence.

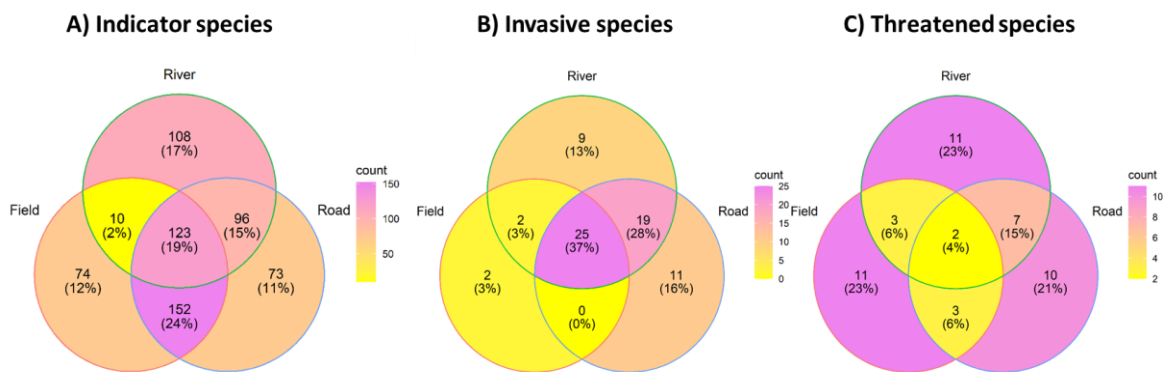


Figure 2. Venn diagrams based on A) indicator species of each habitat and group of two habitats (in this particular case, the central zone corresponds to generalist species that are not specialists in any habitat(s)), B) invasive species, C) Threatened species.

Collectively, these findings emphasize the ecological distinctiveness of each linear habitat type and the critical role of their management in biodiversity conservation. While linear habitats are often grouped together in ecological infrastructure planning, our results argue for a more differentiated approach. In particular, the strong filtering effect of bridges calls for more targeted mitigation measures at road–river intersections to maintain ecological connectivity without promoting homogenization or loss of diversity. Likewise, field margins should be better recognized as conservation priority areas due to their role as refuges for threatened species.

This project advances the understanding of how biodiversity is structured in fragmented landscapes and provides key evidence for optimizing infrastructure and land-use planning to support both

connectivity and conservation. Our multi-scalar, multi-habitat approach offers a replicable framework for assessing biodiversity in other landscapes shaped by linear features and anthropogenic pressures (railway embankments, power line corridors, pipeline corridors, irrigation/navigation canals, ...)

As a synthesis, we conducted an opinion paper project (Sexton et al., in prep.) conjointly with the *NAVIDIV* (ITTECOP-FRB-CESAB) project. *NAVIDIV* focused on the processes involved in biodiversity development along navigated linear infrastructures, and then appeared as complementary to *BRIDGE*. As the climate continues to change at the global scale, species are expected to shift their distributions to track their preferred temperature and moisture regimes. However, many species will not be able to move fast enough to keep pace with the climate, or face barriers preventing their climate migrations. As such, there is a need to identify ways that landscapes can be managed and designed to facilitate climate migrations, whenever possible. We argue that linear infrastructure landscape units (e.g. roads, waterways, railways, Fig. 3) could provide a unique opportunity that, to this point, has been overlooked in their potential to facilitate climate migrations. While linear infrastructures are well known to have negative impacts on biodiversity: increasing invasive species spread, and fragmenting landscapes, they also have the potential to facilitate distributional shifts of native species. However, most of these infrastructures are created or modified by human activities, and need modifications to provide suitable habitat quality for valuable migrating species. In the paper project, we outline potential management and design practices that could favor the dispersal of native populations and therefore enable species to shift their ranges, and open new avenues for climate migrations that would otherwise be impossible. We argue for several evidence-based practices, mostly aiming at increasing habitat quality and landscape connectivity alongside linear infrastructures that could both mitigate their inherently negative impacts on biodiversity and support climate migrations of target species. Additionally, we discuss potential avenues of implementation via funding mechanisms and point towards areas of future research.



Figure 3. Idealized landscape of the Northern Hemisphere showing the importance of linear infrastructures and their interconnexions (Sexton et al., in prep.).

### **III.2.1 Introduction (around 300 characters including spaces): for large audience**

This will be used in the project summary. CESAB-FRB reserves the right to modify the text for publication on its platforms. You will be consulted before publication. As these elements are intended for the general public, be sure to write this text in a way that is easy to understand.

Riparian corridors, road corridors and field margins are likely to interact ecologically through their proximity or their intersections within agricultural landscapes. The scientific objective of BRIDGE was to analyse how such linear habitats shape taxonomic and functional plant diversity at both local and regional scales.

### **III.2.2 [FR] Introduction (environ 300 caractères, espaces inclus): pour grand public**

Ceci sera utilisé dans la fiche résultat du projet. CESAB-FRB se réserve le droit de modifier le texte pour publication sur ses plateformes. Vous serez consulté avant la publication. Ces éléments étant destinés au grand public, veillez à rédiger ce texte dans une optique de vulgarisation.

Les corridors riverains, les corridors routiers et les bordures de champs cultivés sont susceptibles d'interagir d'un point de vue écologique en raison de leur proximité ou de leurs intersections au sein des paysages agricoles. L'objectif scientifique du projet BRIDGE était d'analyser comment ces habitats linéaires influencent la diversité végétale, tant taxonomique que fonctionnelle, à la fois aux échelles locale et régionale.

### **III.3.1 Methods and approaches used for your project (around 700 characters including spaces): for large audience**

This will be used in the project summary. CESAB-FRB reserves the right to modify the text for publication on its platforms. You will be consulted before publication. As these elements are intended for the general public, be sure to write this text in a way that is easy to understand.

First, we compiled a homogeneous database based on 11,400 samples distributed along a European gradient from northern Spain to the United Kingdom, including species abundance per site, their traits, and environmental variables. For the study of river–road intersections (bridges), we considered both local (transverse) and regional (longitudinal) environmental gradients. In addition to standard statistical analyses, we used spatially explicit models (AEM, MEM) to distinguish directional factors (related to corridor properties) from non-directional factors (diffuse across the landscape) involved in the structuring of plant communities. For the large-scale comparison of species pools across the three linear habitats, we first identified species significantly associated with each habitat or habitat pair, as well as generalist species occurring indistinctly in all three habitats, using the IndVal method. We then assessed the functional composition of each pool using trait-weighted means within species pools and conducted a functional diversity analysis based on the calculation of functional hypervolumes. Among the different ecological groups, we specifically distinguished native from non-native species, as well as threatened and invasive species.

### **III.3.2 [FR] Méthode et approches utilisées pour le projet (environ 700 caractères, espaces inclus): pour grand public**

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Tout d'abord, nous avons constitué une base de données homogène à partir de 11 400 échantillons répartis le long d'un gradient européen du nord de l'Espagne au Royaume-Uni, incluant l'abondance des espèces par site, leurs traits et des variables environnementales. Pour l'étude des intersections entre rivières et routes (ponts), nous avons pris en compte à la fois les gradients environnementaux locaux (transverses) et régionaux (longitudinaux). En plus des analyses statistiques classiques, nous avons utilisé des modèles spatialement explicites (AEM, MEM) afin de distinguer les facteurs directionnels (liés aux propriétés des corridors) des facteurs non directionnels (diffus dans le paysage) impliqués dans la structuration des communautés végétales.

Pour la comparaison à grande échelle des pools d'espèces des 3 habitats linéaires, nous avons dans un premier temps identifié les espèces significativement associées à chaque habitat ou paire d'habitat et celles, généralistes, qui sont présentes indistinctement dans les trois habitats à l'aide de la méthode IndVal. Puis nous avons évalué la composition fonctionnelle de chaque pool en utilisant les moyennes pondérées des traits au sein des pools d'espèces ainsi qu'une analyse de la diversité fonctionnelle basée sur le calcul d'hypervolumes fonctionnels. Parmi les différents groupes écologiques, nous avons notamment distingué les espèces indigènes des espèces non indigènes, les espèces menacées et les espèces invasives

### III.4 Access to data

Describe any data and/or databases created or added to during the course of the project, and components of your data management plan:

(a) the types of data collected and used

Basically we used three types of data:

- Floristic (species x site) data, with a specific representative collaborator for each dataset (L. Maskell for UKCEH CountrySide Survey, A. Juarez for Lleida Plain Survey, G. Fried for 500 ENI database, E. Tabacchi for ITTECOP-TGB database).
- Plant trait (species x trait) data were retrieved from public databases, concerning: Light, Moisture, Nutrient load, Soil Moisture, Soil acidity Ellenberg's indicators, Plant height, SLA, Lifespan, Midolo et al's Disturbance indicators.
- Additional environmental variables (site x EV): Air T°, rainfall, soil characteristics, Digital Model Elevation, landscape composition, human density population
- Land cover remote sensing data

(b) standards used to document the data

In order to build the BRIDGE database, we used two types of data.

- Basic information on the vegetation samples originated in local datasets already available (ITTECOP-TGB and 500 ENI for France; Lleida Plain Survey for Spain; UKCEH CountrySide Survey for UK).
- Additional information was obtained from public-access databases:
  - Species attributes (plant traits, ecological indicators) were retrieved from: Ellenberg et al., 1991; BASEFLOR (Julve, 2017), TRY (Kattge et al., 2020), LEDA (Kleyer et al., 2008), and Disturbance indicators of Midolo et al., 2023.
  - Species name homogenisation has been conducted using TAXREF v. 17.0 (INPN? 2024) for France and using R *Taxonstand* package (now *WorldFlora* package) that make it possible to standardize plant names according to World Flora Online Taxonomic Backbone at the European scale
  - Additional environmental were retrieved from: BDCarthage, Routes (IGN, 2024), WorldClim (Fick and Hijmans, 2017), International Soil Reference Information Centre (Hengl et al., 2017), Gridded Population of the World V.3. (Columbia University, 2005), Corine Landcover (Copernicus, 2018).
  - Remote Sensing data for France (Sentinel-2A and Sentinel 2B) were retrieved from the Theia catalog (Theia-land, 2024).

(c) policy for access and re-use, short- and long-term storage and management

Data can be accessed and re-used on demand to the participants. A delay in use may be proposed as long as the results of the project have not been published. The ITTECOP-TGB part of the data are available as supplementary material in Rievers *et al.* 2025, Applied Vegetation Science.

(d) people to contact after the end of the project.

- France: G. Fried and E. Tabacchi
- Spain: A. Juarez
- UK: L. Maskell

### III.5 Scientific outcomes of the project

- List of ALL publications (articles, books, book chapters ...) published, submitted or planned (with planned deadlines for submission). Highlight the 3 most significant in your view.

**Published:**

Rievers-Borges, E. R., González-Sargas, E., Casajus, N., Carboni, M., Bauman, D., Fried, G., Maskell, L., Juarez-Escario, A., Planty-Tabacchi, A.M., & Tabacchi, E. (2025). *Road-River Intersections (Bridges) Negatively Affect Plant Species Diversity and Ecological Attributes*. *Applied Vegetation Science*, 28(1), e70011.

Casajus, N., Borges, É. R., Tabacchi, É., Fried, G., & Mouquet, N. (2023). *chessboard: An R package for creating network connections based on chess moves*. *Journal of Open Source Software*, 8(90).

**Planned:**

Fried, G. *et al.* *Comparing plant species pools of three linear habitats: an application of the niche hypervolume in riverside, roadside and field margins*. To be submitted in 2025

Sexton, A. *et al.* *Can linear infrastructures facilitate climate migrations ?* to be submitted in 2025 (conjoint paper BRIDGE-NAVIDIV)

Maskell, L. *et al.* *Drivers of species richness and abundance of invasive species in three linear habitats: role of local disturbances and landscape context*. To be submitted in 2026

- List of oral communications and posters in conferences, past or planned (please, give the dates of these conferences)

Fried G. et Tabacchi E. *Quand corridors routiers, corridors fluviaux et bords de cultures entrent en contact : co-construction paysagère des diversités taxonomiques et fonctionnelles végétales*. Journées ITTECOP 2021. Paris La Défense. Communication orale.

Rievers Borges et al. *Le projet Bridge*. Journées 2022 ITTECOP, Paris La Défense Oral Communication

Rievers-Borges et al., *Plant communities of linear habitats: what happens when roads cross rivers ?* Annual Conference of the Ecological Society of America, 6-11 Aug 2023, Portland, Oregon, USA. Oral Communication

Tabacchi E. et al., *BRIDGE : Biodiversités fonctionnelle et taxonomique de trois infrastructures paysagères*. Journées 2024 ITTECOP, 6-8 nov 2024, Sophia Antipolis, France. Poster.

Tabacchi E. et al. *Quand les corridors fluviaux rencontrent les corridors routiers et les bordures de champs cultivés : comment les structures linéaires du paysage en interaction construisent les biodiversités taxonomiques et fonctionnelles*. 6-8 nov 2024, Sophia Antipolis, France. Oral Communication

- Other outcomes (databases, software, R-code, web sites, etc).  
R ChessBoard package (Casajus et al., 2023). A way to automatically build a connectivity matrix from site coordinates.

- List of grant proposal submitted or planned (with planned deadlines for submission).

Rievers E. European Marie Curie Grant (on another theme, successful, 2024)

*Note: we are aware the elaboration and diffusion of project outcomes will occur for several years after the end of the project.*

*Thank you to systematically thank CESAB in the acknowledgement of your papers. We recommend you use: "This research is a product of the "insert your title here" group funded by the synthesis center CESAB of the French Foundation for Research on Biodiversity (FRB - [www.fondationbiodiversite.fr](http://www.fondationbiodiversite.fr))".*

*When you have **accepted articles**, contact [cecile.thiauourt@fondationbiodiversite.fr](mailto:cecile.thiauourt@fondationbiodiversite.fr) directly so that we can see if we can accompany you with the communication (potential press release, article summary on the FRB website, etc.)*

## IV. Principal conclusions (publishable)

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### IV. 1 Principal conclusions (around 1000 characters including spaces): for large audience

Highlight a key outcome with illustration (graph, map, picture, etc.) and let us know its significance.

This will be used in the project summary. CESAB-FRB reserves the right to modify the text for publication on its platforms. You will be consulted before publication. As these elements are intended for the general public, be sure to write this text in a way that is easy to understand.

The BRIDGE project has demonstrated the important conjoint role of road corridors, riparian corridors and field margins for developing both taxonomic and functional plant diversity at the regional scale. Despite the fact that each of these habitats hosts its own specialized species pool, and that the diversity of this pool can considerably vary along the north-to-south European gradient, the studied habitats share many species with a common ecological response, notably towards physical disturbance, soil humidity, and nutrient load. The example of bridges has shown that intersections among distinct corridors can impact plant diversity, but only at the local scale. The role of non-directional (non-corridor) processes, as well as the potential of human-created linear infrastructures should not be overlooked in terms of biodiversity conservation. Potentially, the studied linear habitats could play a major role in facilitating distributional shifts as a response to climate change. However, future management strategies should account for both positive (refugia for threatened species during climate tracking) and negative (spread of invasive species) roles of these habitats.

#### **IV. 2 [FR] Principales conclusions (environ 1000 caractères, espaces inclus): pour grand public**

Mettez en évidence les résultats à l'aide d'illustrations (graphique, carte, image, etc.) et faites-nous connaître sa signification.

Ceci sera utilisé dans la fiche résultat du projet. CESAB-FRB se réserve le droit de modifier le texte pour publication sur ses plateformes. Vous serez consulté avant la publication. Ces éléments étant destinés au grand public, veillez à rédiger ce texte dans une optique de vulgarisation.

Ce projet a mis en évidence le rôle conjoint important des corridors routiers, des corridors riverains et des bordures de champs cultivés dans le développement de la diversité végétale, à la fois taxonomique et fonctionnelle, à l'échelle régionale. Bien que chacun de ces habitats héberge un cortège spécifique d'espèces spécialisées, et que cette diversité puisse varier considérablement selon le gradient nord-sud en Europe, les habitats étudiés partagent aussi de nombreuses espèces présentant une réponse écologique commune, notamment face aux perturbations physiques, à l'humidité du sol et à la charge en nutriments.

L'exemple des ponts a montré que les intersections entre différents corridors peuvent influencer la diversité végétale, mais uniquement à l'échelle locale. Le rôle des processus non directionnels (c'est-à-dire ne suivant pas la logique de corridor), tout comme le potentiel des infrastructures linéaires créées par l'Homme, ne doit pas être négligé en matière de conservation de la biodiversité. Potentiellement, les habitats linéaires étudiés pourraient jouer un rôle majeur dans la facilitation des déplacements d'espèces en réponse au changement climatique. Toutefois, les futures stratégies de gestion devront prendre en compte à la fois les rôles positifs (refuges pour les espèces menacées sous contrainte climatique) et négatifs (propagation d'espèces envahissantes) de ces habitats.

### **V. Result's impact**

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#### **V. 1 Anticipated (or actual) impact of theses results for science, society, public and private decision making (around 1500 characters including spaces): for large audience**

This will be used in the project summary. CESAB-FRB reserves the right to modify the text for publication on its platforms. You will be consulted before publication. As these elements are intended for the general public, be sure to write this text in a way that is easy to understand.

Beyond the 'Green and Blue Infrastructure' concept, the BRIDGE project introduces a new paradigm of conjoint (multiple interacting, natural or anthropogenic linear habitats) management for planning environmental strategies for biodiversity conservation. The potential of linear landscape infrastructure as spreading conduits or as 'relay habitats' for threatened species should not be underestimated. Also,

the potential of human-made or human-influenced linear infrastructure as biodiversity hotspots should not be overlooked. Although complementary to the taxonomic approach of species diversity, the functional approach allows to better understand the processes shaping biodiversity, and allows to overcome biogeographic variations, or at least to estimate the relative role of local, regional and continental settings within a changing environment.

#### **IV. 2 [FR] Impact pour la science, la société et la décision publique et privé (environ 1500 caractères, espaces inclus): pour grand public**

Ceci sera utilisé dans la fiche résultat du projet. CESAB-FRB se réserve le droit de modifier le texte pour publication sur ses plateformes. Vous serez consulté avant la publication. Ces éléments étant destinés au grand public, veillez à rédiger ce texte dans une optique de vulgarisation.

Au-delà du concept de Trame Verte et Bleue proprement-dit, nous pensons que le projet BRIDGE a permis d'initier un nouveau paradigme de stratégie de gestion intégrée de la biodiversité centrée simultanément sur plusieurs infrastructures paysagères linéaires. Ainsi, le potentiel pour ces infrastructures de refuge (espèces menacées) et de voies de dispersion ne doit pas être sous-estimé. Bien que naturellement complémentaire de l'approche taxonomique classique, l'approche fonctionnelle permet de cibler plus précisément les processus structurant la biodiversité, d'intégrer de façon neutre le facteur biogéographique et ainsi de faire la part des processus actifs aux échelles locale, régionale et continentale, spécialement dans un environnement en mutation rapide.

#### **VI. Outreach and dissemination activities (if relevant)**

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The FRB strongly encourages the dissemination of results toward various non-academic actors including policy makers. Results of research projects can be disseminated and valued in different ways and through different channels: publications, scientific conferences, posters or scientific syntheses (cf. section III), but also via internet sites, syntheses for policy makers, articles in various media, conferences involving non-academic actors, systems to support decision-making, data bases, etc.

- Please describe any dissemination and knowledge transfer activities that have been conducted toward policy makers, managers, socio-economic actors (or any other stakeholder) in relation to the project.
- Let us know about any media articles, interviews, educational projects, etc. in relation with the research conducted in the project.
- Are there any management or decision-making tools which have been developed as a result of the project (e.g. design/implementation of biodiversity indicators)?
- Are there any activities planned (or that could be planned) to expand the utilization or application of the results?

In France, we increased the awareness of Water Agencies and of the Office for Biodiversity to the local importance of road-river intersections (bridges) for disrupting plant diversity along the river continuum (Trail group about Nature-based solutions).

We also informed the French Ministry of Environment program devoted to linear infrastructure (ITTECOP) to not overlook the potential of roadsides for hosting biodiversity.

#### **VII Next steps – the legacy of the CESAB project**

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Are there any actions planned as a result of the CESAB project? Have you submitted proposals resulting from the work conducted during the course of the CESAB project for further work? If yes, have you been successful? What is the current status of the post-doctoral researcher affiliated with the project?

The CESAB-FRB *FELLOW* project (co-Pi: E. Kazakou and G. Fried) will re-use the 500ENI databased used in this project.

Erica Rievers-Borges has contracted an EU Marie Curie Grant at the AMAP laboratory (Montpellier).

Aaron Sexton (formerly the NAVIDIV project post-doc) has been hired by the Cornell University in July 2025.

## VIII CESAB AFTER

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Would you like to consider the organisation of a « CESABAFTER » meeting ?

In such case please list your co-funding opportunities/ideas.

Note that this will be discussed during a scientific assessment meeting that will be held after this report has been submitted; the project would have to be approved by CESAB's scientific direction.

Possibly we would like to consider a 'CESABAFTER' meeting in order to achieve the paper projects currently in progress, but we haven't yet look for co-funding opportunities.

## IX Comments on the execution of the project

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Please comment on any practical aspects (organization, accommodation etc), difficulties encountered, particular issues related to the management of data, etc.

Overall the execution of the project did not encountered any problem. Our work took place in a very cheerful atmosphere. We appreciated the facilities given by frb-cesab and support provided by the staff, as well from the administrative (logistics) as from the technical (data scientist) points of view. Concerning our post-doc, we appreciated the hosting in the CESAB building, fostering many productive interactions between different groups. As researchers, we note that the report of administrative and financial tasks on the CESAB task is a real plus.

However, we can notice that:

The homogenisation of our database from distinct datasets took a long time, limiting our capacity to quickly enter into the analyses, especially for our post-doc. It is worth noting that CESAB's data scientists have since developed tools to streamline the standardization of species names and the retrieval of trait values from multiple databases. As this is a common challenge across many CESAB groups, having access to their time and expertise is highly valuable — a resource that was unfortunately unavailable during our project

Although our final dataset is relatively small, we would have appreciated more calculus power and storage capacity at CESAB , as well as access to secure data-sharing platforms — especially given that bringing together and integrating datasets is central to CESAB's mission.

The difficulties to gather all the participants in Montpellier (independently from the CESAB facility/willingness) have also limited the performances of the group, especially for overseas partners.

Overall, the participants are thankful to all the FRB-CESAB and will encourage new colleagues to apply to the future FRB-CESAB calls