Knowledge influences perceptions and values of nature-based solutions: The example of soil and water bioengineering techniques applied to urban rivers

Marylise Cottet, Adeline François, Clémence Moreau, Crescience Lecaude, Stéphanie Vukelic, Anne Riviere-Honegger, André Evette

To cite this version:

Marylise Cottet, Adeline François, Clémence Moreau, Crescience Lecaude, Stéphanie Vukelic, et al.. Knowledge influences perceptions and values of nature-based solutions: The example of soil and water bioengineering techniques applied to urban rivers. Anthropocene, 2024, 45, pp.100424. 10.1016/j.ancene.2024.100424 . hal-04809300

HAL Id: hal-04809300
https://hal.inrae.fr/hal-04809300v1

Submitted on 9 Dec 2024

Knowledge influences perceptions and values of nature-based solutions: the example of soil and water bioengineering techniques applied to urban rivers

Cottet M.[1], François A.[2], Moreau C.[1], Lecaude C.[2], Vukelic S.[1], Rivière-Honegger A.[1], Evette A.[2]

[1] Université de Lyon, CNRS, Laboratoire Environnement Ville Société, ENS de Lyon

[2] Université Grenoble Alpes, INRAE, LESSEM, 2 rue de la Papeterie-BP 76, F-38402 St-Martin-d'Hères, France

Publié dans Anthropocene : Volume 45, March 2024, 100424

DOI : 10.1016/j.ancene.2024.100424

Abstract

Soil and water bioengineering (SWBE) is a nature-based solution (NBS) that can be used to stabilize riverbanks with living vegetation. Aside to protecting property and people, SWBE provides benefits for human well-being and biodiversity. Its use remains modest in cities, where the presumed benefits are important in a context of biodiversity crisis and warming. Negative public perceptions have been identified as one barrier to the dissemination of NBS.

This article studies how environmental expertise influences perceptions and values associated with SWBE, and how the possible differences in perceptions and values induced by knowledge contribute to hindering or promoting the dissemination of these solutions.

We carried out an original interdisciplinary study based on a sociological survey and ecological field measurements to characterize: (1) the perceived value that actors associate with several riverbanks equipped with different protection structures (green, hybrid, or gray) according to their level of expertise in the aquatic environment; (2) the interactions between these perceived values and the ecological values measured by restoration ecologists; and (3) the perceived benefits and drawbacks of SBWE techniques.

Our results show that the ecological and social benefits provided by NBS are recognized by all, whatever their level of knowledge. Despite this consensus, we observed different hierarchies of value associated with bank protection structures among the surveyed actors, depending on their level of environmental expertise (some prioritising ecological values, others relational values), and these could hinder the dissemination of NBS. The most tangible obstacle to the dissemination of NBS in urban areas relates to the risk perceptions of lay people, who experience a higher sense of vulnerability than they do with traditional gray solutions.

1. Introduction

Soil and Water BioEngineering (SWBE) is a set of techniques that can be used to stabilize riverbanks through the use of living vegetation and forms an alternative to “gray” techniques, which are mainly based on civil engineering (*e.g.,* riprap, gabions). Unlike traditional gray techniques, SWBE techniques are based on the observation and imitation of natural processes, and uses the mechanical, physiological, and biological properties of plants; for instance, plant cover and the anchoring of the root system to protect soil from erosion (Rey, 2018). As such, SWBE techniques are referred to as green techniques. These techniques combine the use of living plant material (cuttings, plantings) and inert material (logs, geotextiles) to produce emerging positive synergistic effects (Rauch et al. 2022). For example, they may use fascines (Figure 1a), wattle fences (Figure 1b.), or brush layers and seedlings (Figure 1c). Some hybrid techniques can also be used, combining green with gray elements, such as a vegetated crib wall or riprap on the toe with a bed of plants and seedlings on top.

Figure 1: photographs of bank protection structures based on SWBE: (a) a living fascine; (b) a living wattle fence; and (c) brush layers above riprap

SWBE is a way to restore riparian zones and most of their associated ecological services: biodiversity, ecological connectivity, carbon storage, pollutant capture, and bank stabilization, while at the same time providing protection with a lower carbon footprint than gray techniques (Symmank et al., 2020, Rauch et al., 2022). SWBE also contributes to human health and well-being (Andersson et al., 2014), creates islands of freshness that can regulate the temperature during heat waves (Trimmel et al 2016), and can offer cultural ecosystem services by supporting recreational, aesthetic, cultural, sacred, scientific, and educational values (Riis et al 2020). SWBE has particular potential in urban contexts where the importance of protection is high (due to the omnipresence of property and people requiring protection) and where challenges of social well-being and biodiversity restoration are considerable. Since urban environments often make it infeasible to envisage restoring the mobility of the channel, green techniques can be an alternative to ecological restoration.

SWBE techniques can be considered to be Nature-Based-Solutions (NBS) (Nesshöver et al. 2017, Preti et al. 2022), with these being defined as "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (Cohen-Schacham et al., 2016; p. 2). According to the European Commission (Faivre et al., 2017), NBS are considered to be solutions that clearly address a societal challenge (in the case of SWBE, reducing the risk of bank erosion and climate change adaptation) and provide wider co-benefits for society and/or ecosystems by drawing on the functionalities of ecosystems. NBS involve innovative forms of territorial and environmental action requiring a new rationale according to recognition of the need to work with nature to support social well-being, rather than opposing or separating Humans from Nature (Potschin et al., 2015).

However, despite their benefits, NBS (including SWBE techniques) are not widely used today, especially in urban areas (Symmank et al., 2020). Their implementation raises numerous issues including technical (e.g., land restriction, short-term vulnerability of installations, limited site access) (Morris and Moses, 1999; Simon and Steinemann, 2000; Sotir, 2001), governance (SWBE techniques require the support and coordination of a wide range of stakeholders and the development of a community of practice) (Moreau et al., 2022; Bark et al., 2021; Nesshöver et al., 2017), and perception issues. Anderson and Renaud (2021) and Han and Kuhlicke (2019) showed that three perception-related dimensions influenced support for NBS: perceptions of effectiveness, perceptions of risk, and the importance attached to ancillary benefits generated by the resulting green structures. Negative public perceptions have been identified as one barrier to the dissemination of NBS in general (Ramírez-Agudelo et al., 2020; Kabisch et al., 2016), and riverbank SWBE in particular (Moreau et al., 2022). Reluctance expressed by the public can weigh on the decision-making process regarding the choice of techniques, and can be detrimental to green solutions. Therefore, we need to know more about the public’s perceptions of SWBE.

Previous studies have pointed out that a difference in knowledge could be at the root of the difference in perception between lay people and experts in aquatic environment management. Although not necessarily opposed in content (Agrawal, 1995), a distinction can be made between so-called "expert" knowledge - that of "scholars" (members of the scientific world or technicians) (Damay et al., 2011) -

and so-called "ordinary" or "lay" knowledge, which corresponds to experiential "open-air" knowledge (Callon et al., 2001). These different forms of knowledge influence actors' perceptions and values, and ultimately their positions on a given problem. According to Linton and Budds (2014), lay people use “context specific and non-scientific forms of knowledge’’ to assess the quality of a river, which sometimes create differences from expert’s assessments based on theoretical scientific forms of knowledge. Technical rationality can be challenged by cultural rationality, which is based on " personal and familiar experiences rather than depersonalized technical calculations” (Fischer, 2004, p. 87).

Today, public action can call the power of traditional expertise into question, including through the valorization of "lay" knowledge (Fromentin and Wojcik, 2008). It is increasingly recognized that citizens have their own knowledge and vision for the development of their living environment (Damay et al., 2011). It is also increasingly recognized that scientific knowledge does not constitute a monolithic, "certain" entity, but corresponds to a "juxtaposition of knowledge drawing on a variety of epistemic cultures" (Bourblanc, 2013). Lay people are therefore gaining a certain legitimacy in decision-making. In particular, they are taking a growing role in socio-technical decisions alongside scientific experts, including the field of water resource management (Aubriot, 2013).

The success or failure of an innovation depends on a network capable of linking heterogeneous actors (Akrich *et al.*, 2006), and mobilization of such a network contributes to the development and dissemination of innovation. Various controversies can emerge within this network, resulting from the expressions of the involved actors: expression of their interests, clarification of how they perceive the problem and possible solutions, and reformulation of objectives. These controversies create arenas where knowledge and positions confront each other, contributing to the dissemination or abandonment of socio-technical innovation. The interactions between knowledge, perceptions, and values (here defined as “the result of all the operations by which a quality is assigned to an object, with varying degrees of consensuality and stability”, and which are “a function of the nature of the object being evaluated, the nature of the evaluators and the nature of the evaluation context”; Heinich, 2017;

p. 296) of actors, and therefore their positions towards certain environmental innovations, provide a better understanding of the conditions or obstacles to their dissemination.

From this perspective, this article studies how environmental expertise influences the perceptions and values associated with SWBE. In particular, the purpose is to find out whether lay people have the same confidence as experts in the protection provided by NBS, and whether they identify and value (like experts) the associated ecological and social benefits. The purpose is also to consider whether the possible differences can create controversies or conflicts of value likely to undermine the cohesion of the network of actors concerned, and thus hinder the dissemination of green structures.

To this end, we carried out an original interdisciplinary study based on a mixture of sociological surveys and ecological field measurements. These methods were combined to characterize: (1) the perceived value that actors associate with 12 riverbanks equipped with different bank protection structures (green, hybrid, or gray) according to their level of expertise in the aquatic environment; (2) the interactions between these perceived values and the ecological values measured by restoration ecologists using several indicators; and (3) the perceived benefits and drawbacks of using SBWE techniques (Figure 2).

2. Materials and Methods

To cross-reference the evaluations, the measured ecological value (based on indicators) and the perceived values of riverbanks were evaluated through sociological and ecological surveys concerning 12 sites equipped with bank protection structures – green, hybrid, or gray. The sociological survey was based on a photo-questionnaire, whereas the ecological survey was based on field measurements (Figure 2).

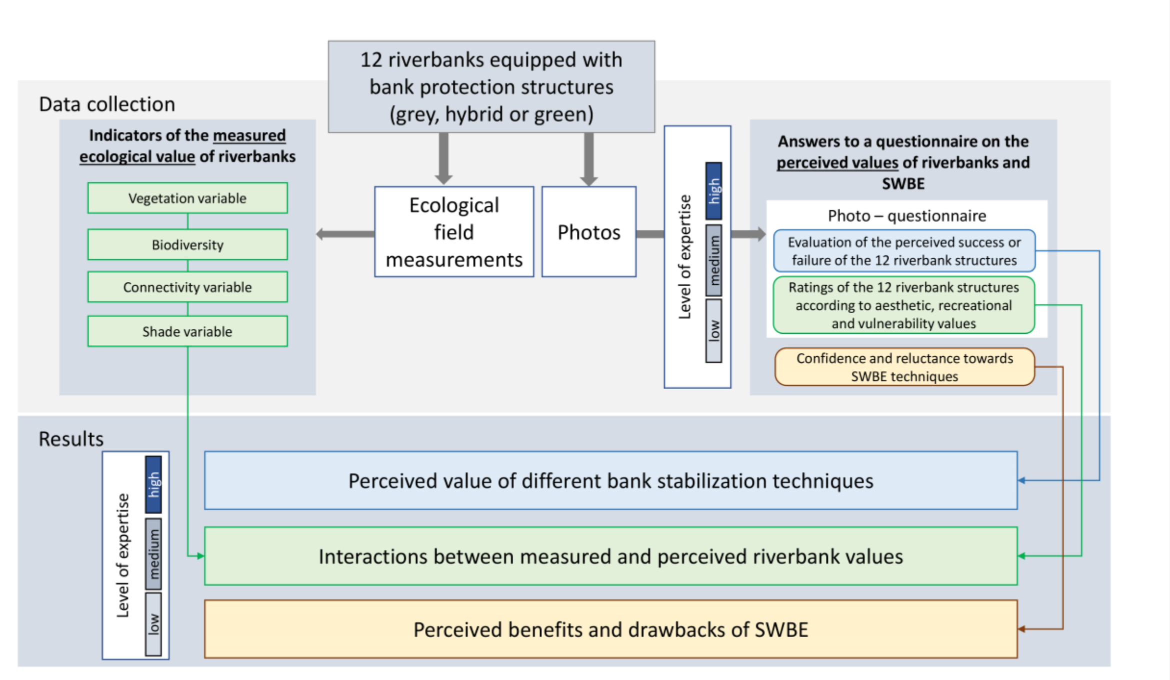

Figure 2: Data processing flow chart

2.1. Study area

We investigated the riverbanks of 12 small rivers that were equipped with erosion control structures of green, hybrid, or gray types. These rivers are located in urban or peri-urban areas in the Auvergne-Rhone-Alps region of France. The sampled erosion control structures were arranged into a vegetationgradient that includes five gray structures (riprap; Gray.1 to Gray.5), three hybrid structures with a combination of riprap at the toe and soil bioengineering at the upper part of the bank (Hybrid.1 to Hybrid.3), and four green structures using SWBE (Green.1 to Green.4) (Figure 3).

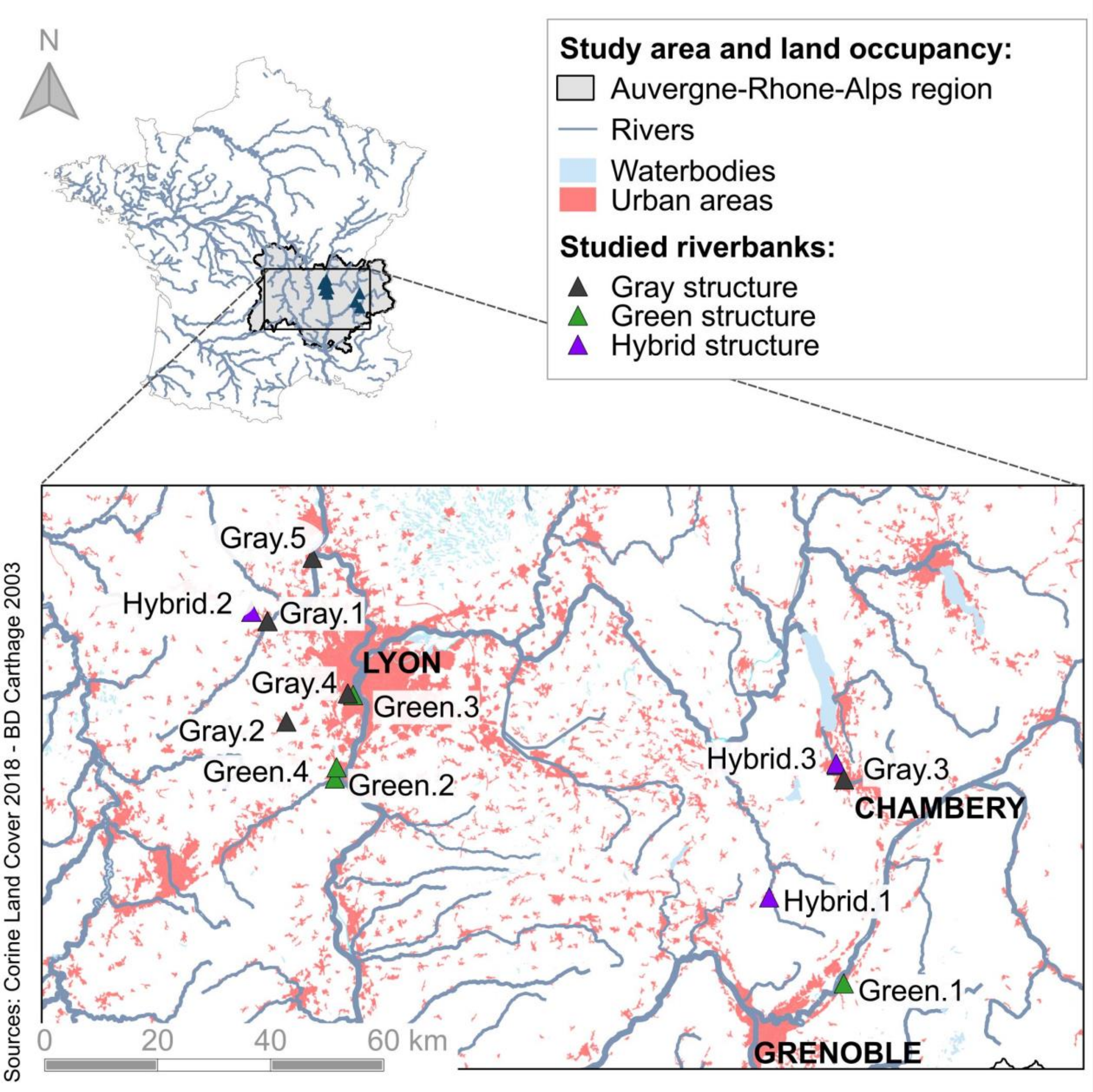

Figure 3: The study area and distribution of the sampled urban riverbank structures.

2.2. Sociological survey

We analyzed people’s perceptions of SWBE using an online photo-questionnaire created with LimeSurvey software. This survey was distributed between February and March 2021.

We aimed to survey both lay people and professional managers of natural environments, especially aquatic environments, with a varied environmental expertise. To reach them, we established a contact database. Lay people were recruited by targeting the press (local and departmental newspapers, regional daily press) and associative networks (recreational activities, neighborhood, students, naturalists, sustainable mobility associations) using institutional e-mail addresses and social networks. Professional managers were targeted by contacting institutions or professional networks specialized in water and environmental management (river associations, engineering offices, Rhône water basin agency).

We consider our final sample of 429 respondents to be reasonably representative of the French population[1] regarding some socio-demographic criteria such as gender (45% of women in our sample compared with 49.6% in the French population) and place of living (29.1% of rural residents compared with 32.8% nationally). However, the collected sample was clearly unbalanced in terms of age and education, being biased towards a younger population (30% of 30–44-year-olds compared with 18.3% nationally) and high degree of education (73.7% had more than a bachelor degree compared with 30% nationally). However, the respondent’s diplomas were not necessarily linked with the environment: 45.2% of the respondents stated that they had no particular expertise in this field through their work or training (and were therefore considered as lay people), 32.6% stated that they had an average expertise, and 22.1% stated a high expertise.

The photo-questionnaire method deployed used landscape photographs as a medium for the assessment of the surveyed landscapes. In this method, the participants were asked to rate the quality of the landscape shown in the photograph according to one or more criteria defined by the interviewer. The different scores were then compared to rank the values associated with the different landscapes (Shafer, 1969; Le Lay et al., 2012). In our case, the 12 photographs of riverbanks used (Figure 4) were taken in the field during the ecological field measurements. Particular care was taken to ensure homogeneity in the composition of the photographs (with the same angle of view). The questionnaire was structured into three sections. The first section aimed to characterize the values associated with the different types of riverbank structures and to understand the criteria used to assess them: respondents were asked to select the riverbank structures they judged the most and least

---

[1] INSEE data, The French National Institute for Statistics and Economic Studies, 2017

successful[2], to justify their choice using an open-ended question, and to rate each of the riverbank structures using a visual analogue scale according to the three criteria of aesthetic value, recreational value, and vulnerability[3]. The second section focused on the confidence and reluctance towards SWBE structures and the perceived benefits associated with them. The third section aimed to characterize the socio-demographic profiles of the respondents, their relationship to the river, and their environmental expertise, assessed in a declarative mode[4].

Figure 4: The photographs of riverbank structures (gray, hybrid, and green) used in the photo-questionnaire, arranged according to increase in the variable representing vegetation.

2.3. Ecological field measurement

We assessed the ecological value of the banks through measures of soil and vegetation cover, biodiversity, ecological connectivity, and mean shade cover (a proxy for freshness capabilities),

---

[2] The use of the term "successful" - vague and largely subjective in the way we can understand it - without giving any further details, was deliberate, since the aim of this question was to understand the criteria used by respondents to evaluate the global performance of riverbank structures.

[3] These three criteria were formulated in the survey as follows: How much do you agree with the following statements (0: strongly disagree / 10: strongly agree): "This bank is a beautiful landscape" (aesthetic value), "This bank is suitable for recreation" (recreational value), "This bank is vulnerable to erosion, which can lead to flooding" (vulnerability value).

[4] The following question was used to assess the environmental expertise: “Given your profession or training, do you have any particular expertise related to the aquatic environment or environmental management?”, the possible answers being "none", “medium” or “high”.

evaluated in field surveys conducted in May and June 2020. The point contact method was used to obtain soil and vegetation cover and biodiversity data. Three 20-meter long transects were positioned parallel to the riverbank (close to the shoreline, at the highest point of the bank, and at an intermediate height), and the plant species diversity and frequency were noted, as well as the soil characteristics such as stone, ground, litter, and community structure (herbs, shrubs, or trees). Measurements were taken every 50 cm along each transect. To assess biodiversity, the total species richness, Shannon index, and relative cover of invasive alien species (IAS) were calculated from the transect data.

To understand the potential ecological connectivity capabilities of the riverbank protection structures, we assessed: (i) the lateral connectivity from the bottom to the upper part of the bank, (ii) the longitudinal connectivity of the vegetation, and (iii) the landscape connectivity linking the riparian vegetated strip to other vegetated strips in the landscape (González del Tánago, et al. 2011) (Table 1). Lateral connectivity was estimated through two quantitative variables (bank slope, bank vegetation cover) and two semi-quantitative variables (slope beyond the bank within 5 m, and vegetation beyond the bank within 5 m). Slope was measured using a laser rangefinder (TruPulse 200x). Longitudinal connectivity was estimated using two semi-quantitative variables representing the longitudinal vegetation connectivity along the bank, one for shrubs, the other for trees. Landscape connectivity was estimated using a semi-quantitative variable representing the artificial quality of the landscape surrounding the riverbank structure. Coding details for these semi-quantitative variables are available in the supplementary material to Table A.1.

Mean shade cover was used as a proxy for ‘island of freshness’ functionality, and was estimated on the central transect using a concave spherical densiometer (Ganey, 1994).

Using the mean values of the five soil-cover variables and the seven connectivity variables, we constructed two synthetic indices reflecting the multivariate similarity between the riverbanks. To do this, we used the first axis of each of two principal component analyses (Supp. Mat., Fig. A.1). The first synthetic variable represented a ground-vegetation cover gradient, named vegetation cover gradient, and the second a connectivity gradient. The coding details for these semi-quantitative variables are available in Table A.1.

Table 1: Description of the variables used to build the vegetation cover and connectivity gradients

Variable	Description (unity)	Mean (sd)	Range
Vegetation cover gradient			
Riprap	Cover of riprap (%)	52.67 (± 37.28)	[5.33–100]
Ground	Cover of bare ground (%)	14.47 (± 16.61)	[0–50]
Litter	Cover of litter (%)	31.89 (± 27.63)	[0–69.33]
Herb.cov	Cover of herbaceous strata - <1.5 m (%)	72.06 (± 37.62)	[7.33–100]
ShrubTree.cov	Cover of shrub and tree strata - over 1.5 m (%)	39.47 (± 36.07)	[0–105.6]
Connectivity gradient			
Lateral connectivity			
Slope	Bank slope (°)	39.14 (± 13.78)	[18.47–60.73]
Veg.cov	Bank vegetation cover	75.25 (± 37.11)	[7.33–100]
Slope.env	Slope index beyond the bank within 5 m (Class 1 to 5)	3.75 (± 1.42)	[1–5]
Side.veg	Vegetation index beyond the bank within 5 m (Class 1 to 5)	2.42 (± 0.90)	[1–5]
Longitudinal connectivity			
Shrub.connect	Longitudinal shrub connectivity index (Class 1 to 3)	2.67 (± 0.65)	[1–3]
Tree.connect	Longitudinal tree connectivity index (Class 1 to 3)	1.75 (± 0.87)	[1–3]
Landscape connectivity			
LC	Landscape context (Class 1 to 5)	2.67 (± 1.50)	[1–5]

2.4. Data processing and statistical analysis

All statistical analyses were performed using R v. 4.1.0 (R Core team 2021).

For the perception-based assessment, differences in the responses to closed-ended questions or rating scales between the groups of respondents, particularly according to their level of expertise, were analyzed with chi-squared tests. The open-ended answers to justify the choice of the most successful structure were addressed by thematic content analysis, which is based on “identifying, analyzing, and reporting patterns (themes) within data” (Braun and Clarke, 2006; Berelson, 1952).

For the ecological-based assessment, the correlations between the vegetation cover gradient on the 12 riverbanks and the three indices of biodiversity, connectivity gradient, and mean shade cover were tested using non-parametric Spearman rank correlation because of the small sample size.

To investigate whether perception-based and ecological-based assessments of the riverbank structures correlated, we fitted generalized mixed models and studied the significance of the estimated coefficients. Perception-based assessments — aesthetical, recreational, and vulnerability — were the dependent variables, while ecological-based assessments — vegetation cover gradient, connectivity gradient, species richness, and mean shade cover— were explanatory variables. Ecological variables were centered and scaled. Models were built for each pairing of perception and ecological assessment. Because perceptions could also be influenced by the level of environmental expertise of the respondents, we considered this variable as an explanatory factor with an interaction effect. We fitted models with a beta error distribution and link logit because the dependent variables of the “perception-based assessments” assumed positive continuous values in intervals ranging from 0 to 10 (Cribari-Neto and Zeileis, 2010). Dependent variables were normalized between 0 and 1 using the Smithson and Verkuilen method (2006). According to the pattern of each combination of perception and ecological-based assessments, we chose the model that best fitted the data following the principle of Equation (1), or Equation (2) if the results looked like a curve. Then, partial Wald test (Z value) statistics and a p value were calculated for each estimated coefficient to verify the significance of estimated values and the interactions between ecological-based assessments and the declared level of expertise.

Equation (1): logit (perceived value) = ecological variable * declared level of expertise

Equation (2): logit (perceived value) = ecological variable * declared level of expertise + ecological-variable ^{2}

3. **Results**

3.1. Perceived value of different bank stabilization techniques

After the participants considered the set of photographs showing different bank protection structures, their preferences clearly pointed to SWBE (Figure 5), with the structures Green.3, Green.1, and Green.2 perceived as the most successful (in order) by the greatest number of people. Gray.3 was identified as the least successful structure by 65% of respondents. The preferences of the respondents with average or no expertise were more varied than those of respondents with high expertise: those with average or no expertise sometimes declared a preference for gray structures (Gray.5, Gray.2) or hybrid solutions (Hybrid.1), which was rarely the case for those with high expertise.

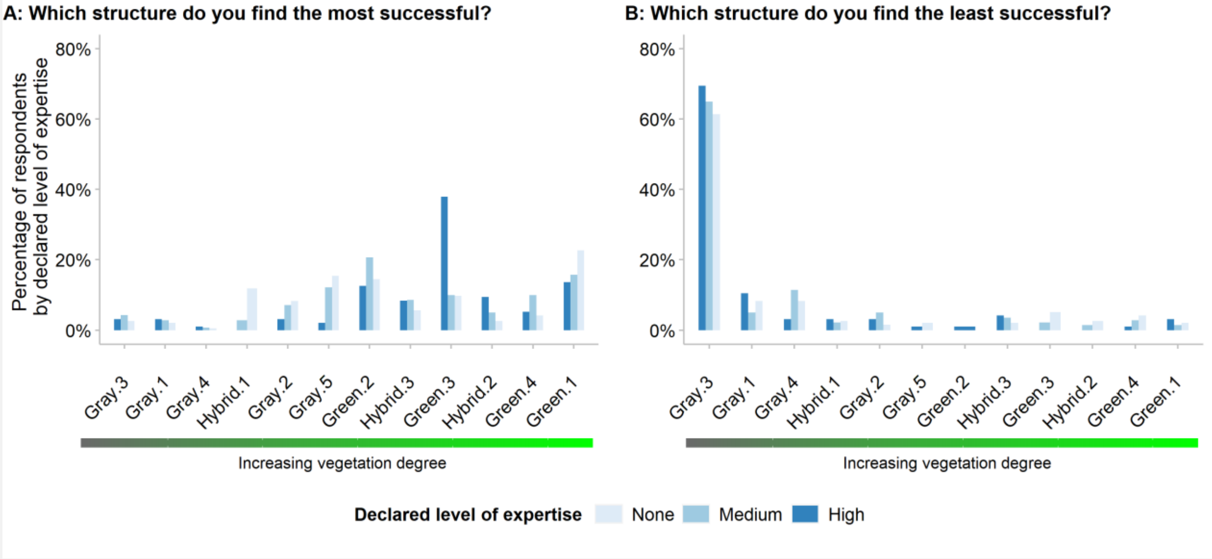

Figure 5: Percentage of respondents who selected each individual bank protection structure as the most (A) and least (B) successful according to the level of expertise (none, medium, and high, n = 194, 140, and 95, respectively).

Green solutions were by far the favorites, but the preferences were only partly linked to the degree of vegetation on the banks (Figure 5), with some moderately vegetated structures being judged as the most successful by a large number of people (Green.2), and some highly vegetated structures (Hybrid.2 and Green.4) being judged the most successful by only a small number of people. The reasons given for the preferences provide further insight into the criteria used by the respondents to assess the success of the structures (Figure 6). The judgment of success depended primarily on the perceived naturalness of the banks and the presence of vegetation[5]. Perceived naturalness was used significantly more by people without environmental expertise ($\chi^2 = 9.72$, $p = 0.008$, df = 2), whereas the presence of vegetation was used by people with high expertise ($\chi^2 = 8.69$, $p = 0.013$, df = 2). Other criteria, while less prominent, were also well emphasized in the responses. People with no environmental expertise gave greater importance to physical and visual access to the river ($\chi^2 = 11.535$, $p = 0.031$, df = 2),

---

[5] In the analysis of the open-ended question, the theme “naturalness” refers to responses that used subjective qualifiers such as “natural” or “wild” to describe the riverbanks, while the theme “vegetation” refers to responses that noted the presence of vegetation, without using any qualifiers.

whereas people with high expertise placed greater importance on the vegetation diversity[6] (stratification and species; $\chi^2 = 33.912$, $p = 4.33.10^{-8}$, df = 2) and ecological functionality ($\chi^2 = 17.145$, $p = 0.0002$, df = 2). People with high expertise also referred more to the geomorphology ($\chi^2 = 16.53$, $p = 0.0003$, df = 2). All percentages and p-values are available in the supplementary material to Table A.2.

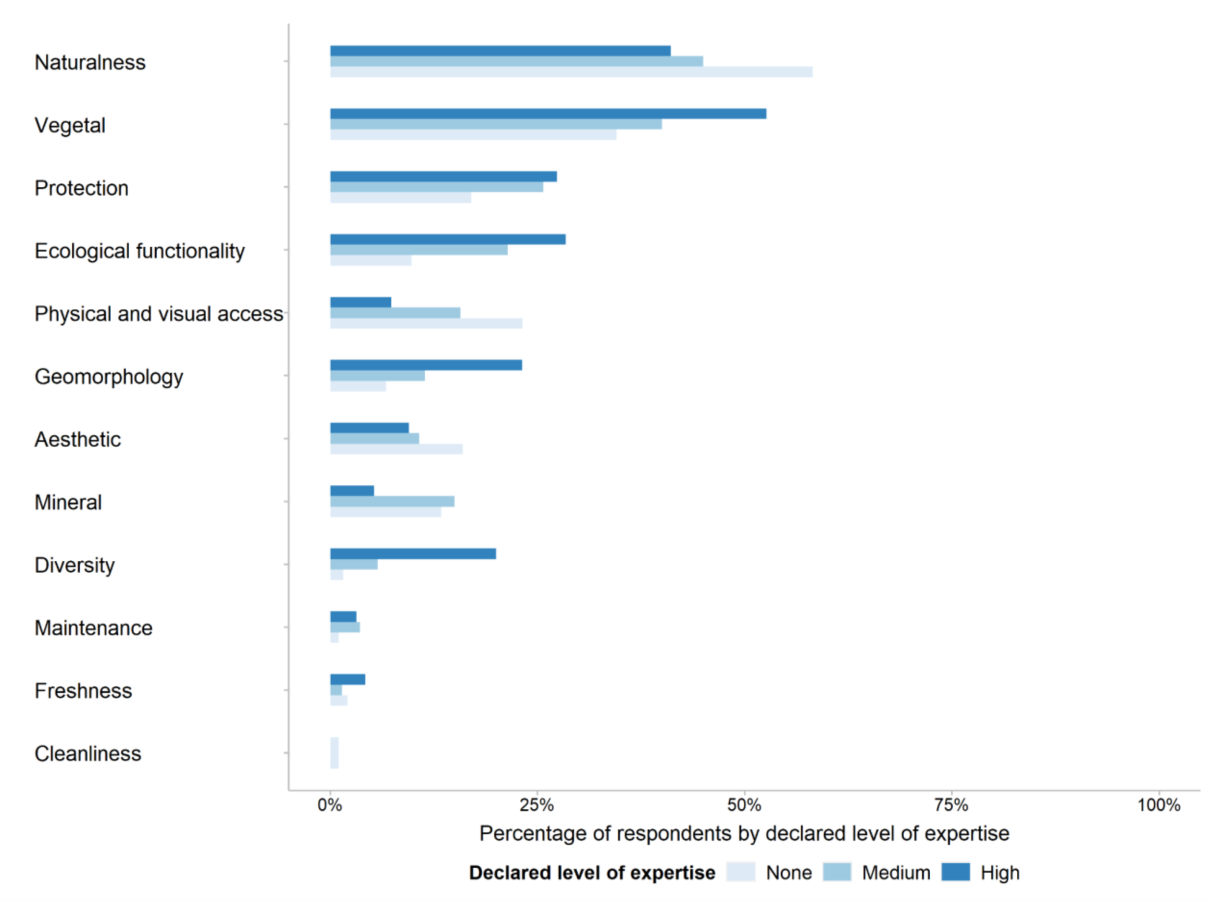

Figure 6: Criteria used by the respondents to justify their choices for the most and least successful structure, according to their level of environmental expertise

---

[6] In the analysis of the open-ended question, the theme “biodiversity” refers to responses that mention a diversity of plant species or strata; the theme “ecological functionality” to responses that mention habitats in good condition for flora and fauna, longitudinal and lateral connectivity, or shading for fish; and the theme “geomorphology” to responses that mention river landscape forms, such as the slope of the banks or width of the bed.

3.2 Interactions between measured and perceived riverbank values

The ecological field measurements recorded 191 species among the 7989 counts made in the woody, shrubby, and herbaceous strata of the 12 riverbanks. Twenty species were classified as IAS. The five most abundant species were *Salix purpurea L.* (counted 1385 times), *Urtica dioica L.* (523 times), *Salix viminalis L.* (473 times), *Rubus fructicosus L.* (406 times), *Galium aparine L.* (358 times), and *Anisantha sterilis L.* (338 times). The mean species richness was 32 species per site, ranging from 8 to 52, and was significantly positively correlated with the vegetation cover gradient (Spearman's rho = 0.59, p = 0.049) (Figure 7).

The Shannon biodiversity index averaged 2.4, ranging from 1.36 to 2.96. The IAS cover exceeded 10% (up to 35%) on five of the structures (Gray.1, 5, 2, Green.4, Gray.4; ranked in decreasing order of IAS cover). The mean shade cover (ranging from 7.8% to 90.3%, with an average of 47%) and the connectivity gradient showed significant positive correlations with the vegetation cover gradient (Spearman's rho = 0.690 and 0.615, p = 0.013 and 0.037, respectively).

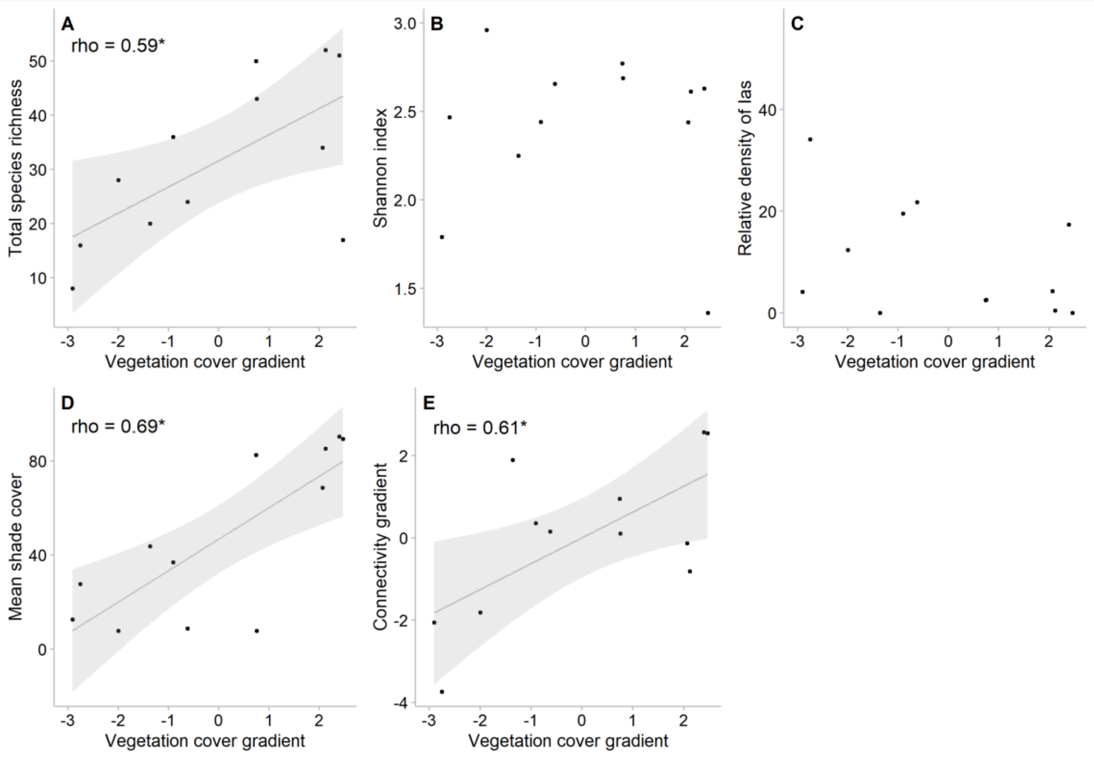

Figure 7: Ecological variables (total species richness, Shannon index, relative cover of IAS, mean shade cover, and connectivity gradient) as a function of the vegetation cover gradient of the sampled

riverbanks (n=12). Gray lines represent the relationships between the ecological variables and vegetation cover gradient, and the gray areas the 95% confidence intervals. Letters (A-E) allow each curve to be linked to the equations provided in Tables A.3 and A.4 of the supplementary data.

Figure 8 shows a significant relationship between each type of perceived value and each ecological variable measured on the sites: vegetation cover gradient, connectivity gradient, species richness, and mean shade cover. The equations and coefficients of the models are available in the Supplementary Materials (Tables A.3 and A.4).

The ratings for aesthetic value showed significant increases according to increases in each ecological variable: the more vegetated the banks and the higher the species richness and connectivity gradient, the higher was the perceived aesthetic value. This relationship was significantly more pronounced among those with high expertise, especially regarding the vegetation cover gradient and species richness criteria. These respondents rated the banks with low values for ecological variables lower than did the respondents with medium or no expertise.

The ratings for recreational value were linked to both vegetation cover and the connectivity gradient, and varied according to a significant negative quadratic relationship. Low recreational values were assigned to both the less vegetated and most vegetated riverbanks, whereas the highest values were given to the moderately vegetated riverbanks. A similar pattern was observed for the connectivity gradient. The perceived recreational value showed a significant linear increase in association with species richness and mean shade cover. Respondents with the highest expertise gave a lower recreational value to the banks with the lowest vegetation cover gradient, species richness, and mean shade cover than did respondents with medium or no expertise.

Finally, the ratings for vulnerability value increased significantly with the three ecological variables: vegetation cover gradient, connectivity gradient and species richness. The more vegetated the banks, the greater their diversity and connectivity, the more vulnerable they are to erosion. Respondents with medium or low environmental expertise placed less confidence in the safety provided by the most vegetated banks in comparison with respondents with high expertise.

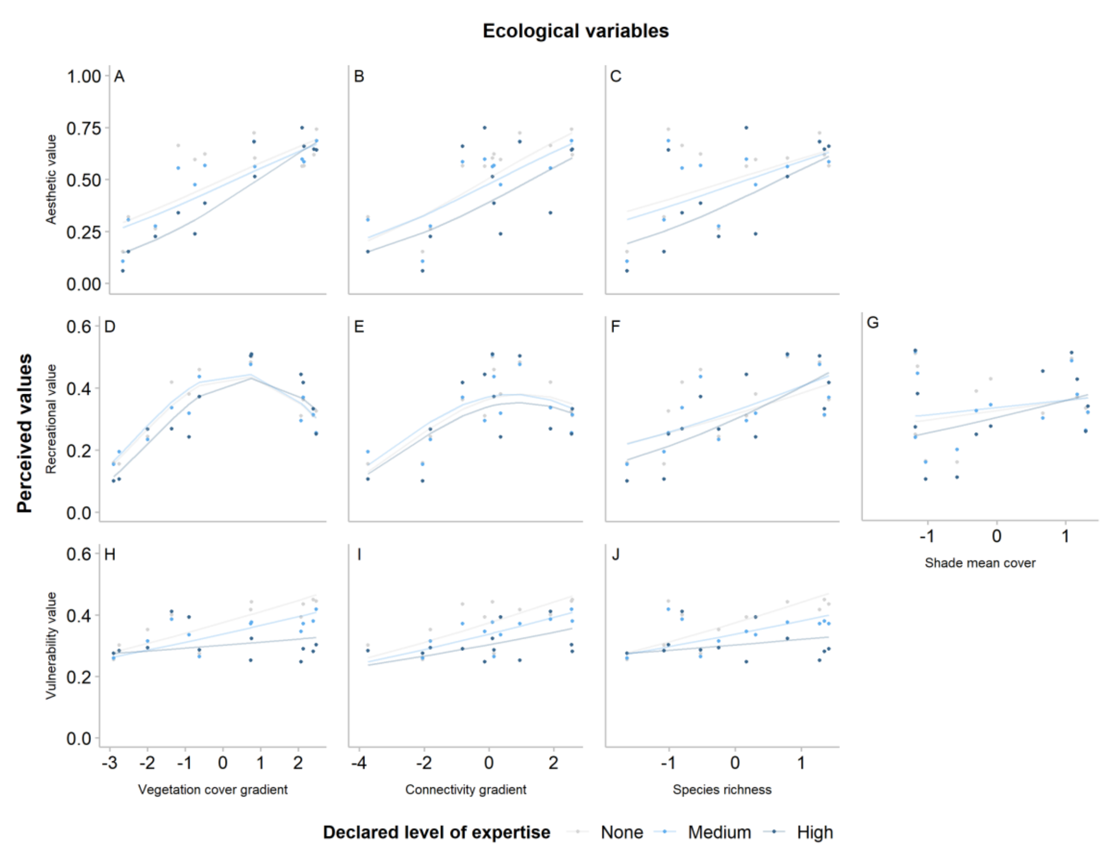

Figure 8: Relationship between the perceived aesthetic, recreational, and vulnerability values and each measured ecological variable for the 12 riverbank structures shown in the photographs. All ecological variables (i.e. Vegetation cover gradient, Connectivity gradient, Species richness, and Mean shade cover) are centered and scaled. Dots represent the average of the ratings given by the 429 respondents, and lines represent the adjustment model for each level of environmental expertise. Letters A-J allow each curve to be linked to the models' equations and coefficients available in Table A.3 and A.4 of the supplementary material.

3.3. Perceived benefits and drawbacks of SWBE

More than half of respondents (57%) declared that they were very confident about the protection provided by SWBE. This level of confidence increased significantly with the level of expertise (46%, 58%, and 77% of people with no, medium, and high expertise, respectively). This gradient highlights a greater reluctance towards SWBE among people with average or no expertise (Table 3). Those who declared that they were not really confident or not confident at all nevertheless formed a minority of the respondents (7%), regardless of expertise.

Table 2: Level of confidence in SBWE structures for providing riverbank protection, according to the subjects' level of environmental expertise

If your property were to be protected from stream erosion, would you be confident about such SWBE techniques?				
	High expertise (%)	**Medium expertise (%)**	**No expertise (%)**	**Full sample: all levels of expertise combined (%)**
Very confident	77	58	46	57
A little confident	14	24	33	26
Neither confident nor not confident	5	9	14	10
Not really confident	2	6	5	5
Not confident at all	2	3	2	2
Total	100	100	100	100

The respondents assigned benefits to SWBE structures other than simple protection of riverbanks (Figure 9). They emphasized their role in preserving urban biodiversity (29.6%), creating the aesthetics of the city (11.4%), and providing a refreshing effect (13.8%). There were significant differences in the percentage of respondents that cited biodiversity and refreshing benefits according to the level of environmental expertise ($\chi^2 = 7.04$, $p=0.030$, $df = 2$; and $\chi^2 = 6.28$, $p=0.043$, $df = 2$, respectively); the higher the level of expertise, the more the respondents cited the biodiversity benefits, whereas the lower the expertise, the more they cited the refreshing benefits.

Almost half of the respondents mentioned they had no reluctance towards the use of SWBE (49.2%). However, this absence of reluctance depended on the level of environmental expertise, with the most expert participants being the most confident: 42.3%, 45.7%, and 68.4 % of respondents with no, medium, and high expertise, respectively, considered SBWE as being quite efficient and safe for protecting riverbanks. When the reasons for the reluctance towards SWBE were examined in more detail, the first three most-cited reasons (from a list proposed in a multiple-choice question) related to the fact that the construction of this technique initially involves destroying nature (10%; for example, by cutting down trees), that they are new and that we have no experience with them (8.2%), and that the banks built by SWBE look poorly maintained (6.5%; e.g., plants were not well trimmed, which made the riverbanks unclean and not pretty). The reasons for reluctance were not strongly related to the level of environmental expertise, apart from two exceptions: the novelty of the techniques and the lack of experience with them ($\chi^2 = 6.74$, $p = 0.034$, df = 2), which were mentioned more by people with no or medium expertise; and the lower certainty of protection, which increases the risk of dwellings being damaged ($\chi^2 = 7.69$, $p = 0.021$, df = 2), and was mentioned more by people with no expertise. Reluctance towards SBWE because of the costs involved or invisibility of the structures in the landscape was only marginal. All results are available in the supplementary material to Table A.5.

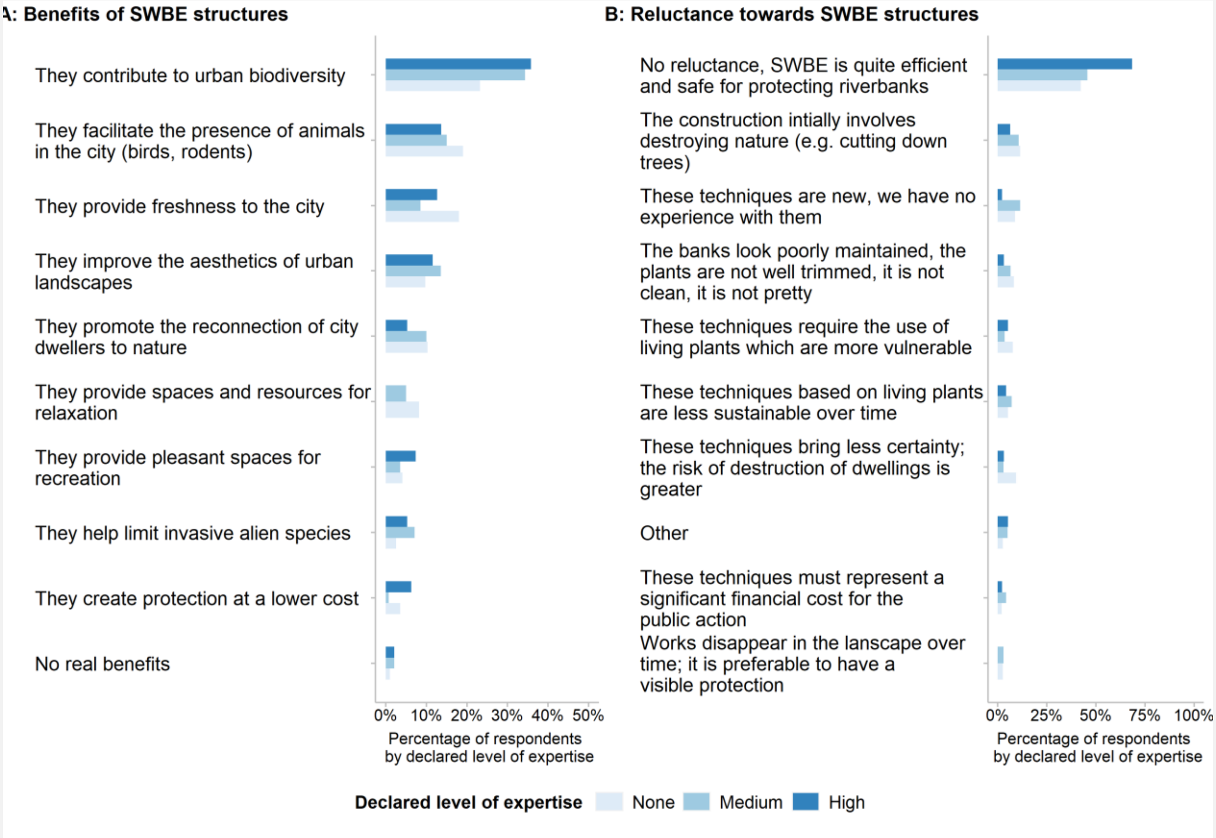

Figure 9: *Benefits (A) and reluctance towards (B) SWBE structures according to level of environmental expertise.*

4. Discussion

Our work highlights three main results that we discuss in the following sections.

1. Whatever their level of expertise, the actors valued riverbanks equipped with SWBE structures more than gray solutions because of the ecological and social benefits they produce. However, there was a difference in the way these benefits were assessed: most experts mentioned ecological benefits more (*e.g.,* biodiversity, connectivity), whereas those with lower expertise referred more to socio-cultural benefits (*e.g.,* naturalness, aesthetics, recreational amenities).
2. While there was a strong convergence between these ecological and socio-cultural benefits, our data also show conflicts of values that could hinder the dissemination of SWBE solutions.
3. The main point of dissension between experts and non-experts concerned the protection provided by SWBE solutions. Those with lower expertise reported a higher sense of vulnerability with SWBE solutions than they did with gray solutions, with a sense of vulnerability being a source of significant reluctance towards SWBE.

4.1. Shared values for ecological and social benefits of SWBE

Our results show a difference in perception between those who declared a high level of environmental expertise and those who not declared such expertise. The former focused more on ecological benefits, whereas the latter referred more to socio-cultural benefits. These different perceptions can be explained by different relations to urban ecosystems, induced by different learning modalities. In the first case, we observe a cognitive prism in the relation, with a scientific approach towards ecosystems that emphasizes their functional issues (e.g., vegetation diversity, habitats in a good state, connectivity). In the second case, we observe a sensitive prism in the relation, with an experiential approach to ecosystems that emphasizes their relational issues (e.g. visual and physical access to the river, contribution to the freshness of the city). To assess the value of riverbanks stabilized by different green, hybrid, and gray techniques, most experts tend therefore to rely more on functional ecological criteria, whereas those with lowest expertise rely more on relational criteria. These expertise-associated differences in the criteria used to evaluate aquatic environments were previously highlighted (Cottet et al., 2013; Boyer et al., 2018). Some authors even call for a relational turn for sustainability science, which would enable us to draw on more diverse and situated knowledge for decision-making (West et al., 2020). Although the evaluation criteria differ, the results of the evaluations are broadly the same: vegetated banks, also perceived as the most natural, are highly valued, and green banks are much more strongly preferred than gray ones. Kabisch et al. (2017) previously pointed to this convergence between ecological and social issues in relation to the use of NBS in urban areas. In the case of SWBE, the revegetation of riverbanks generally benefits both the functionality of ecosystems and the well-being of city dwellers. For this reason, some authors refer to these techniques as win-win solutions (Anderson et al., 2022). Anderson et al. (2022) made a similar observation of a high value being placed on the ecological and social benefits provided by SWBE in coastal and rural contexts. They demonstrated that these so-called auxiliary functions are more highly valued than the primary functions of stabilizing banks and protecting property and people. This convergence of values is likely to strengthen the cohesion of the network of actors who gravitate around these socio-technical solutions, thereby creating conditions favorable to their dissemination (Akrich, et al., 2006). The ecological and social benefits induced by SWBE in urban areas, constitute an important lever toward its promotion because they are widely recognized and valued. These benefits create improved performance of technical solutions for combating bank erosion in urban areas, in favor of SWBE compared to gray ones (Moreau et al., 2022).

4.2. Conflicting values according to expertise and the requirement for certain compromises

Despite the shared recognition of ecological and social values, the different weights given to ecological functionality and relational issues according to the level of the valuer’s expertise (cf part 4.1.) can lead to conflicts and the emergence of controversy about SWBE. First, the recreational value of riverbanks can conflict with their ecological value: dense riparian vegetation, although a guarantee of ecological continuity, was considered less suitable for recreational practices, especially by people with no expertise, probably because it prevents physical and visual access to the river. Access to the river is seen as an important dimension of the recreational use of riverbanks in an urban context, particularly because it contributes to local nature experiences in areas where the presence of nature is marginal (Gobster and Westphal, 2004). Adam et al. (2020) showed that pathways that provide easy access to rivers contributed to an increase in their perceived value. Thus, some authors call for restoring social connectivity to urban rivers (Kondolf and Pinto, 2017). Conversely, recreational activities along the banks of watercourses can damage the ecological quality of the site (e.g., trampling of soil, disturbance to wildlife, pollution...) (Venohr et al., 2018; Meyer et al., 2021). Another example of value-based conflict according to the level of expertise relates to the definition of what is called nature. When assessing riverbanks, people with a high level of expertise tend to refer to the concept of biodiversity and rely on synthetic indicators that can consider both the species richness and the relative abundance of species in a given assemblage. This definition of nature may be far from that of people without expertise, who may understand nature in a less technical way that is more related to aesthetic, recreational, or spiritual dimensions (Gobster, 2001; Buijs, 2009). For example, our results showed that some non-experts had a reluctance towards SWBE because they felt that the corresponding landscapes were not sufficiently maintained. This echoes previous work showing that lay people appreciate natural landscapes that are considered clean and tidy, and subject to human care (Nassauer, 1992). This difference in the definition of nature, and by extension what it means to restore nature, can lead to conflicts. The use of SWBE often implies redesigning the morphology of the banks, and therefore removing the existing vegetation, including trees. However, for most lay people, trees represent a symbolic element of nature and as such have a high spiritual value (Dwyer et al., 1991). Therefore, tree cutting can be strongly opposed by lay people, even in the context of ecological restoration, highlighting a wide gap between approval of the goals of restoration and disapproval of the means of achieving them (Barro and Bright, 1998). The consequent transformation of landscapes associated with SWBE can also conflict with people's attachment to a place. Han et al. (2023) demonstrated that place identity was a negative predictor of a supportive attitude towards NBS.

The dissemination of SWBE on riverbanks could therefore benefit from certain adaptations made by the actors concerned by the innovation. According to Callon *et al.* (1999), there is "no adoption without adaptations", that is the destiny of a socio-technical innovation relies on the joint transformation of the environment (including the social environment) and the content of the innovation, through compromise, negotiation, and successive adaptations to match actors' expectations with the proposed solutions. In the case of SWBE, we could imagine compromises such as the creation of windows within the riparian corridor favoring physical and visual access to the water, and favoring scenarios that limit the removal of existing trees as much as possible when designing a project.

4.3. Perceptions of high risk among lay-people

The greatest differences in perception according to expertise concerned the perceived risk and feeling of vulnerability induced by the use of SWBE. According to Anderson et al. (2022), NBS are only accepted when one feels effectively protected. Our survey shows that perceptions of risk induced a certain reluctance towards the use of SWBE, with this reluctance increasing as environmental expertise decreased. Professionals involved in SWBE projects (Moreau et al., 2022) or NBS in general (Seddon et al., 2020; Brillinger et al., 2021) have already noted the reluctance of riverine residents and elected officials, who question the effectiveness of SWBE to address risks. Those actors perceive the use of gray solutions as reassuring, less risky, more controlled, and with a greater historical grounding. It is true that the protection provided by SWBE is difficult to model because of the complexity of living systems, including the interactions between vegetation, soil, water, and other living organisms (herbivores, pathogens). The design of SWBE structures is generally based on empirical approaches (Evette et al., 2018). Although professionals and scientific literature actually highlight the lower effectiveness of SWBE structures immediately after their installation in the field, they do not question their effectiveness in the longer term (Moreau et al., 2022). Indeed, some authors highlight the increasing performance of SWBE over time and the need to develop knowledge on this topic (Pinto et al 2016). The dissemination of SWBE techniques therefore requires more evidence of their effectiveness in terms of risk protection efficiency, but managers typically lack such evidence when giving arguments to raise public awareness on the value of these techniques (Brillinger et al., 2021). Without proof, and in view of the questioning of the expert's legitimacy in public action (Damay *et al.*, 2011), the dissemination of SWBE solutions could be compromised when faced with the high stakes of protecting property and people. To remedy this situation, some experts are calling for evidence of the success of SWBE, for instance by setting up pilot projects that can act as showcases and demonstrate to actors the effectiveness of SWBE approaches, whether or not the actors are experts in aquatic environments (Evette et al., 2023).

5. Conclusion

This interdisciplinary work showed that the ecological and social benefits provided by SWBE were recognized by the vast majority of surveyed actors, whatever their level of environmental expertise. These benefits can therefore create cohesion within the network of actors concerned. As such, they can represent a solid lever for mobilizing support for green riverbank management solutions and contribute to their dissemination in urban areas.

Despite this convergence of perceptions, we also highlighted different hierarchies of values among the surveyed actors, depending on their level of environmental expertise. Those with the greatest environmental expertise gave particular importance to ecological values (connectivity, biodiversity), whereas those with the least expertise gave particular importance to relational values (physical and visual access to riverbanks, islands of freshness). These conflicting values may explain some of the controversies surrounding the use of nature-based solutions for riverbank stabilization (hindering access to riverbanks, the need to cut trees in preparation for works), controversies that can hinder their dissemination.

The most tangible obstacle to the dissemination of nature-based solutions in urban areas was shown to relate to risk perception. Lay people feel a greater sense of vulnerability with SWBE than with gray solutions.

This work opens up both operational and scientific perspectives. In operational terms, it emphasizes the importance of highlighting the ecological and socio-cultural benefits of SWBE in order to promote such solutions in an urban context. To overcome reluctance to a protect – and given that it is still difficult to model the effectiveness of protection in the case of solutions based on a living environment – it seems important to create proof of the effectiveness of the techniques, which could be done through the use of demonstration sites and the documenting of feedback, whether positive or negative. Finally, our study shows the importance of relying on a participatory approach with local residents and riverbank users to identify potential conflicts of value that could affect the acceptance of SWBE structures locally, and underlines the importance of adapting the proposed solutions to the socio-territorial context. From a scientific point of view, this paper calls for further work in ecology to assess the resistance of the structures and the effectiveness of the protection provided. It also encourages the development of work in the social sciences to support reflection on the acceptance of the risks associated with the use of nature-based solutions. Finally, our study shows how important it is to take a legal look at the regulatory issues associated with the use of NBS, particularly clarifying and defining responsibilities.

References

Adam, M., Cottet, M., Morardet, S., Vaudor, L., Coussout, L., Rivière-Honegger, A., 2020. Cycling along a River: New access, new values?. Sustainability. 12(22), 9311.

Agrawal, A., 1995. « Dismantling the divide between indigenous and western knowledge », *Development and Change*, 26(3), p. 413-439

Akrich, M., Callon, M., Latour, B., 2006. Sociologie de la traduction : textes fondateurs. Presses des Mines.

Anderson, C. C., Renaud, F. G., 2021. A review of public acceptance of nature-based solutions: the ’why’, ’when’, and ’how’ of success for disaster risk reduction measures. Ambio. 50(8), 1552-1573.

Anderson, C. C., Renaud, F. G., Hanscomb, S., Gonzalez-Ollauri, A., 2022. Green, hybrid, or grey disaster risk reduction measures: What shapes public preferences for nature-based solutions?. Journal of Environmental Management. 310, 114727.

Andersson, E., Barthel, S., Borgström, S., Colding, J., Elmqvist, T., Folke, C., Gren, Å., 2014. Reconnecting cities to the biosphere: stewardship of green infrastructure and urban ecosystem services. Ambio. 43, 445-453.

Aubriot, O., Riaux, J., 2013. Savoirs sur l'eau: les techniques à l'appui des relations de pouvoir?. Autrepart. 2, 3-26.

Bark, Rosalind H., Martin-Ortega, J., Waylen, K. A., 2021. Stakeholders' views on natural flood management: implications for the nature-based solutions paradigm shift? Environ. Sci. Pol. 115, 91–98.

Barro, S. C., Bright, A. D., 1998. Public views on ecological restoration: a snapshot from the Chicago area. Restoration & Management Notes. 16(1), 59-65.

Berelson, B., 1952. Content analysis in communication research, Glencoe, Ill.: Free Press, 220p.

Bourblanc, M., 2013. Les trajectoires bifurquées de la « Réserve écologique » sud-africaine : d'une logique aménagiste à une logique écologique. Autrepart. 65, 27-45.

Boyer, A. L., Comby, E., Flaminio, S., Le Lay, Y. F., Cottet, M., 2019. The social dimensions of a river's environmental quality assessment. Ambio. 48, 409-422.

Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. Qualitative research in psychology. 3(2), 77-101.

Brillinger, M., Henze, J., Albert, C., Schwarze, R., 2021. Integrating nature-based solutions in flood risk management plans: A matter of individual beliefs?. Science of The Total Environment. 795.

Buijs, A. E., 2009. Lay people's images of nature: Comprehensive frameworks of values, beliefs, and value orientations. Society and Natural Resources. 22(5), 417-432.

Callon, M., Lhomme, R., Fleury, J., 1999. Pour une sociologie de la traduction en innovation. Recherche & Formation, 31, 113-126.

Callon, M., Lascoumes, P., Barthe, Y., 2001. Agir dans un monde incertain. Essai sur la démocratie technique, Paris, Le Seuil, 358 pages.

Cohen-Schacham, E., Walters, G., Janzen, C., Maginnis, S., 2016. Nature-based solutions to address global societal challenges. IUCN: Gland, Switzerland, 97, 2016-2036.

Cottet, M., Piégay, H., 2013. Diversité des savoirs relatifs aux milieux aquatiques : quels impacts pour la restauration écologique?. Le cas des bras morts du Rhône et de l'Ain. Géocarrefour. 88(1), 15-30.

Cribari-Neto, F., Zeileis, A., 2010. Beta Regression in R. J. Stat. Softw. 34.

Damay, L., Duez, D., Denis B., 2011. Introduction "Savoirs experts et profanes dans la construction des problèmes publics", in Damay, L., Duez, D., and Denis, B. (eds), Savoirs experts et profanes dans la construction des problèmes publics, Publications des Facultés universitaires Saint-Louis : Bruxelles, p.9-25.

Dwyer, J. F., Schroeder, H. W., Gobster, P. H., 1991. The significance of urban trees and forests: toward a deeper understanding of values. Journal of Arboriculture. 17(10), 276-284.

Evette, A., Recking, A., Piton, G., Rauch, H.-P., Frossard P. A., Jaymond, D., 2018. The limits of mechanical resistance in bioengineering for riverbank protection. IALCCE. Ghent.

Evette, A., Poulin, M., Cottet, M., Moreau, C., 2023. Promouvoir le génie végétal au Québec. Sciences Eaux & Territoires, 43, 73–80.

Faivre, N., Fritz, M., Freitas, T., de Boissezon, B., Vandewoestijne, S., 2017. Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges. Environmental Research. 159, 509–518.

Fischer, F., 2004. "Citizen deliberation and the problem of expertise: resituating knowledge in practical reason", in Castagna, B., Gallais, S., Ricaud, P., and Roy, J.-P. (eds), La situation délibérative dans le débat public, vol. 1, Presses universitaires François-Rabelais, Tours.

Fromentin, T., and Wojcik, S., 2008. Le profane en politique. Compétences et engagements du citoyen, L'Harmattan, Paris, 2008.

Ganey, J., 1994. Technical Note A Comparison of Two Techniques for Measuring Canopy Closure. Western Journal of Applied Forestry. 9, 21–23.

Gobster, P. H., 2001. Visions of nature: conflict and compatibility in urban park restoration. Landscape and urban planning. 56(1-2), 35-51.

Gobster, P. H., Westphal, L. M., 2004. The human dimensions of urban greenways: planning for recreation and related experiences. Landscape and urban planning. 68(2-3), 147-165.

González del Tánago, M., García de Jalón, D., 2011. Riparian Quality Index (RQI): A methodology for characterising and assessing the environmental conditions of riparian zones. Limnetica. 30(2): 0235-0254.

Han, S., Kuhlicke, C., 2019. Reducing hydro-meteorological risk by nature-based solutions: what do we know about people’s perceptions? Water. 11 (12), 2599.

Han, S., Bubeck, P., Thieken, A., Kuhlicke, C., 2023. A place-based risk appraisal model for exploring residents’ attitudes toward nature-based solutions to flood risks. Risk analysis. 00, 1–19.

Heinich, N. (2017). Dix propositions sur les valeurs. Questions de communication, (31), 291-313.

Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M.,..., Bonn, A., 2016. Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. Ecology and society. 21(2).

Kabisch, N., Korn, H., Stadler, J., Bonn, A., 2017. Nature-based Solutions to Climate Change Adaptation in Urban Areas, Theory and Practice, Springer Nature.

Kondolf, G. M., Pinto, P. J., 2017. The social connectivity of urban rivers. Geomorphology. 277, 182-196.

Le Lay, Y.-F., Cottet, M., Piégay, H., Rivière-Honegger, A., 2012, Chapter 13. « Ground Imagery and Environmental Perception: Using Photo-questionnaires to Evaluate River Management Strategies ». In: Carbonneau, P., Piégay H. (Eds.), Fluvial remote Sensing for Science and Management. New York, Wiley-Blackwell, p. 405-429.

Linton, J., Budds, J., 2014. The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water. Geoforum. 57, 170-180.

Meyer, N., Schafft, M., Wegner, B., Wolter, C., Arlinghaus, R., Venohr, M., & von Oheimb, G. (2021). A day on the shore: Ecological impacts of non-motorised recreational activities in and around inland water bodies. Journal for Nature Conservation, 64, 126073.

Moreau, C., Cottet, M., Rivière-Honegger, A., François, A., Evette, A., 2022. Nature-based solutions (NbS): A management paradigm shift in practitioners' perspectives on riverbank soil bioengineering. Journal of Environmental Management. 308.

Nassauer, J. I., 1992. The appearance of ecological systems as a matter of policy. Landscape Ecology. *6*(4), 239-250.

Morris, S., Moses, T., 1999. Urban stream rehabilitation: a design and construction case study. Environmental Management. 23, 165–177.

Nesshöver, C., Assmuth, T., Irvine, K. N., Rusch, G. M., Waylen, K. A., Delbaere, B., Haase, D., Jones-Walters, L., Keune, H., Kovacs, E., Krauze, K., Külvik, M., Rey, F., van Dijk, J., Vistad, O. I. Wilkinson, M. E., Wittmer, H., 2017. The science, policy and practice of nature-based solutions: An interdisciplinary perspective. Science of The Total Environment. 579, 1215-1227.

Pinto, A., Fernandes, L., Maia, R., 2016. Monitoring Methodology of Interventions for Riverbanks Stabilization: Assessment of Technical Solutions Performance. Water Resources Management. 1-18.

Potschin, M., Kretsch, C., Haines-Young, R., E. Furman, Berry, P., Baró, F. (2015): Nature-based solutions. In: Potschin, M. and K. Jax (eds): OpenNESS Ecosystem Service Reference Book. EC FP7 Grant Agreement no. 308428. Available via: www.openness-project.eu/library/reference-book

Preti, F., Capobianco, V., Sangalli, P., 2022. Soil and water bioengineering (SWB) is and has always been a nature-based solution (NBS): a reasoned comparison of terms and definitions. Ecological Engineering. 181.

Ramírez-Agudelo, N. A., Porcar Anento, R., Villares, M., Roca, E., 2020. Nature-based solutions for water management in peri-urban areas: barriers and lessons learned from implementation experiences. Sustainability, 12(23).

Rauch, H. P., von der Thannen, M., Raymond, P., Mira, E., Evette, A., 2022. Ecological challenges for the use of soil and water bioengineering techniques in river and coastal engineering projects. Ecological Engineering. 176.

Rey, F., 2018. Restaurer les milieux et prévenir les inondations grâce au génie végétal. Editions Quae.

Riis, T., Kelly-Quinn, M., Aguiar, F.C., Manolaki, P., Bruno, D., Bejarano, M.D., Clerici, N., Fernandes, M.R., Franco, J.C., Pettit, N., Portela, A.P., Tammeorg, O., Tammeorg, P., Rodríguez-González, P.M., Dufour, S., 2020. Global Overview of Ecosystem Services Provided by Riparian Vegetation. BioScience. 70, 501–514.

Seddon, N., Chausson, A., Berry, P., Girardin, C.A.J.J., Smith, A., Turner, B., 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philos. Trans. R. Soc. B Biol. Sci. 375.

Shafer E. L., 1969. Perception of natural environments. Environment and behavior. 8, p. 71-82.

Simon, K., Steinemann, A., 2000. Soil bioengineering: challenges for planning and engineering. J. Urban Plann. Dev. 126 (2).

Smithson, M., Verkuilen, J., 2006. A better lemon squeezer? Maximum-likelihood regression with beta-distributed dependent variables. Psychol. Methods. 11, 54–71.

Sotir, R.B., 2001. Integration of soil bioengineering techniques for watershed management. Proceedings of the 2001 Wetlands Engineering and River Restoration Conference. pp. 645–652.

Symmank, L., Natho, S., Scholz, M., Schröder, U., Raupach, K., Schulz-Zunkel, C., 2020. The impact of bioengineering techniques for riverbank protection on ecosystem services of riparian zones. Ecol. Eng. 158.

Trimmel, H., Weihs, P., Leidinger, D., Formayer, H., Kalny, G., 2016. Can riparian vegetation shade mitigate the expected rise in stream temperatures during heat waves in a pre-alpine river?. Hydrol. Earth Syst. Sci. Discuss. 1-27.

Venohr, M., Langhans, S. D., Peters, O., Hölker, F., Arlinghaus, R., Mitchell, L., & Wolter, C. (2018). The underestimated dynamics and impacts of water-based recreational activities on freshwater ecosystems. Environmental Reviews, 26(2), 199-213.

West, S., Haider, L. J., Stålhammar, S., Woroniecki, S. (2020). A relational turn for sustainability science? Relational thinking, leverage points and transformations. Ecosystems and People, 16(1), 304-325.