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Why do we restore rivers and streams and how do we assess restoration success? Evidences from a questionnaire for multi-country stakeholders

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Título del trabajo de fin de máster: ¿Por qué restauramos ríos y arroyos y cómo evaluamos el éxito de la restauración? Evidencias de un cuestionario para partes interesadas de varios países

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¿Por qué restauramos ríos y arroyos y cómo evaluamos el éxito de la restauración? Evidencias de un cuestionario para partes interesadas de varios países

Resumen (español)

En este trabajo se aborda la importancia de la restauración fluvial y los métodos utilizados para evaluar su efectividad. Se centra en comprender las motivaciones detrás de los proyectos de restauración de ríos y arroyos, así como en identificar las prácticas y criterios más efectivos para medir su éxito.

Para ello, se realizó una serie de encuestas a partes interesadas - stakeholders - involucradas en proyectos de restauración en cuatro países (España, Brasil, Alemania y Suecia). De este modo se recopiló información detallada sobre los objetivos establecidos, las metodologías implementadas y los indicadores utilizados para evaluar los resultados de las intervenciones. Además, se analizaron los desafíos y limitaciones enfrentados durante el proceso de restauración.

Gracias a los datos proporcionados por los entrevistados, concluimos que los objetivos que motivan los proyectos de restauración dependen de cada país, siendo el principal impulsor la degradación de los ecosistemas, por lo que estos dependen del contexto ambiental y socioeconómico. Del mismo modo, los indicadores de éxito varían entre países. Además, sí se usan indicadores de éxito prematuro, al contrario que los indicadores de servicios ecosistémicos, pues en ambos casos hace más información obre su implementación. Finalmente, se ha visto que los factores que impiden el éxito en los proyectos son distintos para cada país, sin embargo, destacaría la falta de financiación y las perturbaciones humanas y naturales, así como algunas posibles similitudes.

Destacamos la necesidad de establecer objetivos claros desde el inicio de los proyectos de restauración, lo cual facilita la selección de indicadores adecuados y la evaluación efectiva del éxito alcanzado. Estos objetivos deben ir ligados al contexto ambiental y socioeconómico. Asimismo, se resalta la importancia del monitoreo continuo y sistemático para ajustar y mejorar las prácticas de restauración a largo plazo.

La participación activa de las partes interesadas se identificó como un factor clave para garantizar la sostenibilidad y el éxito de los proyectos, promoviendo la colaboración interdisciplinaria y el intercambio de conocimientos.

Finalmente, se recomienda la implementación de metodologías estandarizadas y la promoción de estudios comparativos entre diferentes contextos geográficos y sociales para enriquecer el conocimiento en el campo de la restauración fluvial.

Palabras clave

Diagnosis, Objetivos de restauración, Evaluación, Indicadores, Monitoreo, Ecosistemas, Restauración de ríos, Proyectos, Partes interesadas, Entrevistas.

Per què restaurem rius i rierols i com avaluem l'èxit de la restauració? Evidències d'un qüestionari per a parts interessades de diversos països

Resum (català)

En aquest treball s'aborda la importància de la restauració fluvial i els mètodes utilitzats per a avaluar la seva efectivitat. Se centra en comprendre les motivacions darrere dels projectes de restauració de rius i rierols, així com a identificar les pràctiques i criteris més efectius per a mesurar el seu èxit.

Per a això, es va realitzar una sèrie d'enquestes a parts interessades - stakeholders - involucrades en projectes de restauració en quatre països (Espanya, el Brasil, Alemanya i Suècia). D'aquesta manera es va recopilar informació detallada sobre els objectius establerts, les metodologies implementades i els indicadors utilitzats per a avaluar els resultats de les intervencions. A més, es van analitzar els desafiaments i limitacions enfrontats durant el procés de restauració.

Gràcies a les dades proporcionades pels entrevistats, concloem que els objectius que motiven els projectes de restauració depenen de cada país, sent el principal impulsor la degradació dels ecosistemes, per la qual cosa aquests depenen del context ambiental i socioeconòmic. De la mateixa manera, els indicadors d'èxit varien entre països. A més, sí que s'usen indicadors d'èxit prematur, al contrari que els indicadors de serveis ecosistèmics, perquè en tots dos casos fa més informació obri la seva implementació. Finalment, s'ha vist que els factors que impedeixen l'èxit en els projectes són distints per a cada país, no obstant això, destacaria la falta de finançament i les pertorbacions humanes i naturals, així com algunes possibles similituds.

Destaquem la necessitat d'establir objectius clars des de l'inici dels projectes de restauració, la qual cosa facilita la selecció d'indicadors adequats i l'avaluació efectiva de l'èxit aconseguit. Aquests objectius han d'anar lligats al context ambiental i socioeconòmic. Així mateix, es ressalta la importància del monitoratge continu i sistemàtic per a ajustar i millorar les pràctiques de restauració a llarg termini.

La participació activa de les parts interessades es va identificar com un factor clau per a garantir la sostenibilitat i l'èxit dels projectes, promovent la col·laboració interdisciplinària i l'intercanvi de coneixements.

Finalment, es recomana la implementació de metodologies estandarditzades i la promoció d'estudis comparatius entre diferents contextos geogràfics i socials per a enriquir el coneixement en el camp de la restauració fluvial.

Paraules Clau

Diagnosi, Objectius de restauració, Avaluació, Indicadors, Monitoratge, Ecosistemes, Restauració fluvial, Projectes, Parts interessades, Entrevistes.

Why do we restore rivers and streams, and how do we evaluate the success of restoration? Evidence from a survey of stakeholders from various countries

Summary (English)

This work addresses the importance of river restoration and the methods used to assess its effectiveness. It focuses on understanding the motivations behind river and stream restoration projects, as well as identifying the most effective practices and criteria to measure their success.

To do this, a series of stakeholder surveys - stakeholders - were carried out involved in restoration projects in four countries (Spain, Brazil, Germany and Sweden). In this way, detailed information was collected on the objectives set, the methodologies implemented and the indicators used to assess the results of the interventions. In addition, the challenges and limitations faced during the restoration process were analysed.

Thanks to the data provided by the interviewees, we conclude that the objectives that motivate the restoration projects depend on each country, being the main driver of the degradation of ecosystems, so they depend on the environmental and socioeconomic context. Similarly, success indicators vary between countries. In addition, premature success indicators are used, unlike ecosystem service indicators, because in both cases it makes more information open its implementation. Finally, it has been seen that the factors that prevent success in projects are different for each country, however, I would highlight the lack of funding and human and natural disturbances, as well as some possible similarities.

We highlight the need to establish clear objectives from the start of restoration projects, which facilitates the selection of appropriate indicators and the effective evaluation of the success achieved. These objectives must be linked to the environmental and socio-economic context. The importance of continuous and systematic monitoring to adjust and improve long-term restoration practices is also highlighted.

The active participation of stakeholders was identified as a key factor in ensuring the sustainability and success of projects, promoting interdisciplinary collaboration and knowledge exchange.

Finally, the implementation of standardised methodologies and the promotion of comparative studies between different geographical and social contexts is recommended to enrich knowledge in the field of river restoration.

Keywords

Diganosis, Restoration objectives, Evalutacion, Indicators, Monitoring, Ecosystems, River restoration, Projects, Stakeholders, Interviews.

Poder viure a prop d'aquest camí
poder beure l'aigua d'aquest riu.
Sentir la pluja com cau i ens mulla
i tenir-te al meu costat
agafant-te de la mà
per si no ho podem fer demà.

Veure els arbres créixer cap al cel
i saber que res no els pararà.
Voldria escriure que això canvia
i aquest món es pot salvar
però em temo que tot això se'n va.

Obro els ulls, miro al meu voltant
i veig com tot això s'acaba.
Si algú em volgués explicar per què
ningú no ho vol intentar
que això es pot salvar.
[...]

Sau - Això es pot salvar

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Thank you for always being there for me.

Una abraçada molt forta!

P.S.: I promise to stop enrolling in master's programs (at least for a while).

Content

1. Introduction

Rivers and streams provide numerous ecosystem services, such as food provision, water purification, and nutrient mitigation (Costanza et al., 1997). As integrators of all activities occurring across the landscape, streams are sensitive to a wide range of stressors, including the impacts of urbanization, agriculture, deforestation, invasive species, flow regulation, water extraction, and mining (Palmer et al., 2010). Human activities have altered the natural hydromorphology of these water bodies for centuries, affecting hydrological regimes, channel structure, and their connection to floodplains (Bernhardt et al., 2007). These changes have modified both the quantity and timing of water availability and the fluvial landscape (Whipple & Viers, 2019), negatively impacting associated ecosystems, including fluvial ecosystems, riparian zones, and river channels.

Natural riverine ecosystems are self-sustaining and dynamic, exhibiting great temporal variability due to natural and anthropogenic disturbances (Palmer et al., 2005). Overall, these impacts have reduced hydromorphological complexity and riparian ecosystem integrity, contributing to biodiversity loss (Bernhardt et al., 2007) and degrading ecosystem processes such as energy flows, nutrient uptake, and others (Cunha et al., 2022).

To address these issues, efforts toward river restoration have been initiated using a wide range of techniques (Bernhardt et al., 2007). Restoration is becoming an increasingly important tool in humanity's attempt to manage, conserve, and repair the world's ecosystems (Hobbs, 2007). The overarching goal of restoration is to achieve systems that are natural—or as close to natural as possible—ecologically valuable, and self-sustaining (Halle, 2007). However, defining ecological restoration is not as straightforward as it may seem (Palmer et al., 1997). River restoration encompasses a broad range of management actions, from riparian vegetation replanting and dam removal to channel redesign, among others (Bernhardt et al., 2007). Repairing the numerous components of fluvial processes and their interactions in highly modified rivers remains a central challenge in river ecosystem management and restoration (Whipple & Viers, 2019).

Restoration efforts are implemented in headwater streams, large lowland rivers, and entire river networks across urban, agricultural, and less intensively modified landscapes (Wohl et al., 2015).

Restoration requires clearly defined objectives. Sometimes this is done by using reference ecosystems, or relatively undisturbed areas that resemble the original state of the degraded site (Hobbs, 2007), or even through historical data, reference conditions, models, and river classification based on expert knowledge (Palmer et al., 2005). Returning a system to a pre-human-influence state can be an unrealistic objective, as nature is dynamic and varies through space and time; thus, there is no single "correct" state to target (Hobbs, 2007).

The outcomes expected from a restoration project are influenced by the interests of different stakeholders, as well as by financial constraints (Halle, 2007), along with political factors and social agendas. However, the process through which restoration is carried out must be driven by science (Palmer, 2009).

Restoration ecology has undergone major advances in recent decades and is now well positioned to contribute not only to the practical repair of damaged ecosystems but also to the development of broader ecological concepts (Hobbs, 2007). Ecological restoration has experienced rapid growth and now encompasses both classical ecological theory and utilitarian concerns, climate change adaptation, and the provision of ecosystem services (Palmer et al., 2014). A key example of these services is the retention of nitrogen and phosphorus derived from human activities. Since restoration can enhance the ability of ecosystems to retain these nutrients, quantifying such retention has become a valuable indicator of the effectiveness of restoration efforts (Newcomer Johnson et al., 2016). Other advancements in the field include the recognition that ecological processes are interconnected, providing practitioners, managers, and policymakers with a stronger foundation for developing strategies that improve the integrity and resilience of riverine ecosystems (Whipple & Viers, 2019). Restoring impacted aquatic ecosystems is a complex process that must include a critical diagnosis and management of multiple stressors prior to intervention, as well as prolonged monitoring after implementation (Cunha et al., 2022). It is essential that managers identify and critically evaluate the stressors affecting degraded streams and prioritize resources toward those limitations most likely to constrain restoration effectiveness (Palmer et al., 2010).

To carry out effective restoration, it is fundamental to have a clear vision, perform ecological assessments, demonstrate ecological improvements, avoid long-lasting damage, and enhance ecosystem resilience (Palmer et al., 2005). Demonstrating improvement requires comparative assessment of the restored stream components against their previous condition or a reference point, such as an undisturbed or less degraded stream (Palmer et al., 2005). However, only 10% of projects include any kind of monitoring, and available information is rarely accessible (Bernhardt et al., 2005). Evaluation should be established at the beginning of the restoration project and be based on well-defined objectives (Morandi et al., 2014).

Long-term monitoring is essential due to the low predictability of system development (Halle, 2007). According to Jenkinson et al. (2006), the availability of information is critical for identifying which restoration measures have been most successful and which have not, along with the reasons behind these outcomes. Data collection enables progress in the field of restoration, increases efficiency, and prevents harmful effects in restored environments, while helping solidify scientific understanding of ecosystems. It is necessary to develop robust metrics to evaluate achievements, particularly regarding the desired level of self-sustainability (Halle, 2007).

The evaluation of a restoration process can be based on different indicators, which may include vegetation characteristics, population attributes, or ecosystem functioning responses (Lindig Cisneros, 2017). Pre- and post-restoration indicators evaluate not only the success of restoration but also whether irreversible damage has occurred to ecological properties of the system (Palmer et al., 2005). An important area of research, therefore, involves developing the capacity to correctly diagnose ecosystem damage (Hobbs, 2007). However, literature on river restoration practices across countries remains limited (Palmer et al., 2005).

Currently, restoration must adopt a more holistic approach, one that includes broader hydromorphological and habitat improvements to fully restore ecological processes in these vital ecosystems, while promoting the use of ecosystem function metrics as integrative indicators of ecological recovery and restoration success (Gutiérrez Cánovas et al., 2024).

Within this broader and more integrated perspective, the inclusion of stakeholder perspectives is essential. According to Palmer et al. (2005), projects that meet stakeholder needs and advance both the science and practice of river restoration can also be considered ecological successes. However, progress in river restoration science and practice has been hindered by the lack of agreed-upon criteria to judge ecological success. It is crucial for practitioners to consider environmental differences when applying restoration criteria (Palmer et al., 2005).

Now more than ever, strengthening collaboration between science and practice is essential (Dickens & Suding, 2013). Such collaboration enhances the rigor and authenticity of research and validates the effectiveness of recommended guidelines (Arlettaz et al., 2010). This is particularly relevant in decision-making processes, which must not be isolated from sociopolitical and cultural contexts; rather, they must consider stakeholder concerns and viewpoints (Perko et al., 2019). Successful ecological restoration projects are characterized by community participation and the exchange of knowledge among scientists, practitioners, community members, and administrative organizations in the decision-making process (Bernhardt et al., 2007; Tischew & Kirmer, 2007).

Collaborations strengthen the robustness of foundational research and validate recommended restoration practices (Arlettaz et al., 2010). Numerous studies highlight the need to incorporate scientific knowledge into restoration practice (Hobbs, 2007; Palmer, 2009; Weiher, 2007). Practical restoration efforts must be largely based on theoretical and empirical research on how communities develop and are structured over time (Palmer et al., 1997). Lessons learned from both successful and unsuccessful projects show that progress is possible through open participation and acknowledgment of diverse ideas, needs, and limitations (Dickens & Suding, 2013).

As with conservation, scientific knowledge is indispensable but not sufficient; stakeholder concerns must be addressed, meaning that restoration is strongly linked to communication (Halle, 2007). Ecological restoration can significantly benefit from—and contribute to—scientific understanding of natural systems (Halle, 2007).

A substantial portion of the science produced has not been effectively communicated to potential users, or—more commonly—has not yet reached the translation stage (Palmer, 2009). Therefore, an important current area of research involves translating recent advances in ecosystem and landscape dynamics into conceptual and practical frameworks for restoration (Hobbs, 2007). One example is the development of the Open Standards for the Practice of Conservation, a key framework that incorporates restoration and climate change, and facilitates decision-making through collaboration with the academic community (Schwartz, 2012).

In projects similar to the present work, Hassett et al. (2007) highlighted the importance of stakeholder involvement and the need for funding initiatives dedicated to project monitoring. Policymakers and practitioners often find themselves at odds with researchers due to misunderstandings of their needs or economic limitations affecting restoration implementation (Halle, 2007). This reflects the perception among many practitioners that research focuses on issues that are not directly applicable to their work or overlook social, political, and logistical constraints (Arlettaz et al., 2010). Given these two perspectives of the same challenge and the lack of mutual understanding that could improve collaboration and support shared goals, it is essential to gather and integrate diverse opinions.

This study compiles the responses to a survey conducted within the framework of the international RESTOLINK project. This phase of the project, as will be described throughout this work, surveyed stakeholders from various professional sectors, environmental organizations, and community representatives to gather information on motivations, approaches, and outcomes of river restoration efforts in their respective regions: Brazil, Spain, Germany, and Sweden. Through this methodology, the aim was to bring together differing viewpoints to facilitate mutual understanding and address key challenges, enabling professionals across sectors to more efficiently implement river and stream restoration. By incorporating an international scope, the project seeks to identify potential similarities across countries and to learn from the experiences of practitioners from other bioregions.

In summary, throughout this work we focus on addressing existing knowledge gaps in river restoration by analyzing the perspectives of key stakeholders in multiple countries with contrasting socioeconomic and environmental challenges. In doing so, we aim to contribute to the improvement of river and stream restoration by providing insights into the experiences and viewpoints of relevant actors in the field, thereby fostering mutual understanding.

The overall objective of this work is to examine perceptions of river restoration across different professional sectors and countries. We established three specific objectives:

1. To investigate whether differences exist in river restoration goals among the four participating countries, and to explore the potential reasons underlying these differences.

2. To analyze the use of success indicators in river restoration projects, identify the most commonly used indicators in each country and their similarities, and assess whether premature success indicators are employed, as well as their relationship with ecosystem services.

3. To identify the factors that may hinder the success of river restoration project

Our working hypothesis is that perceptions of river restoration differ depending on the country in which the projects are implemented. More specifically, this study tests the following hypotheses:

H1: The primary restoration objectives vary by country.

H2: The reasons behind the selection of primary restoration objectives vary by country.

H3: Success indicators vary by country, as does their use.
H3.1: Premature success indicators are not employed.
H3.2: Ecosystem services are not directly monitored through specific indicators.

H4: The factors that may hinder the success of a restoration project are similar across different countries.

2. Materials and methods

This master's thesis is framed within one of the phases of the RESTOLINK project. The project and the materials and methods used are explained below. For the purposes of this work, data were obtained from a specific phase of the project, namely the stakeholder surveys. Additionally, contributions were made to conducting some of these surveys. To carry out this study, it was necessary to provide contextualization through a literature review, as well as data management, extraction, and analysis (Figure 1).

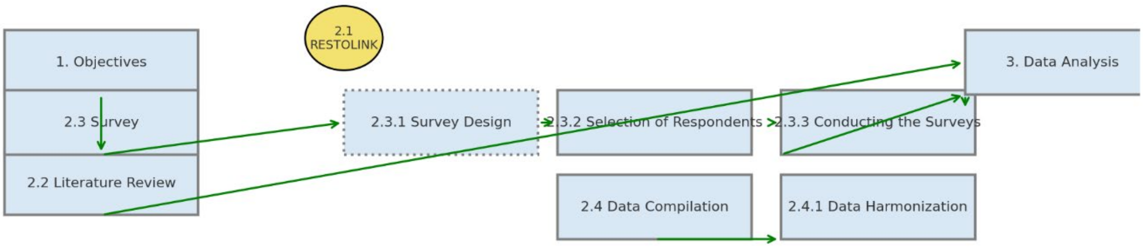

Figure 1: Diagram of the methodology followed for the development of this work.

2.1 About RESTOLINK

The RESTOLINK project (Quantifying restoration success across biomes by linking biodiversity, multifunctionality and hydromorphological heterogeneity) arises from the global interest in river and stream restoration, seeking a new framework for evaluating restoration success by connecting hydromorphology, biodiversity, and essential fluvial ecosystem functions. It compares restoration efforts carried out in diverse biomes, such as the Cerrado and the Atlantic Forest in Brazil, temperate forests, temperate deciduous forests and Mediterranean vegetation in Europe, and boreal landscapes in Sweden, in order to identify effective management practices and the physical conditions that support success. Fieldwork is conducted in Sweden, Germany, Spain, and Brazil using joint protocols and with stakeholder participation. Coordinated by the Helmholtz Centre for Environmental Research in Germany, this project is aligned with the European Union's Biodiversity Strategy for 2030.

Figure 2: Map of the location of participating partners in the project RESTOLINK. Source: biodiversa.eu.

The participating partners are (Figure 2):

- Engineering, University of São Paulo, São Carlos, Brazil
- Geosciences, Federal University of São João del-Rey, São João del-Rey, Brazil
- Environmental Sciences, University of Koblenz- Landau, Landau, Germany
- Evolutionary Biology, Ecology & Environmental Sciences, University of Barcelona, Barcelona, Spain
- Ecology and Environmental Science, Umeå University, Umeå, Sweden

The goal of RESTOLINK is to develop a mechanism to quantify restoration success using tools grounded in scientific evidence. These tools will support territorial stakeholders in selecting the most effective restoration measures, tailored to the specific conditions of each biome, thereby ensuring proper evaluation and monitoring. The project targets regional and national administrations and agencies to facilitate the integration of its findings into environmental policies.

This work is framed within a specific component of the RESTOLINK project, in which, as will be detailed below, professionals from the four participating countries and from different sectors were surveyed on five topics related to restoration. The aim of analyzing these data was to provide a diagnosis of the current state of the field, identify strengths and aspects requiring greater effort, and compare the diverse perspectives involved.

2.2 Bibliographic search

First, a literature review was conducted using the Scopus database to identify relevant studies on river restoration and stakeholder perceptions. In addition to Scopus, the Connected Papers tool was used to find related articles and explore connections among academic works. After reviewing and selecting the articles, key findings were summarized, highlighting methodologies and conclusions relevant to the objective of this study. This approach provides a scientific literature foundation to contextualize the master's thesis and to enable a comprehensive understanding and interpretation of the results.

2.3 Interviews

Surveys have become a widely used research tool in today's information society. They are designed to use data from a relatively small sample to obtain information about a broader population and are therefore one of the most common tools in social research, including scientific articles and publications (Grifo, n.d.). Despite the limitations of studies based exclusively on interviews, they provide a large amount of information, as professionals share their stories and expertise (Hassett et al., 2007).

The questionnaire used in this study is adapted from the original version developed by Bernhardt et al. (2007). That questionnaire was designed through a collaborative process that identified the primary research questions regarding the motivations and evaluation of river restoration. The initial survey was reviewed by an expert in interview design and interpretation.

The goal of the questionnaire in this study is similar to that of the original survey: to explore the motivations for restoration, the scope and types of project evaluation, assessments of success, and lessons learned. This survey seeks to improve understanding of the main characteristics, challenges, and stakeholder perceptions of river restoration initiatives in each of the participating countries.

The complete questionnaire is available in its original language (English). It is also available in the other official languages of the participating countries (Swedish, Catalan, German, and Portuguese).

The questionnaire is divided into the following six sections, of which this study focuses on Sections I, IV, and V. Additionally, it includes an introduction explaining the project.

Table 1: Sections of the questionnaire, including the number of questions (❓) and subsections.

Block I – General information/Characterization ❓: **3 (+ 2 subsections)** Its purpose is to gather information on the respondent's profile and the objectives of the restoration projects.	**Block II – Project design, implementation, and coordination** ❓: **3 (1 subsection)** It focuses on the reasons behind the implementation of restoration projects.	**Block III – Monitoring** ❓: **1 (+ 3 subsections).** It asks about monitoring data, potential constraints, and the types of monitoring conducted.
Block IV – Evaluation ❓: **3** It evaluates success indicators, the factors that hinder success, and the areas that require greater attention.	**Block V – Indicators of success** ❓: **5 (+ 2 subsections)** It focuses on the indicators and their importance, the available tools, and the evaluation of ecosystem services.	**Block VI – Climate change** ❓: 5 It addresses climate change, its effects, and how these aspects are being approached.

This questionnaire includes various types of questions and response formats. Below is a brief description of the question types:

- Yes/No questions
- Numerical responses: These questions require whole numeric values.
- Open-ended text responses: These allow respondents to answer freely.
- Multiple-choice questions with a single response: Several alternatives are provided, and only the most appropriate option may be selected.
- Multiple-choice questions with more than one response: Similar to the previous type, but more than one option may be selected.
- Optional open-text responses: Respondents may write their own answer if none of the provided options is suitable.

Thus, the dataset includes categorical responses to questions on project design, implementation, and evaluation, as well as open-text descriptions of monitoring methods and lessons learned. While quantitative surveys are generally easier to answer and allow for larger sample sizes, qualitative approaches enable participants to respond in more diverse and individualized ways and support a deeper understanding of minority perspectives (Bavin et al., 2020).

To conduct the interviews, each project partner first selected professionals to participate, after pilot testing the survey with a few stakeholders and committing not to include those pilot data in the final database. Participant selection was performed using a combination of random and chain referral sampling. This approach constitutes a limitation, as the results originate from individuals who are accessible and available in a field that is difficult to sample due to its high level of specialization. This may introduce some bias and lack of randomness (Snowball sampling method in research – ATLAS.ti, n.d.). Nevertheless, this does not imply poor sample quality; rather, selection criteria were adapted to the nature of the study (Blanco & Castro, n.d.).

Interviewees first received a document describing the objectives of the study. If they agreed to participate, they were sent the survey along with a project description and confidentiality conditions. An interview was then scheduled to be conducted via videoconference, telephone, or in person. Due to the broad geographical range, in-person interviews were often not feasible. Each interview was recorded (with informed consent) to facilitate data entry and ensure data quality. Interviews lasted between 25 and 60 minutes.

All participants were asked the same questions in the same order. Standardized prompts were developed to define terms or clarify questions when needed. Some open-ended responses had to be classified by the interviewer, who, when encountering difficulties, asked the interviewee for clarification, such as choosing between two response options considered the most suitable.

It should be noted that interviewees often tend to portray an optimistic view of project outcomes, not necessarily intentionally, but because they may still be closely involved with the project (Hassett et al., 2007).

Once completed, survey results were compiled into a shared cloud document accessible to all participating centers. The interviews were conducted between May 2023 and May 2024. As part of this master's thesis, three interviews were conducted with stakeholders in Spain, and their data were included along with those collected by other interviewers.

Personal data of respondents were used exclusively by each research center to conduct the interviews and were not shared with others. In shared documentation, interviewees were labeled as "Stakeholder" followed by an identification number, allowing each center to track the interview without compromising privacy. Furthermore, results are discussed only in aggregate form, thereby safeguarding interviewee confidentiality. This approach ensures compliance with privacy regulations in all participating countries. All participants were assured that they would not be identifiable in any published materials and that they retained the right to withdraw at any time.

2.4 Data entry and management procedure

Each interviewer entered all data—except for confidential information about the interviewee—into a cloud-based database. In addition to the responses to the survey questions, a section was included to identify the origin of the data by specifying the country name and a numerical code assigned to stakeholders, known only to the interviewers, to facilitate follow-up in case of technical issues.

A homogenization process was carried out to ensure that all data followed the same criteria. For example, if a participant did not answer an open-text question, the response was recorded as "no" to maintain consistency.

Furthermore, the German team modified the "Yes" and "No" categories to "On" and "Off," respectively, so they were standardized to match the formats used by the other countries. Open-ended responses from the German participants were also translated into English, as they were originally provided in German. This translation was performed using online translation tools.

Additionally, it was verified that the selected response options were valid according to the maximum number of choices allowed for each question. For instance, in the case of the employment sector, some open-text responses required harmonization. Categories such as "University" and "Public Administration" were standardized to ensure consistency across responses. Likewise, nonprofit organizations were classified as "NGO." This is one example of the data homogenization performed.

2.5 Data analysis procedure

First, descriptive statistics were performed for all questions (21 in total). Of these, 10 had simple responses, 3 were open-ended text questions, and 8 allowed multiple responses. Due to these differences in structure, each type of question was analyzed using appropriate methods.

Subsequently, statistical tests such as the Chi-square test were applied to the questions considered most relevant. This non-parametric test allowed us to detect differences between categorical variables. Given the limited number of variables in the closed-ended responses and the lack of relationships between groups, the Chi-square test was an appropriate analytical tool in this context (Flores-Ruiz et al., 2017). All statistical analyses were performed using RStudio.

3. Results and Discussion

3.1 Profile of the participants

Out of the 71 surveys conducted, we obtained 23 interviews from Germany (GER), 21 from Brazil (BRA), 12 from Spain (SPA), and 11 from Sweden (SWE) (Figure 3). The unequal contributions across countries, both in the number of surveys and in participant profiles, considerably limit the analyses. Therefore, percentages were used, and the results should be interpreted as approximations due to the limited amount of data.

Regarding the professional sectors (I.1) (33), most respondents belonged to public authorities, followed by academia (15), consultancies (13), NGOs (7), and other research institutions (3) (Fig. S1, S2, S3). This unequal distribution of the participants among countries and professional sectors represents a considerable limitation, as some countries have little to no representation from certain professional sectors, which means that only regional approximations can be made. This constrains any potential analysis of professional background in relation to the responses to other questions.
With regard to professional experience (I.2), there is a wide range represented, from one year to 35 years (Figure 4). Germany contributed the perspectives of more experienced professionals, while Brazil showed the opposite pattern. The sample includes individuals who are just beginning their careers as well as those who have spent their entire professional trajectory in the field, along with many participants with around ten years of experience. This suggests that the survey captures a broad spectrum of knowledge and backgrounds, providing a comprehensive overview that reflects both early-career viewpoints and those of experts with extensive experience.

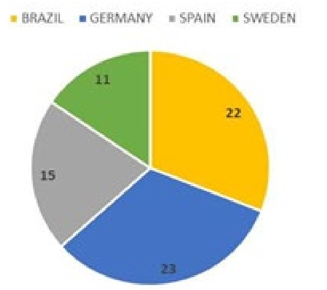

Figure 3: Distribution of participants per country.

As for the number of projects in which participants have been involved (I.3), Figure 5 shows that most respondents reported experience ranging from a few projects up to fifty, with Germany presenting the widest distribution in this regard.

Public authorities and consultants reported exceptionally high figures, ranging from 200 to 2000 projects, and some professionals from Spain and Sweden indicated experience in 100 to 200 projects. Overall, consultants and public authorities tend to have participated in a larger number of projects.

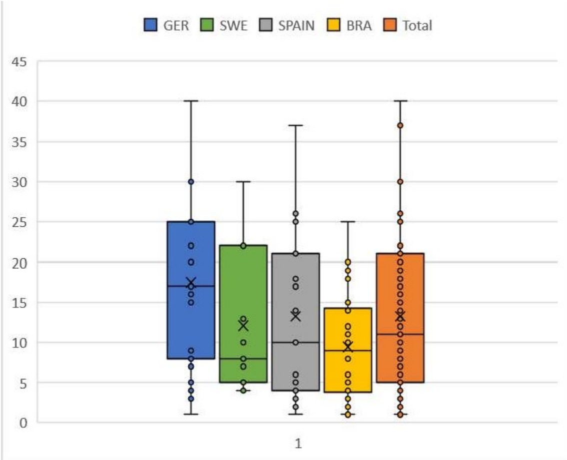

Figure 4: Experience in the field (years) by country.

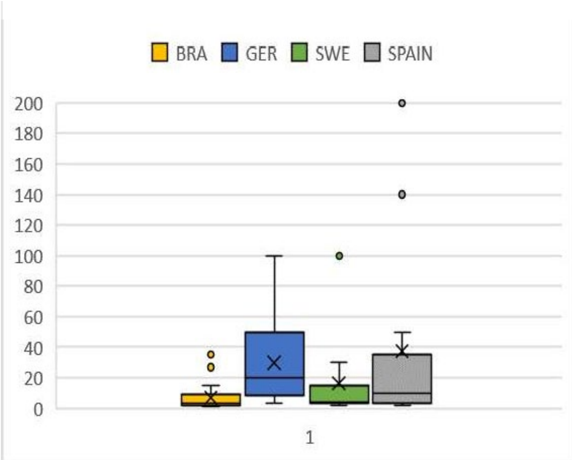

Figure 5: Number of participated projects.

The interviewees held a variety of roles (I.5) (Figure S4). The most commonly identified role was project coordinator, representing 49.3% of all respondents. There were also other responses that did not fit into any of the predefined categories, indicating a lack of foresight in capturing the participation of certain professional profiles. Once again, we observe that the limited sample size results in an uneven distribution. Moreover, the dataset shows a shortage of more technical or field-oriented roles, as most respondents were coordinators or managers. Therefore, we propose that in a later phase of the project, interviews be conducted with professionals directly responsible for project implementation.

The analysis of project design (I.6) (Figure S5) reveals a general trend toward significant involvement of private contractors in project design across all participating countries, indicating a pattern of outsourcing, with variable roles played by governmental agencies and non-governmental organizations. Overall, public agencies appear as the primary entities responsible for design. Differences in the involvement of local, regional, and national agencies highlight distinct approaches and priorities regarding project design and management at the national level.
The open-text responses indicate that universities and independent research institutions also play a role in project design.

Each country exhibits a distinct combination of implementing entities (I.7) (Figure S6), reflecting different management approaches. In Spain and Brazil, private contractors are the main implementers (34.4% and 46.2%, respectively), which could suggest a stronger trend toward project outsourcing. In Germany, local or regional authorities are the primary actors (22.9%), indicating strong governmental involvement at the local level. In Sweden, implementation is dominated by state agencies (24%), followed by private contractors (20%), suggesting a more centralized management structure.

It is important to highlight the absence of information regarding the gender identity of respondents, as this variable was not included. Incorporating gender data in future phases could provide valuable insights into how gender influences perception and experience, and could also reveal potential gender gaps within the field of ecological restoration.

3.2 River restoration measures

Once contextualized, and with a clearer understanding of the profiles and individual objectives by country, the following results refer to the questions from Block I of the questionnaire. Through this block, it is possible to identify the restoration measures and the specific objectives in each country.

Restoration objectives establish expectations and provide a detailed management plan, along with quantifiable criteria for evaluating success (Ehrenfeld, 2000). For this reason, it is important that they be specific and supported by data collection and post-restoration assessment (Palmer et al., 2005).

Due to the structure of the survey, in which questions are framed around the respondents' professional trajectories, the objectives analyzed here are global in nature.

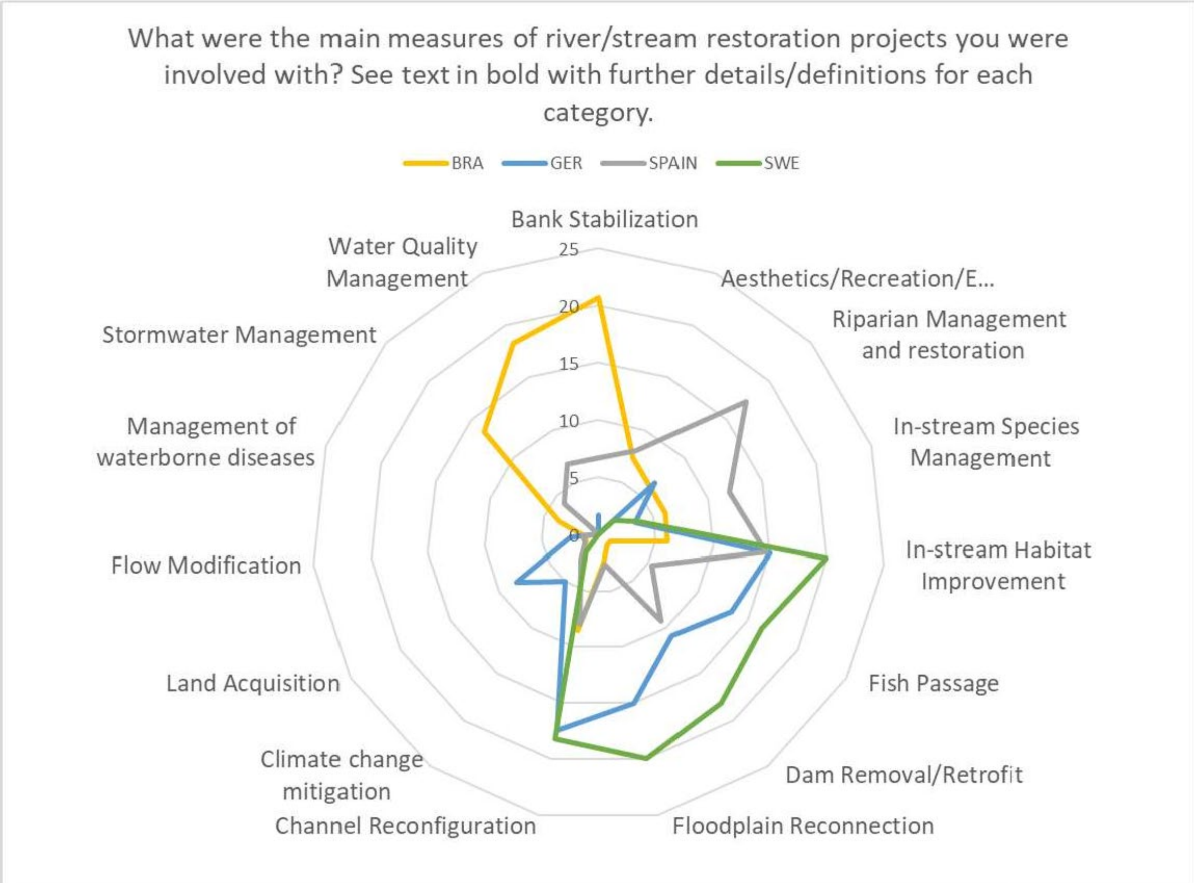

Figure 6: Radar chart showing the restoration objectives by country, represented as the percentage of responses corresponding to each objective.

The collected data reveal a wide range of reasons for implementing restoration projects (I.4) (Figure 6). In general, the most frequently cited objectives are broad in nature, encompassing more specific goals within them. The primary reasons identified were habitat restoration and channel reconfiguration, followed by fish passages, dam removal, and channel reconnection.

The least common measures were land acquisition and waterborne disease management, as well as those related to aesthetics and recreational use. Brazil shows greater diversity in restoration measures compared to the other countries. We also observe that Sweden and Germany share similar primary objectives, while Brazil and Spain exhibit alignment between them.

When analyzing country-specific priorities, in Brazil, water-related measures were particularly prominent, such as improving water quality, bank stabilization, and stormwater management. Brazil is characterized by high rainfall and ongoing issues linked to wastewater discharges, making these measures especially relevant. Although globally important, wastewater and stormwater pollution remain significant threats in the region, and there is a lack of established monitoring and control policies to mitigate environmental and human health impacts (Ferreira et al., 2019).

In Sweden, the main restoration focuses include improving riverine habitats, floodplain reconnection, barrier removal, and channel reconfiguration. In Germany, the most highlighted objectives include the management of waterborne diseases, floodplain reconnection, and installation of fish passages. In Spain, the leading objectives include riparian management and restoration, management of aquatic species, and improvement of aquatic habitats.

One major objective in both Sweden and Germany is the removal of dams and weirs, which is a positive indicator of shifting societal values toward river use and conservation (Sneddon et al., 2017). This practice is expanding, particularly where structures are obsolete or no longer in use (Duda & Bellmore, 2022). Recent studies support the growing importance of dam removal, especially in North America and Europe, as a means to improve river connectivity and ecosystem status. However, further research is still required regarding impacts across ecological scales and the balance between restoration and safety concerns (Ding et al., 2019).

Clear differences in restoration measures among countries were confirmed by a Chi-square test ($X^2 = 113.56$), with a significant p-value ($p < 0.05$). The result remained significant even when excluding individual countries and rerunning the analysis, suggesting strong country-dependent differences in restoration objectives.

Additional pairwise and three-country comparisons also yielded p-values below 0.05, reinforcing these patterns. One comparison—between Germany and Sweden—produced a p-value closer to the significance threshold (0.05), indicating that further research with a larger sample size or more specific objectives may clarify potential similarities.

These country-level differences are likely driven by environmental context (climate, habitat types, natural disturbances), governmental policies, environmental priorities, available resources, and cultural approaches to river conservation. Therefore, restoration professionals must be aware of broader sociopolitical contexts (Bavin et al., 2020) and adopt realistic, adaptive strategies (Ehrenfeld, 2000). It is also essential to allow natural succession to play a role whenever possible, which requires sophisticated planning, flexible management responses, multiple alternative target states, strong progress indicators, and long-term monitoring (Halle, 2007).

One objective missing from this survey relates to improving both ecological and economic efficiency of restoration strategies. According to Palmer et al. (2005), this should be a central goal for scientists, practitioners, and managers working in river restoration.

Overall, the leading motivation for restoration measures (I.4.1) (Fig. S3) was addressing the primary degradation factor affecting each river, followed by legal requirements, availability of funding, and public demand or safety concerns. Again, results showed clear differences between groups ($Chi^2 = 95.9$; $p < 0.05$), indicating that restoration motivations are country-specific.

Pairwise and three-country analyses revealed potentially interesting similarities. For example, Germany and Spain showed a p-value close to the significance threshold (0.05), suggesting a potentially shared reasoning that would merit deeper investigation.

Unlike this study, Hassett et al. (2007) were able to differentiate between primary and secondary objectives because their survey focused on specific restoration projects. Therefore, future research could explore this level of detail in the participating countries.

The selection of primary restoration measures (I.8) (Fig. S7) was based mainly on expert knowledge across all countries, without standardized processes, followed by identification of primary stressors through standardized procedures. In general, diagnostic processes vary between countries, mixing expert-based assessment and standardized methods. A lack of standardization may signal the need for more uniform procedures to improve restoration outcomes.

Diagnostic procedures used (I.8.1) primarily relied on expert knowledge, as respondents cited meetings with managers, field visits, and consultancy reports (see Annex). Empirical indicators were also employed, such as ecological status, habitat characterization, preliminary studies, standardized procedures mandated by regulatory agencies, connectivity analyses, water quality mapping, feasibility studies, and habitat analysis methodologies.

This emphasizes the importance of well-trained and informed professionals, high-quality and up-to-date information flows, and strong ecological and restoration process literacy. Thus, assessing the degradation level prior to any intervention is essential (Halle, 2007).

Knowledge of stressors is based on habitat understanding, expert knowledge, and standardized processes, though these vary by country. This highlights the importance of adapting methodologies and restoration measures to the unique characteristics of each ecosystem.

Diagnostic processes for river restoration vary significantly across countries, ranging from standardized, detailed assessments to expert-based evaluations and GIS analyses. This variability underscores the need to adapt diagnostic approaches to regional conditions and priorities to ensure the effectiveness of restoration measures.

3.3 Evaluation

This section analyzes the results from Block IV questions, addressing monitoring and evaluation of restoration projects through success indicators and the factors that hinder success.

Popular restoration practices require rigorous scientific evaluation in order to determine whether such efforts lead to the desired ecological outcomes (Hobbs, 2007). For this reason, respondents were asked whether success indicators were explicitly stated in project proposals (IV.1). The majority responded affirmatively, with 61.97% confirming their use. This pattern was consistent across all countries except Spain (Fig. S8).

The indicators used (IV.1.1) varied among countries, reflecting differing approaches (see Annex). At a detailed level, Brazil showed a broad range of success indicators with a strong focus on improving biodiversity, water quality, infrastructure, and community participation. In contrast, Germany emphasized ecological and structural improvement, restoration of natural river dynamics, species conservation, and stakeholder acceptance. Sweden placed more weight on the creation of natural habitats, compliance with the Water Framework Directive, and improvement of conditions for aquatic fauna. Spain focused primarily on riparian vegetation restoration, ecological flow establishment, improvement of fish habitats, and invasive species control.

These patterns suggest that success criteria are closely linked to each country's sociopolitical and environmental context, including available resources and priority needs.

Some studies recommend that funding agencies encourage or require collaboration with scientists, particularly during monitoring and evaluation stages (Dickens & Suding, 2013). This would improve both monitoring design and budget allocation, ensuring sufficient resources for evaluation. For certain organizations, restoration is only possible thanks to the dedication of committed volunteers (Dickens & Suding, 2013). The general lack of systematic and objective evaluation of completed projects poses a challenge for advancing restoration science (Kondolf et al., 2007). For projects lacking measurable criteria, it becomes difficult to guide restoration actions without a clear path of objectives or mechanisms to assess progress (Palmer et al., 2005).

Stakeholders emphasized the importance of incorporating local knowledge and community participation in the restoration process. However, many projects struggled to achieve long-term sustainability and resilience, often requiring ongoing maintenance and intervention (Bernhardt et al., 2007; Palmer et al., 2005).

A unified perspective on how to achieve restoration success has not yet been established (Palmer et al., 2014). Nevertheless, to determine whether success has been achieved, empirical evidence is essential—hence the need to use success indicators. In terms of what led projects to succeed (IV.1.2), respondents generally highlighted positive improvements in ecosystem services, followed by beneficial effects on fish, biodiversity, and vegetation, and finally positive impacts on humans (Fig. S9). Among the additional criteria that did not fit predefined categories were several references to long-term objectives and outcomes, recovery of habitats and processes, and mitigation of global change impacts. It is important to note that, for a project to be considered successful, it must be guided by a clear vision, use rigorous evaluation methods, and produce measurable ecological improvements (Bernhardt et al., 2007; Palmer et al., 2005).

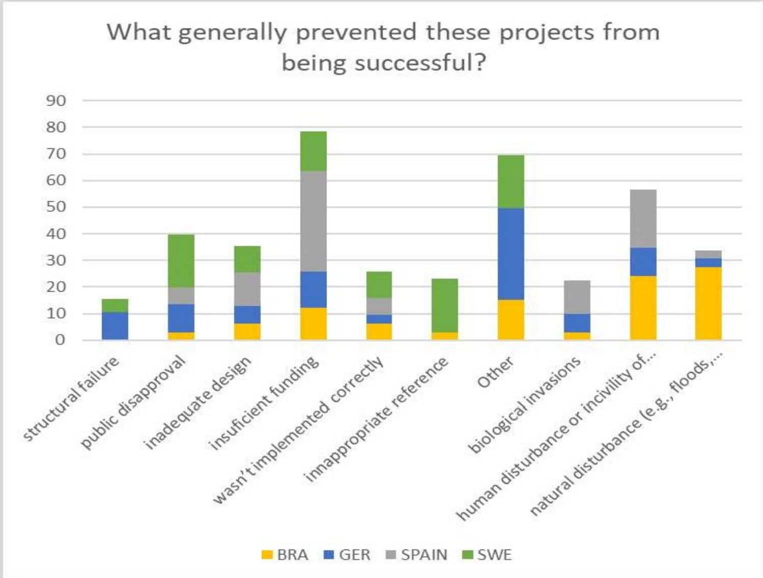

Figure 7: Factors hindering project success expressed as percentage values by country and response category.

The main factors that contributed to project failure (IV.2) varied among countries; however, insufficient funding and human or natural disturbances emerged as common impediments that negatively affect the success of river restoration efforts (Figure 7). It is important to highlight that limited financial resources was a frequently cited factor in all countries, followed by inadequate project design and public disapproval.

However, statistical testing showed that these similarities were not statistically significant. The Chi-square test results ($Chi^2 = 69.048$, $df = 37$, $p < 0.05$) indicated that these limiting factors differ significantly among countries. Similarly, pairwise and three-country comparisons revealed that only the comparison between Sweden and Germany (p-value > 0.05), as well as Germany versus Brazil (p-value > 0.05), showed no statistically significant differences. Some other p-values were above 0.01, so the results remain inconclusive and require deeper exploration. Due to small sample sizes and the high number of response categories, statistical outcomes may be affected by sample-size limitations.

It is crucial to consider the limiting factors affecting restoration success and identify ways to improve restoration outcomes globally. Restoration ecologists must learn from the lessons (both successes and failures) of related fields, including community ecology (Weiher, 2007). A much greater effort is required to compile and disseminate information on restoration methods and outcomes (Palmer et al., 2005).

Regarding proposed improvements (IV.3), respondents emphasized project design, funding, and public participation (Fig. S10). Spain especially highlighted the need for monitoring and project management, Brazil emphasized public involvement, and Sweden focused on implementation and staffing.

Research supports the need for future studies to rigorously evaluate the effects of management and restoration practices on stream ecosystems, establish cause–effect pathways from human disturbances to biological communities, and incorporate analyses of scale effects, land-use heterogeneity, and high temporal hydrological variability (Cooper et al., 2013).

3.4 Indicators of success

Success in restoration must be evaluated in multiple ways, using empirical indicators of river or stream condition, as well as metrics related to aesthetics, protection of nearby infrastructure, and increased opportunities for recreation and community education about rivers (Palmer et al., 2005). Success indicators vary according to restoration objectives and should be easily measurable, sensitive to system stress, able to demonstrate predictable responses to stressors, and integrative in nature (Palmer et al., 2005).

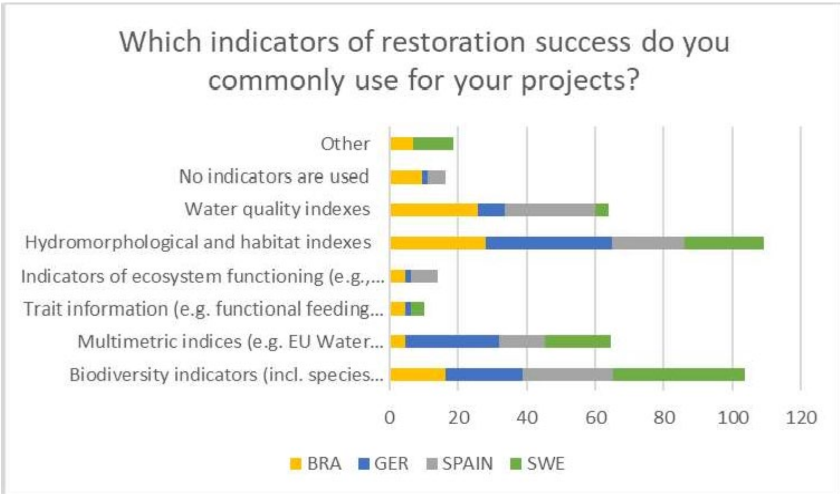

Figure 7: Indicators of success expressed as percentage values by country and response category.

To complement the information from the literature, respondents were asked about the main success indicators used in their projects (V.1). The results showed that hydromorphological and habitat indices were the most commonly used, followed by biodiversity indices, multimetric indices, and water quality indicators (Fig. S8). The least frequently used indicators were physicochemical information and ecosystem functioning metrics.

Sweden was the only country in which none of the respondents indicated that success indicators were not used. Germany stood out for its high use of multimetric indices, hydromorphological and habitat indices, as well as biodiversity indicators.

Additional indicators that did not fit into any of the predefined categories included: physical indicators, reforested area, carbon capture estimates, aesthetic indicators, kilometers of reopened streams, increase in wetland area, growth in fish populations, presence of sensitive species (such as freshwater mussels or otters), flood mitigation, and additional reflections on the adaptation of indicators to river types (see Annex).

Overall, 66.20% of respondents believed that a project could be successful even if the indicators did not show measurable improvements, while 30.92% believed that this was not possible, and 2.8% indicated that no indicators were used (V.2) (Fig. S11).

The indicators most likely to show success not reflected in the ecosystem were biodiversity indicators, multimetric indices, water quality indicators, and responses classified as “other” (V.2.1) (Fig. S12). Similar to earlier questions, these responses reveal a perception that some restoration processes may take longer to show measurable outcomes, that some respondents were unsure how to answer, and that success may be interpreted through alternative biodiversity or process-oriented signals.

Respondents were asked whether they had the tools to assess premature success (V.3) (Fig. S13), as well as whether they would like to know about premature success indicators (V.3.1). The majority answered “yes” or “partially” (Fig. S14). Sweden stood out, as most responses indicated “partially” (81.82%) and none stated they lacked the tools. Most respondents also expressed interest in learning about premature success indicators.

Other indicators mentioned included the need to quantify restored area, colonization efficiency, reproductive strategies of fish species, macrophytes, functional groups, multimetric indices, groundwater levels, fish biodiversity assessed through electrofishing, metabolic and nutrient retention indicators, as well as various continuous monitoring activities (see Annex). These results show that traditional physicochemical indicators coexist with more process-based indicators, such as functional traits and ecosystem metabolism.

Project managers often cite improvements in the physical appearance of the river and positive public perception as measures of success, rather than focusing on measurable ecological outcomes (Bernhardt et al., 2007). In general, measurements should be conducted over longer time periods and across all sites to improve analysis, since respondents noted that ecological processes progress slowly and require repeated measurements at a temporal scale much longer than what is typically used.

These results highlight the need to establish standardized criteria for premature success indicators along with implementation guidelines, allowing practitioners to understand and apply them effectively.

Respondents were asked whether current assessment tools consider ecosystem services from both a structural and a functional perspective (V.4). Most participants in all countries stated that they lack the necessary tools to properly evaluate ecosystem services, although German responses were more evenly distributed (Fig. S15).
German respondents emphasized the need for a broader, goal-oriented perspective beyond single species or specific habitat features. Swedish respondents noted that indicators are often based on standardized methods (such as those used under the Natura 2000 framework), and that the focus remains on services rather than functions, often with an anthropocentric emphasis.

The main impediments to applying ecosystem functioning indicators (V.5) were the complexity involved, followed by lack of understanding, lack of methodology, and lack of precedent (Fig. S16). Only a minority of respondents expressed doubt about the usefulness of these indicators. The second most common response was that ecosystem functioning indicators were already being used in some cases.

Monitoring can provide quantitative documentation of ecosystem responses to restoration efforts; however, in some cases it may be a long and costly process (Hassett et al., 2007).

4. Conclusions and future perspectives

The methodology used for this work allowed us to analyze the current state of river and stream restoration across four countries that differ substantially in both environmental and sociopolitical context. To assess the progress of this phase of the RESTOLINK project within the time constraints of a master's thesis, we focused our analysis on three survey blocks, with particular emphasis on restoration objectives, success indicators, and project evaluation.

Overall, the uneven and limited participation among countries represents a major constraint, as it resulted in a lack of representation for certain professional categories and project roles, restricting the scope of analyses. Nevertheless, despite these limitations, it was possible to obtain valuable preliminary insights and generate a broad overview of the growing field of river and stream restoration.

We can conclude that the responses captured a wide range of professional experience, likely associated with role type and years working in the field. Future studies could explore the relationships between the number of projects, years of experience, and professional category to identify patterns in career development and project scope.

The analysis of project design and implementation reveals a generalized trend toward outsourcing restoration design to private contractors, particularly in Spain and Brazil, although public institutions still play a central role. This reinforces the importance of strengthening cooperation between research institutions, private companies, and public authorities to ensure horizontal knowledge exchange and alignment of objectives. This could be supported through established policy instruments and professional frameworks, such as the Open Standards methodology or the Priority Action Framework (PAF).

Because the restoration objectives analyzed here reflect the general professional trajectory of participants, future research should focus on evaluating specific restoration projects, linking objectives to outcomes and success indicators. The most frequently cited objectives were broad and integrative ones, such as habitat recovery, channel reconfiguration, improved hydrological connectivity through fish passages, and dam removal. The differences observed among countries are likely influenced by social, environmental, economic, political, and cultural factors. Ecological degradation was consistently identified as the primary driver of intervention, with decision-making grounded in expert knowledge of stressors.

In general, success indicators are commonly used, although the type varies among countries. The most prevalent were water quality and habitat-based indices, along with innovative process-based indicators such as ecosystem metabolism. Respondents emphasized the need for standardization and harmonization among success indicators to improve interpretation and cross-country comparisons. They also highlighted the necessity of long-term monitoring, as ecological improvements are often gradual. Therefore, a coordinated national monitoring strategy for a subset of restoration projects is recommended to support evidence-based management.

Successful outcomes were mainly associated with improvements to ecosystem conditions, biodiversity, understanding of biomes, and ecosystem services. These findings indicate that ecological structure and function should be the primary domains represented in success indicators.

Although each country faces challenges specific to its environmental and sociocultural context, limiting factors such as insufficient funding, human and natural disturbances, inadequate project design, and lack of community support were commonly reported. Statistical analyses suggested potential similarities among certain countries (e.g., Germany with Sweden; Germany with Brazil), indicating a need for deeper investigation. In any case, understanding limiting factors is essential for improving future projects and learning from both successes and failures.

Respondents proposed extensive improvements, particularly regarding project design, funding, public participation, monitoring, and management. Given the financial limitations highlighted, funding agencies should revise their criteria to encourage more informed and accountable processes for restoration planning and evaluation.

There is a widespread perception that current evaluation tools are insufficient to measure all relevant aspects of restoration effectiveness. Respondents expressed an urgent need to improve these tools, underscoring the global importance of developing or adopting new evaluation approaches that enhance restoration success.

A critical finding was the disconnect between indicator use and their intended purpose: many respondents felt that a project could be successful even if success indicators failed to demonstrate improvement. This reflects the slow pace of ecological change and the fact that monitoring often ends before effects become detectable. Premature success indicators—widely referenced but not well understood—are therefore essential. These include readily measurable components such as restored area, biodiversity, colonization efficiency, nutrient retention, and ecosystem metabolism. This study demonstrates the need to recognize restoration as a long-term process and to establish clear guidance for the use of indicators, enabling better monitoring, comparability, and long-term evaluation. Such guidance must emerge from collaboration between academic scientists, government agencies, and practitioners, ensuring the greatest ecological benefits at the lowest feasible cost. Regulatory requirements could also mandate monitoring using standardized indicators.

Evaluation of ecosystem services is currently limited by a lack of holistic vision, standardization, and methodological precedents, as well as anthropocentric bias. Most respondents expressed a clear need to broaden the scope of assessment tools.

The research process itself presented several challenges and limitations. Many potential interview candidates did not respond to invitations despite several attempts, leading to a sample influenced by professional accessibility and existing networks. Furthermore, because interviews focused on overall professional experience rather than specific projects, the resulting data represent perceptions rather than objectively documented outcomes. Future studies should therefore incorporate project-level analyses to complement these findings. Despite these limitations, the methodology enabled valuable engagement with stakeholders across professional sectors. We recommend its continued use as an effective approach for understanding the restoration field, strengthening relationships between science and practice, and promoting more collaborative decision-making. The next step is to determine how scientific research can better support practitioners by actively listening to their needs.

Time constraints also posed a limitation, as international collaboration slows data acquisition. Survey responses were finalized in June 2024, leaving limited time for analysis. In future phases, a sociological approach led by an interdisciplinary team—incorporating in-depth interviews and focus groups—would enable stronger contextualization of restoration practice and deeper understanding of the challenges faced by diverse professional groups. Including actors involved in implementation, such as field technicians, would provide a more comprehensive perspective. Adding gender identity variables would also strengthen equity and representation in the analysis.

Future efforts may focus on a more regional scope, such as the Catalan-speaking territories, where proximity to practitioners and ecosystem characteristics could support a more comprehensive study that remains scalable and comparable across restoration contexts.

Finally, multivariate analysis could expand the interpretive value of the results. Preliminary analyses suggest that several interacting factors—such as experience, organizational role, and professional sector—shape restoration approaches, beyond national ecosystem characteristics. A multivariate approach would help identify the most influential variables and could be applied to broader restoration contexts, highlighting strengths and weaknesses across the field and supporting development of clearer criteria for large-scale, multi-ecosystem restoration planning. Such analysis could ultimately contribute to a more global and integrated understanding of restoration science and practice.

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Annexes

Questionnaire

QUESTIONNAIRE (final version, last update 28/June/2023)

PERCEPTION OF STAKEHOLDERS ON RIVER RESTORATION INITIATIVES

You are being invited to participate in the questionnaire "*Perception of Stakeholders on River Restoration Initiatives*". This questionnaire was adapted from the original version produced by Bernhardt et al. (2007) (https://doi.org/10.1111/j.1526-100X.2007.00244.x). The survey among different stakeholders on river restoration initiatives is part of the transnational RESTOLINK project (*Quantifying restoration success across biomes by linking biodiversity, multifunctionality and hydromorphological heterogeneity*). This project is conducted by researchers from the Helmholtz Centre for Environmental Research (UFZ - Germany), University of São Paulo (USP - Brazil), University of Koblenz-Landau (UKL – Germany), University of Barcelona (UB – Spain), and Umeå University (UmU – Sweden). The primary goal of this project is to develop a novel mechanistic framework for quantifying restoration success that interlinks hydromorphological heterogeneity at relevant spatial scales with multi-group biodiversity and essential ecosystem functions. This new framework will advise managers on selecting the most effective restoration measures on ecologically relevant scales. Your participation is very important because it will help us better understand the main characteristics, potential challenges, and stakeholders' perception on previous river restoration initiatives in each country.

Why are you being invited to participate?

We invited you because you are a relevant stakeholder involved with river restoration efforts, and we believe you have the knowledge to help us with this assessment.

What is the questionnaire like and how long will it take to complete it?

This questionnaire is divided into five sections, each with questions allowing you to select one or more answers about the restoration projects' design, implementation, coordination, monitoring, and evaluation. We will conduct a phone interview with you and we estimate it will take approximately 30 minutes to respond to all questions. We are sharing the questions with you before the interview so you can see all the content in advance.

Are you required to participate?

Your participation in this study is entirely voluntary. There are no foreseeable risks associated with this project. However, if you are uncomfortable answering a question, you may leave the survey at any time without giving us a reason.

What will happen to the results of this questionnaire?

We will not request any personal information from you, only the name of the company and the position you hold. Such personal information will be kept strictly confidential. The collected data will be reported only in a grouped form and for solely scientific purposes. Personal or confidential information shared here will not be included in final reports or manuscripts.

We adhere to all of the ethics, privacy, and data management guidelines recommended by each partner country's research agencies. If you want to learn more about them, you can do so at any time during this survey.

If you have any further questions about the research or the methodology used, please contact Dr. Mario Brauns in Germany (mario.brauns@ufz.de), Dr. Davi Cunha in Brazil (davig@sc.usp.br), Dr. Ryan Sponseller in Sweden (ryan.sponseller@umu.se), or Dr. Daniel Von Schiller in Spain (d.vonschiller@ub.edu).

Thank you so much for your time and support.

By agreeing to participate, you declare that you have read and agree with the information above and that you voluntarily accept to participate in the research and answer the questionnaire.

QUESTIONNAIRE
PART I – GENERAL INFORMATION/CHARACTERIZATION
PART II – PROJECT DESIGN, IMPLEMENTATION AND COORDINATION PART III – MONITORING
PART IV – EVALUATION
PART V – SUCCESS INDICATORS

Questions were extracted (with some adaptations and additions) from the NRRSS (National River Restoration Science Synthesis, United States) interview form (Bernhardt et al. 2007 *Res. Ecol.* 15:482-493).

PART I – GENERAL INFORMATION/CHARACTERIZATION

1) Which institution are you
from? o research
institute
o public authority (which level? Federal, state, city...) [TEXT] _______________
o NGO
o consultancy office
o university
o other [TEXT] __________________

2) For how many years have you been involved with restoration projects throughout your career?

____________years (number)

3) Please provide an estimation of the number of restoration projects/initiatives you were involved with throughout your career.

____________projects (number)

For ALL the next questions, please consider your experience in the last TEN YEARS. If you have been involved with restoration for <10 years, please consider the whole period. Please pay attention to the MAXIMUM NUMBER of selected responses allowed for each question.

4) What were the main measures of river/stream restoration projects you were involved with? See text in bold with further details/definitions for each category. Please tick UP TO FIVE boxes (most relevant goals).

- o Aesthetics/Recreation/Education

    Activities that increase community value: use, appearance, access, safety, knowledge, and environmental education

- o Bank Stabilization

    Practices designed to reduce/eliminate erosion/incision or slumping of bank material into the river channel. This category DOES NOT include stormwater management, see next intent category

- o Channel Reconfiguration

    Restoration of the layout of the river channel, modification of channel plan form or longitudinal profile and/or daylighting (converting culverts and pipes to open channels). Includes stream maeander restoration and in-channel structures that alter the thalweg of the stream

- o Dam Removal/Retrofit

    Removal of dams and weirs or modifications/retrofits to existing dams to reduce negative ecological impacts. Excludes dam modifications that are simply for improving Fish Passage (see next category)

- o Fish Passage

    Removal of barriers to upstream/downstream migration of fishes. Includes the physical removal of barriers and also construction of alternative pathways. Includes migration barriers placed at strategic locations along streams to prevent undesirable species from accessing upstream areas

- o Floodplain Reconnection

    Practices that increase the flood Frequency of floodplain areas and/or promote flux or organisms and material between riverine and floodplain areas

- o Flow Modification

    Practices that alter the timing and delivery of water quantity (DOES NOT include stormwater management). Typically, but not necessarily associated with releases from impoundments and constructed flow regulators

- o In-stream Habitat Improvement

    Modifying structural complexity to increase habitat availability and diversity for target organisms and provision of breeding habitat and refugia from disturbance and predation. (In some cases, habitat improvement may be an action with the intent of In-stream Species Management; in Other cases, Habitat Improvement may be the intent and might be accomplished through Channel Reconfiguration; be very careful to separate action from intent when deciding whether to select this category

- o In-stream Species Management

Practices that directly alter aquatic native species distribution and abundance through the addition (stocking) or translocation of animal and plant species and/or removal of exotics. Excludes physical manipulations of habitat/breeding territory (see In-stream Habitat Improvement)

o Land Acquisition

Practices that obtain lease/title/easements for streamside land for the explicit purpose of preservation or removal of impacting agents and/or to facilitate future restoration projects. Note: Simple Purchase and preservation to prevent potential future land conversion are insufficient. Projects should demonstrate intended or actual cessation of detrimental activities in acquired land or active restoration components

o Management of waterborne diseases

Actions that prevent waterborne diseases through drinking water and contact with contaminated water, such as riparian reforestation to prevent diffuse contamination, habitat modification to prevent intermediate host proliferation, and water quality improvement focusing on waterborne diseases

o Riparian Management and restoration

Revegetation of riparian zone and/or removal of exotic species (e.g., weeds, cattle). Excludes localized planting Only to stabilize back áreas (see Bank Stabilization)

o Stormwater Management

Special case of flow modification that includes the construction and management of structures (ponds, wetlands, and flow regulators) in urban areas to modify the release of storm run-off into waterways from watersheds with elevated imperviousness into waterways. These practices/structures generally aim to reduce peak flow magnitudes and extend flow duration. Stormwater management here refers to water quantity not quality. Urban sediment, litter, and temperature control should be categorized as Water Quality Management

o Water Quality Management

Practices that protect existing water quality or change the chemical composition and/or suspended particulate load. Remediation of acid mine drainage falls into this category as does Combined Sewer Overflow separation. Excludes urban runoff quantity management (see Stormwater Management)

o Climate change mitigation

Measures taken specifically to increase the resilience of watercourses to climate change impacts (as drought or floods).

4.1) Why were these measures (pointed in the last question) the main ones? Please tick UP TO TWO boxes.

o greatest factor influencing river degradation

o legal requirements

o focus for which funding was available

o public demand and/or safety

o problem that could be most easily addressed

o other? [TEXT] __________________

What role did you play in restoration projects? Please tick UP TO TWO boxes.

o manager/coordinator

o consultant

o designer

o implementer

o evaluator

o funder

o other? [TEXT] __________________

5) Who designed the projects? Please tick UP TO THREE boxes.

o Private contractor

o City/county agency

o Local or regional authority (e.g., Conservation District, Water Management Authority)

o State agency

o Federal agency

o Volunteers

o Non-governmental/Not for profit organization

o University

o other? [TEXT]__________________

6) Who implemented the projects? Please tick UP TO THREE boxes.

o Private contractor

o City/county agency

o Local or regional authority (e.g., Conservation District, Water Management Authority)

o State agency

o Federal agency

o Volunteers

o Non-governmental/Not for profit organization o other? [TEXT] __________________

7) Restoration measures can only be successful if the the stressors are tackled. Were the restoration measures based on a proper diagnosis of the the stressors?

o Yes, all major stressors were known based on a standardized procedureWe believe that the major stressors were known (expert knowledge, but no standardized assessment procedure)
o No, we are unsure if we really tackle all stressors by our restoration measures
o Other answers? [TEXT]

8.1) If yes, please give diagnosis procedures [TEXT]____________________

PART II – PROJECT DESIGN, IMPLEMENTATION AND COORDINATION

1) What factors led to the prioritization of these sites over other possible restoration sites? Please tick UP TO THREE boxes.

o funds available
o public interest
o scientific interest
o ecological concerns
o infrastructure concerns
o legal requirements
o in watershed plan
o recreation
o land availability
o other [TEXT] __________________

1.1) Which of these factors was the most important?_______________________

2) What was the most important expected benefit after the project implementation? Please tick ONLY TWO boxes.

o Hydromorphology recovery
o Biodiversity improvement
o Ecosystem functioning improvement
o Flood control
o Landscape improvement

- o Ecosystem services improvement
- o Other (e.g., aesthetics, social/emotional acceptance or recovery of a forgotten/lost space) [TEXT] ___

3) What guideline was used in creating and evaluating the design plan that was selected? Please tick UP TO TWO boxes.

- o Manual/Book/Report/Government agency guidelines. Which ones specifically?____
- o Peer-reviewed journal
- o Models or project site analysis
- o Individuals (If so, what area(s) of expertise?)
  - o Hydrology
  - o Biology
  - o Ecology
  - o Geomorphology
  - o Engineering
  - o Other: [TEXT]
- o Past and local experience from the interviewee
- o Other

PART III – MONITORING

1) Did your organization or some other entity collect specific monitoring data to these projects in in order to evaluate further the restoration initiative? [Yes/No]_

1.1) If no, what constraints prevented you from collecting data in order to evaluate the restoration projects? Please tick UP TO TWO boxes.

- o Lack of funding
- o Personal (lack of people power or staff time and/or not hired to do data collection
- o Equipment (lack of materials needed for data collection and/or lack of technology or expertise for data analysis)
- o No suitable method available
- o Not part of my organizational mission
- o Lacking knowledge how to design appropriate monitoring
- o Other [TEXT]________________

1.2) In any case, what would you have monitored if there had been no restrictions? Please tick UP TO THREE boxes.

o physical variables

o hydromorphological variables

o chemical variables

o biological variables (including biodiversity indicators)

o photo monitoring (including satelite/drone imagery)

o ecosystem functioning (e.g., organic matter decomposition, nutriente uptake)

o ecosystem services

o no interest

o other [TEXT]________________

If yes, what enabled your team to monitor these projects? Please tick UP TO THREE

o Pursuit of other additional sources of funding

o Funding mandate

o Local volunteer interest

o Interested expert

o Academic researcher involvement

o Ongoing regional effort (e.g., watershed management plans)

o Legal requirement

o Personal commitment

o Existing monitoring method

o Monitoring already installed

o Other [TEXT]________________

PART IV – EVALUATION

1) Were success criteria explicitly stated in the projects' design plan? [Yes/No] _________

1.1) If yes, what were they?____________[TEXT]

1.2) What generally made these projects successful? Please tick UP TO TWO boxes.

o Overall positive effects on riverine ecosystem services

o Overall positive effects on fish, wildlife, plantsPositive effects on human community

- o Increased understanding of river systems
- o Other criteria [TEXT]____________________________
- o The project was not successful

2) What generally prevented these projects from being successful? Please tick UP TO THREE boxes.

- o biological invasions
- o structural failure
- o public disapproval
- o human disturbance or incivility of human actions (e.g., vandalism)
- o natural disturbance (e.g., floods, extreme weather events)
- o inadequate design
- o insuficient funding
- o no increase in measures of success
- o wasn't implemented correctly
- o inappropriate reference
- o other [TEXT]___________

3) If you had the opportunity, what changes, if any, would you make to any aspects of these projects? Please provide further details. Please tick UP TO THREE boxes.

- o Partners/team/personnel (technical expertise, input from scientists)
- o Project management process (as opposed to the particular players in the previous bullet)
- o Funding and associated requirements
- o Design process
- o Implementation process
- o Monitoring
- o Evaluation
- o Public involvement
- o Other? [TEXT]_______________

PART V – SUCCESS INDICATORS

1) Which indicators of restoration success do you commonly use for your projects? Please tick UP TO THREE boxes.

- o Biodiversity indicators (incl. species diversity indices, community composition)
- o Multimetric indices (e.g. EU Water Framework Directive)
- o Trait information (e.g. functional feeding groups)
- o Indicators of ecosystem functioning (e.g., aquatic metabolism, nutrient uptake, leaf litter decomposition, stable isotopes, food web metrics)
- o Hydromorphological and habitat indexes
- o Water quality indexes
- o No indicators are used
- o Other [TEXT]______________________

2) Do you think that a restoration project can be successful but the indicators failed to assess this?

o Yes

o No

2.1) If yes, for which indicators would this be most likely the case? [TEXT]______

3) Ecosystem restoration often takes time, but it is useful to document success already by early indicators, e.g. of communication of measures to be adjusted. Do you have the proper tools to evaluate early success?

- o Yes
- o No
- o Partially

3.1) If not, would you like to see such early success indicators? o Yes

o No

Comments? Please provide early success Indicators if available [TEXT]______________

4) Ecosystem services are indicated by both ecological structures (e.g., community composition etc.) and functions (e..g., metabolism, food web processes). Do you feel that both aspects are properly tackled by your evaluation tools?"

- o Yes
- o No

Comments? [TEXT]_______________If not, what impedes the application of indicators of ecosystem functioning in your restoration projects? Please tick ONLY ONE box.

o Don’t know exactly what this is

o No suitable method available

o Too complicated/laborious

o Cannot be connected to existing/previous assessments

o I do not believe that functional indicators work

o Indicators of ecosystem functioning have been applied in the projects I have been involved with. Please name them [TEXT]_______________

PART VI – CLIMATE CHANGE

1) How many restoration projects have you accompanied/implemented that were primarily concerned with reducing the negative impacts of climate change? [NUMBER] ___

2) Which direct effects of climate change have been addressed with the restoration measure(s)? o Flood

o Drought incl. drying

o Temperature increase

o Other: [TEXT]________________

o I have not yet accompanied/implemented any climate change relevant projects.

3) Do current hydromorphological reference conditions sufficiently take into account the effects of climate change on the success of restoration?

o Yes

o No

3.1) If not, how could hydromorphological reference conditions be adapted to adequately take climate change into account? [TEXT]__

4) Do current biological reference conditions sufficiently take into account the effects of climate change on the success of restoration?

o YesNo

4.1) If not, how could biological reference conditions be adapted to adequately take climate change into account? [TEXT]_______

5) Do you feel methodically capable of accompanying/implementing climate change-specific restoration projects?

o Yes

o No

5.1) If not, what would be needed to accompany/implement climate change-specific restoration projects?

o Specific handouts (manuals, guidelines)

o Closer cooperation with scientific institutions

o Overview of the state of knowledge

o Models of how measure will develop under different climate scenarios

o Other assessment methods

o Others

Questionnaire item types

The following table presents the questions and subsections, along with the corresponding question type for each.

Table: Types of questions in the questionnaire.

Part	Question number	Yes/No	Num.	Text	One option	Multiple options			Optional text
						2	3	5	
Part I	1				X				X
	2		X						
	3		X						
	4							X	
	4.1					X			X
	5					X			X
	6						X		X
	7						X		X
	8				X				X
	8.1			X					
Part II	1						X		X
	1.1			X					
	2					X			X
	3					X			X
Part III	1	X							
	1.1					X			X
	1.2						X		X
	1.3						X		X
Part IV	1	X							
	1.1			X					
	1.2					X			X

Part	Question number	Yes/No	Num.	Text	One option				Question number
						2	3	5	
	2						X		X
	3						X		X
Part V	1						X		X
	2	X							
	2.1			X					
	3				X				
	3.1	X							X
	4	X							
	5				X				X
Part VI	1		X						
	2				X				X
	3	X							
	3.1			X					
	4	X							
	4.1			X					
	5	X							
	5.1				X				

Graphs reresenting the data

The following section includes the data figures that were not incorporated into the main body of the text. The figures are organized by survey block and include the corresponding question number and wording, as well as the open-ended responses.

Block I

Fig. S1: Which institution are you from?

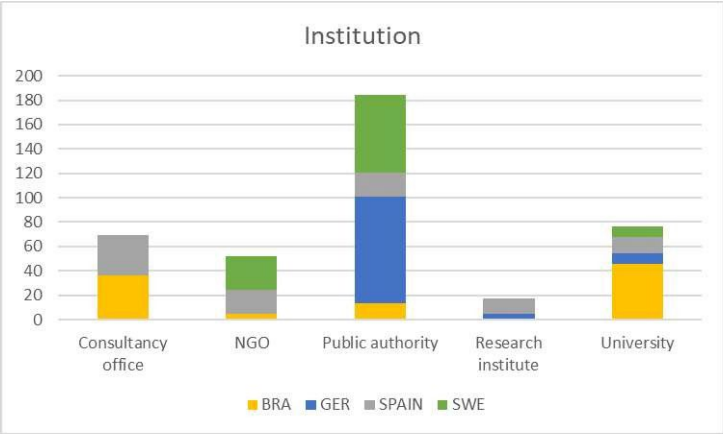
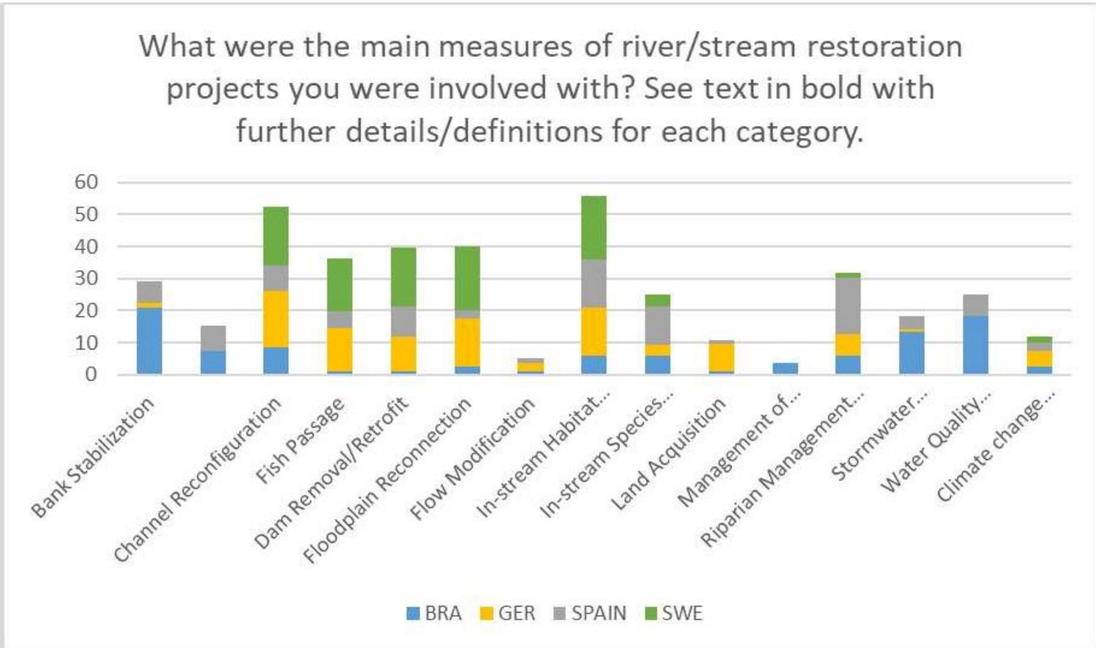


Fig. S2: What were the main measures of river/stream restoration projects you were involved with? See text in bold with further details/definitions for each category.



Main reasons:

- Bank Stabilization
- Aesthetics/Recreation/Education
- Channel Reconfiguration
- Fish Passage
- Dam Removal/Retrofit

- Floodplain Reconnection
- Flow Modification
- In-stream Habitat Improvement
- In-stream Species Management
- Land Acquisition
- Management of waterborne diseases
- Riparian Management and restoration
- Stormwater Management
- Water Quality Management
- Climate change mitigation

Fig. S3: Why were these measures (pointed in the last question) the main ones?

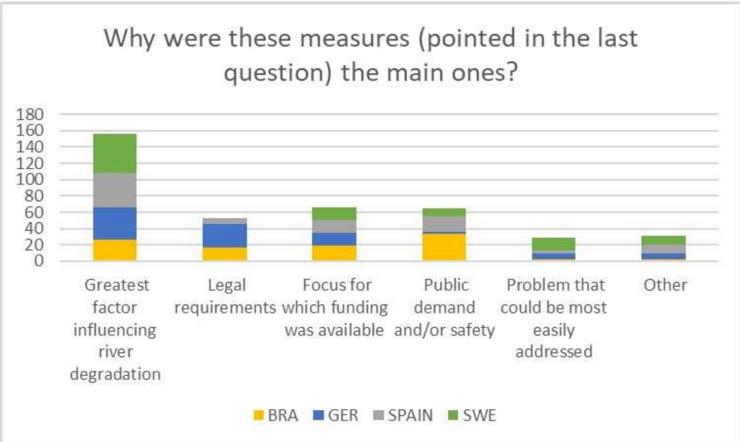


Fig. S4: What role did you play in restoration projects?

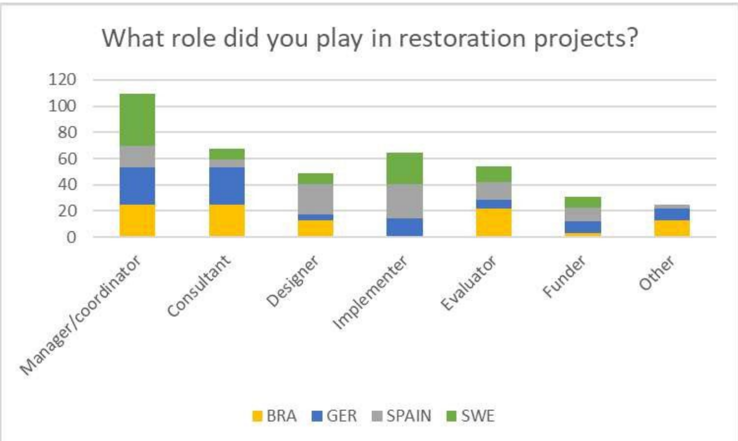


Fig. S5: Who designed the projects?

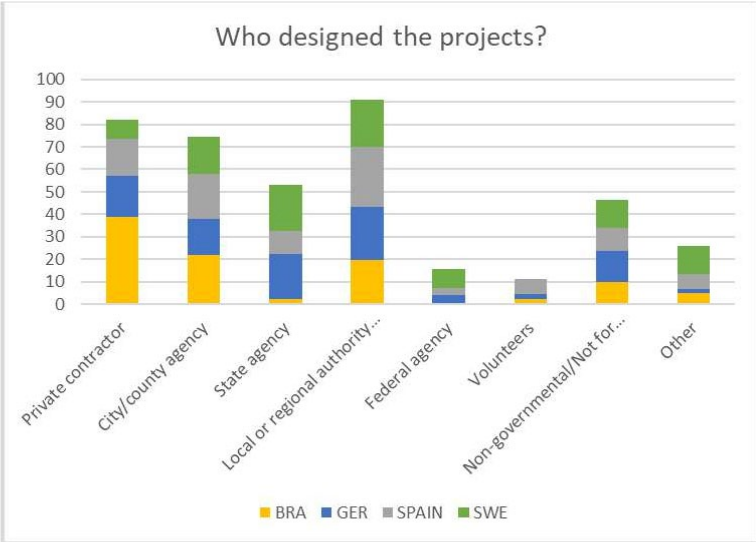


Fig. S6: Who implemented the projects?

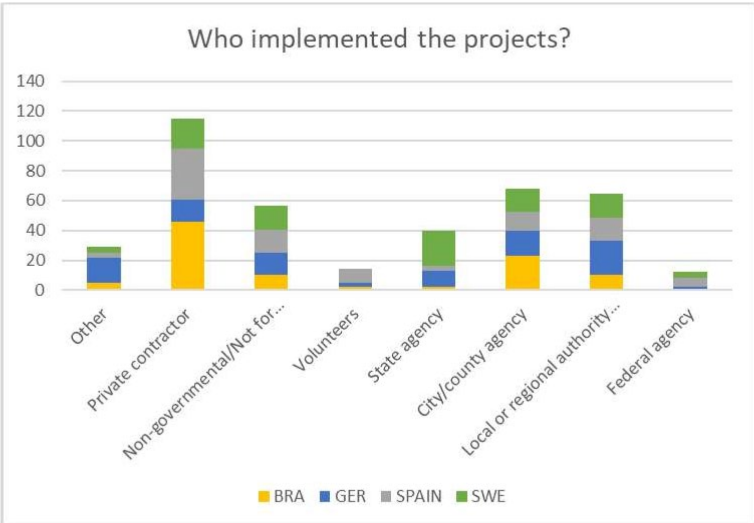
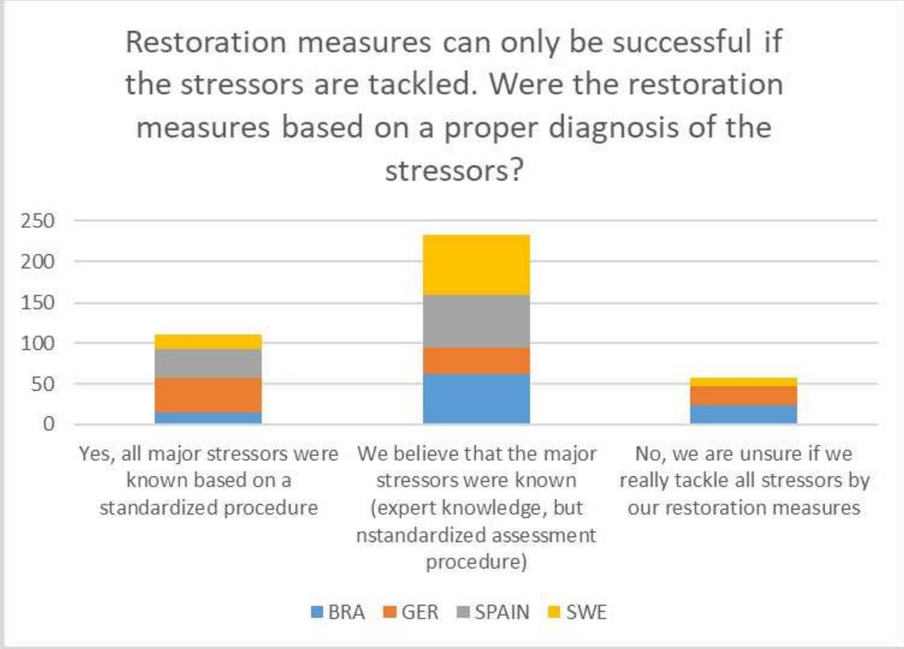


Fig. S7: Restoration measures can only be successful if the stressors are tackled. Were the restoration measures based on a proper diagnosis of the stressors?



Text answers:

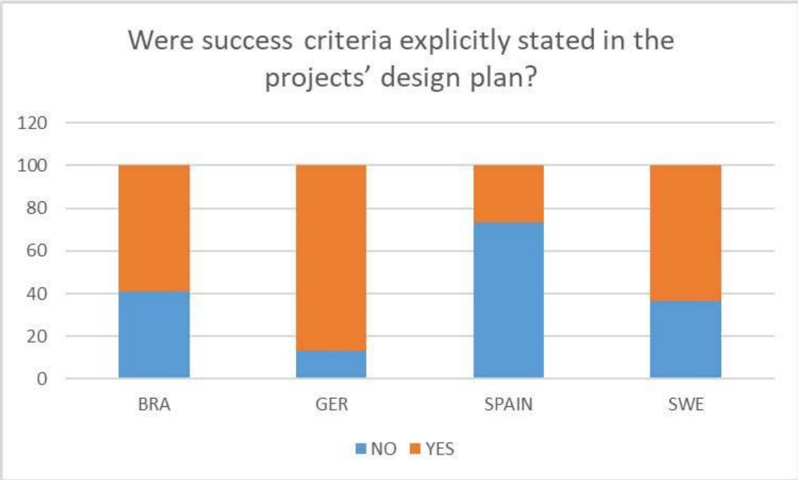
- Data from the WFD monitoring programs
- Important is also identify how these stressors interact with each other and in what hierarchical order. Some stresses are also independent and can be done without consider such relations.

8.1 - If yes, please give diagnosis procedures

- Diagnosis of the basin, which took into account the amount of water produced, number of springs and conditions of the riparian forest.
- Diagnosis of the recovered section with the implementation of structural techniques, such as physical/chemical water quality parameters and assessment of the channel's complexity.
- Meetings with managers for validation, field visits (priorization of sites based on different degradation typologies)

Block IV

Fig. S8: Were success criteria explicitly stated in the projects' design plan?



1.1 - Results for the explicit success indicators used in project design, broken down by country

Brazil (BRA):

- Landscape Improvement: Enhancements to linear parks, erosion control, and slope stability.
- Elimination of Irregular Housing: In areas of permanent preservation (APP).
- Interruption of Wastewater Discharge
- Infrastructure Improvement.
- Use of Local Areas for Recreation and Leisure.
- Increase in Biodiversity.
- Functional Indicators: Nutrient retention and metabolism.
- Comparison with Water Quality Guidelines and Standards.
- Flood Reduction: Frequency and severity, rainwater retention and infiltration capacity, reduction of erosive processes.
- Sediment Analysis: Upstream and downstream of the water flow.
- Physico-Chemical Parameters.
- Species Diversity.
- Connectivity with Adjacent Areas.
- Community Participation and Environmental Education.
- Increase in Fish and Invertebrate Density and Diversity.
- Improvement in Water Quality and Flood Control.
- Sanitation and Wastewater Collection.
- Carbon Sequestration and Reforestation.
- Improvement in Public Health and Scenic Beauty.

Germany (GER):

- Monitoring of Compensation Targets.
- Restoration of Hydromorphological Dynamics
- Increase in Biodiversity: Increase in biodiversity.

- Area Sizes and Stream Lengths.
- Improvement of Water Body Structural Quality
- Conservation Status (Habitat Directive)
- Ecological Status (Water Framework Directive)
- Structural Improvement and Connectivity
- Biological Criteria: Biological criteria (number of species, composition).
- Presence of Target Species: Presence of target species.
- Navigability: Maintenance of navigability.
- Improvement of Floodplain Condition Parameters: Improvement of floodplain condition parameters.
- Renaturation Framework Concept:
- Acceptance by the Project Leader: Acceptance by the project leader and decision-making bodies (municipal/council).

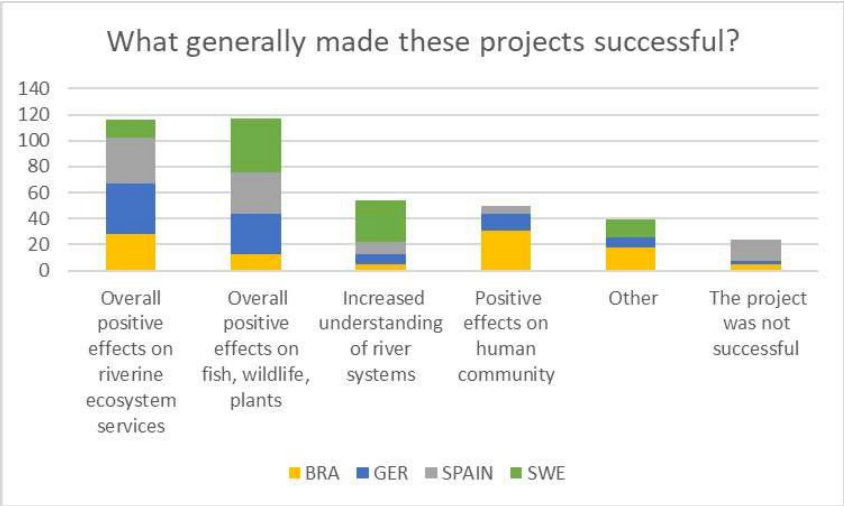
Sweden (SWE):

- Recreation of Natural Habitats: Natural structures, functions, and processes for native species.
- Increase in Fish Abundance: Electrofishing.
- Infections in the Freshwater Community: E.g., glochidia of pearl mussels.
- Target Areas for Spawning Habitats.
- Target Number of Wood Habitats.
- Increase in Aquatic Habitat Areas.
- Water Framework Directive: Achievement of objectives.
- Open Migration for Fish and Aquatic Species.

Spain (SPAIN)

- Establishment of Environmental Flows.
- Restoration of Riparian Vegetation.
- Increase in Fish Distribution Area.
- Improvement of Fish Habitats.
- Survival of Plantations and Control of Invasive Species Regrowth.

Fig. S9: What generally made these projects successful?



IV.2- What generally prevented these projects from being successful?

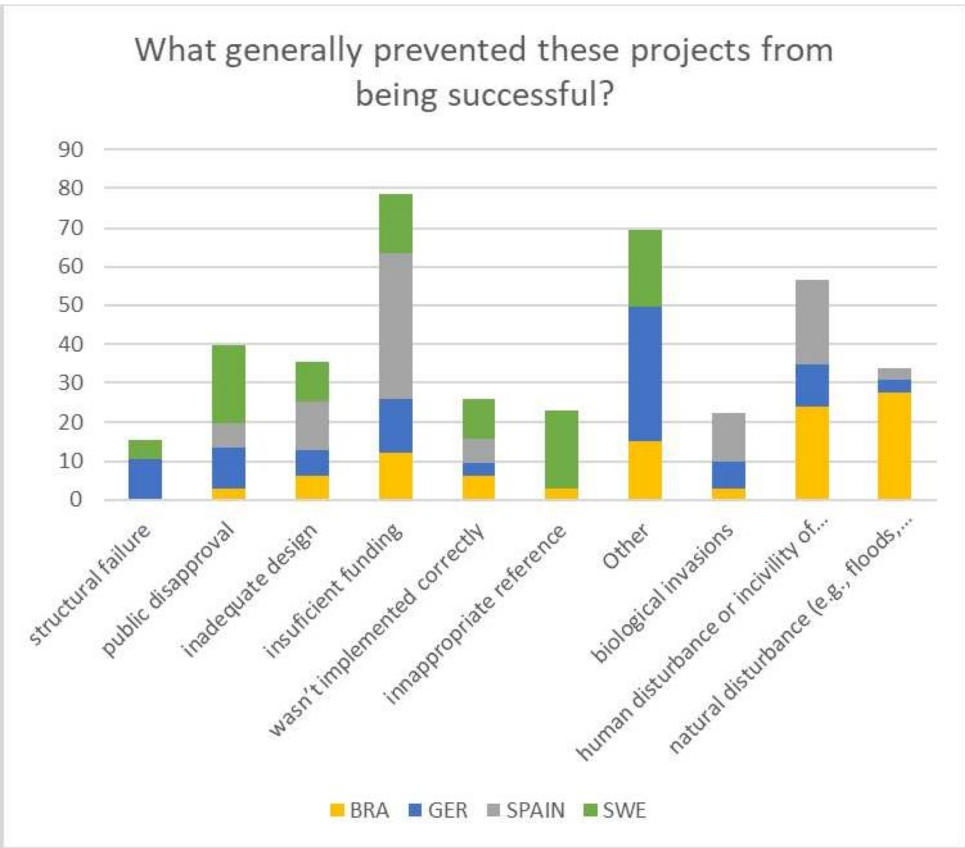
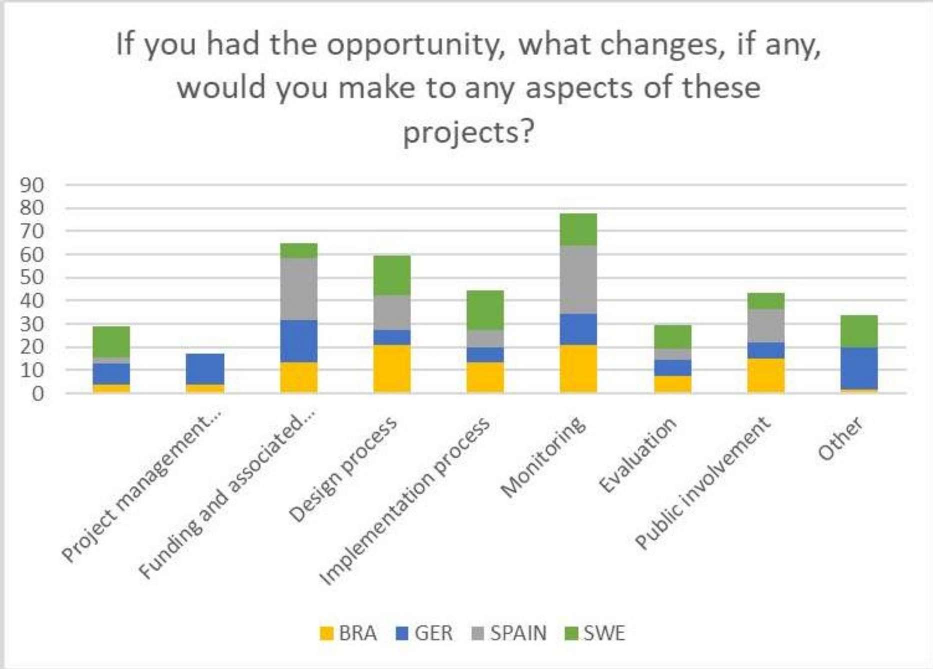


Fig. S10: If you had the opportunity, what changes, if any, would you make to any aspects of these projects?



Block V

V.1-Which indicators of restoration success do you commonly use for your projects?

Others:

- Physical indicators
- Flood mitigation; number of restoration projects summited to the local authority
- Reforested and fenced area, estimates of carbon sequestration
- Aesthetic
- Success depends on matching outcomes to river processes and soil types. E.g., for stable coarse sediment/bedrock, a static river design is needed; for fine sediment soils, interventions should enable self-adjustment to a natural state. Neglecting these factors deems the intervention unsuccessful.
- Numbers of spawning beds used, km of streams opened up, increased wet area when we do the river restoration (we usually have to broaden the streams back to their original riverbed), increased number of fish, freshwater pearl mussels and otters

Fig. S11: V.2 - Do you think that a restoration project can be successful, but the indicators failed to assess this?

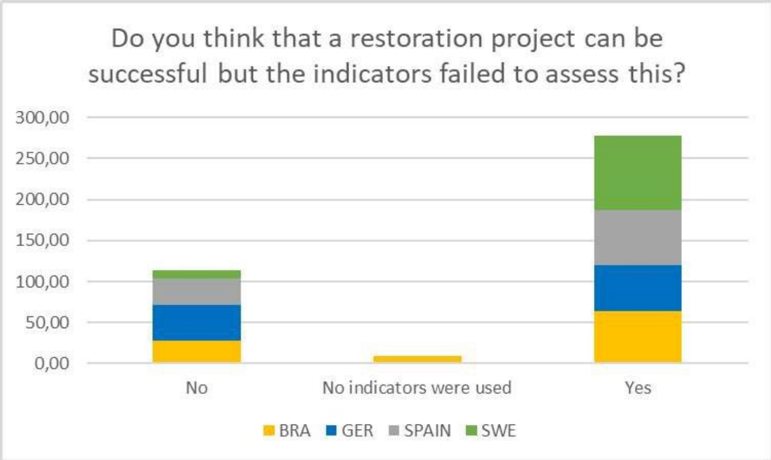
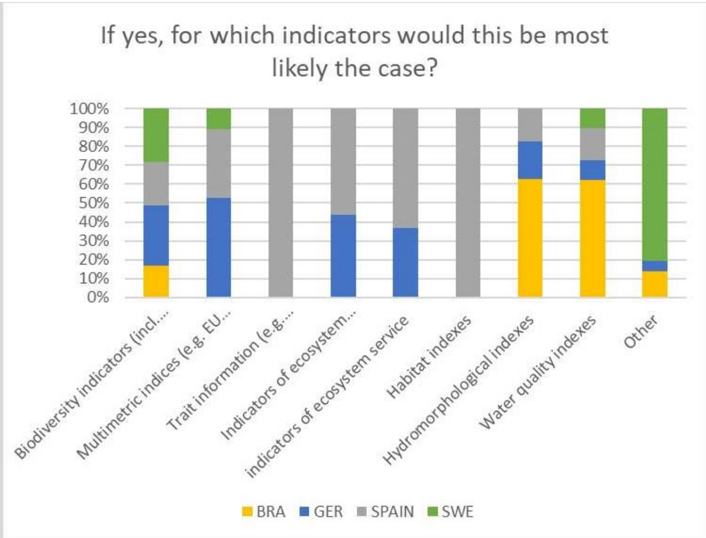


Fig. S12: V.2.1 - If yes, for which indicators would this be most likely the case?



Others:

- Don't know
- The assessment is situation-dependent and cannot be limited to individual indicators.
- Water quality and migratory fishes that can be affected by other factors
- Timeframe. What does it happen after restoration?
- It is important to track exactly what the restoration measure was intended to fix, and not the end goal which dependends on "every aspect" being fixed (and there might be plenty, many diffuse). Geomorphic restoration is oftenly being incorrectly followed up, for example by monitoring biotic response.
- It is not necessary the indicators that fail, the time factor may be crucial
- I feel that we do not have enough resourses to do proper monitoring after the projects have ended. We can use our regular monitoring and see the changes, but it is a bit insufficient and the monitoring sites have not been chosen because we are doing restoration work in the area
- Time since restoration

- Those that take a long time to respond or are impacted by other factors (e.g. fish populations).
- Indicators of biodiversity, water functionality, and physics-chemistry
- Survival of plantations and regrowth of invasive species
- Biodiversity, ecosystem services, hydromorphology

Fig. S13: V.3 - Ecosystem restoration often takes time, but it is useful to document success already by early indicators, e.g. of communication of measures to be adjusted. Do you have the proper tools to evaluate early success?

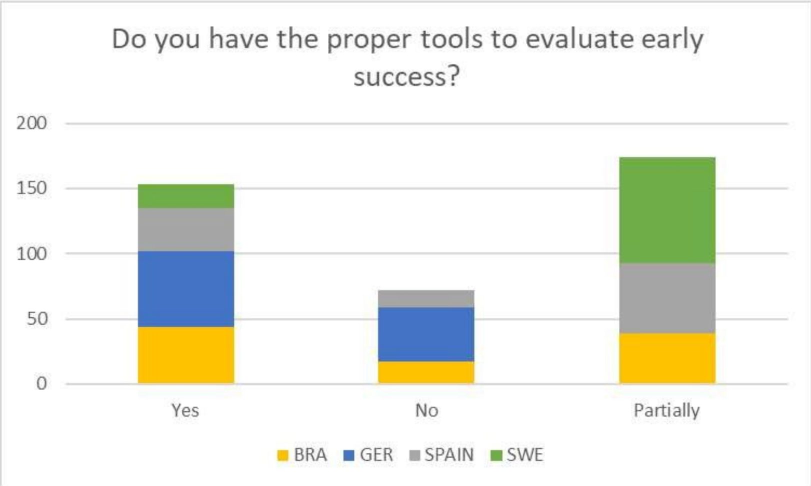
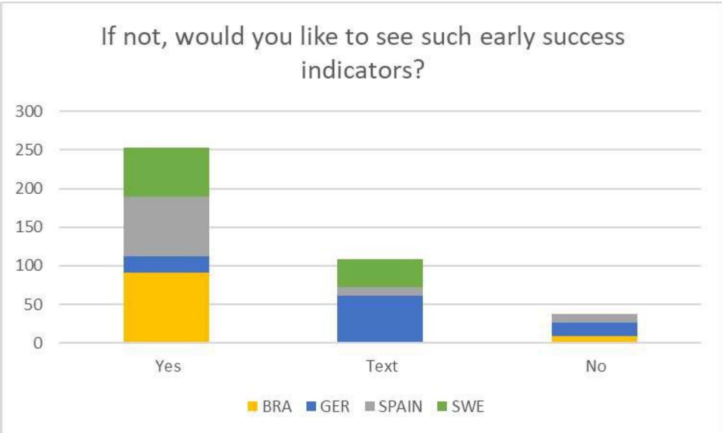


Fig. S14: V.3.1 - If not, would you like to see such early success indicators?



Germany (GER)
- Hydromorphology
- Water Structure
- Morphology, Macrophytes
- Multimetric Method Based on Perlodes and FIBS
- Official Monitoring of Project Water Bodies
- Regular Success Monitoring According to LAWA Handbook
- Floodplains, Groundwater Levels, etc.
- Electrofishing

- Diverse Monitoring
- Characterization of Individual Parameters After Completion of the Measure

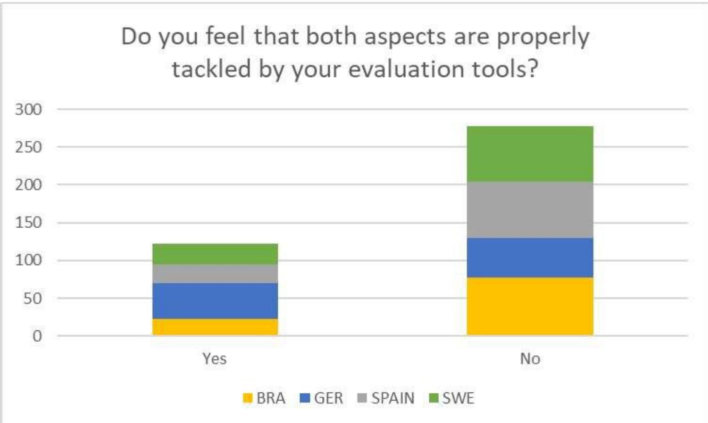
Sweden (SWE)

- Successful methods to locate and quantify area of restored key habitats
- Indicators focusing on life history traits and colonization efficiency. For example, it can be expected that efficiently dispersing and multivoltine generalist macroinvertebrates ("r-species"), colonize first and that the specialists (often larger body size), and slower dispersers ("K-species") comes after – often in accordance with maturation of organic aspects in the water (i.e., directly after geomorphic restoration the environment is purely mineralogic with little algal and moss cover, no decayed dead wood etc.).
- This is a difficult question, it would be nice to see early success and in some cases we can, for instance fish that use our created spawning beds or fish that pass further upstream where there has been a migration barrier. But as you write, ecosystem restoration takes time so we have to be patient
- Yes, we are actually thinking about this, trying to interpret early indicators to infer future conditions

Spain (SPAIN)

- Hydromorphological indexes
- Express interest in indicators related to metabolism and nutrient retention.

Fig. S15: V.4 - Ecosystem services are indicated by both ecological structures (e.g., community composition etc.) and functions (e.g., metabolism, food web processes). Do you feel that both aspects are properly tackled by your evaluation tools?



Other:

Germany (GER)

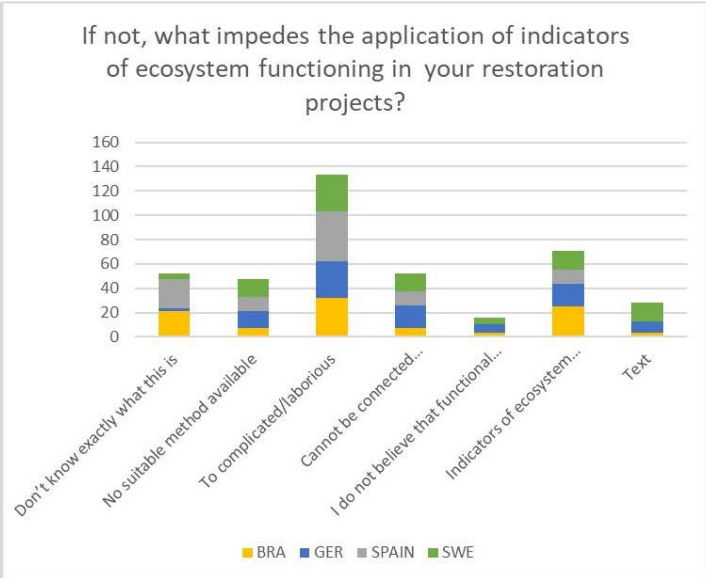
- In the context of river studies, comprehensive functional assessment approaches still need to be developed.
- There is a lack of an overall view of the measure's impact on the entire ecosystem.
- Typically, only the structural quality of the water is evaluated.
- The question cannot be answered.
- Depending on the project's objective, relevant assessment tools should be chosen.

- Diversity is only measured within selected species groups.
- Ecosystem functions are not analyzed.
- Static orientation of state classification according to OGewV regarding biological components and their assessment methods.
- Exclusively biological components.
- Function is prioritized (the assessment focuses on specific FG according to type), and positive changes in diversity, for example due to beavers, are not yet reflected.

Sweden (SWE)

- Indicators tend to focus on N2000 target species (due to funding) which seldom evaluate food web processes in a broader perspective
- Standardized evaluation methods are often focusing on aspects relating to ecological structures as in focus on occurring species, and not the functional response, nor on Community structures relating to colonozation and life-history aspects.
- Often we only measure ecosystem services and not the functions
- I do not care about ecosystem services since they are from a an anthroposophical point of view. Yes, the measures done within the projects are beneficial for humans as well but that is not our major goals. We have done a report about ecosystem services in one of my projects. It was done by consultants
- Goals from Natura 2000

Fig. S16: V.5 - If not, what impedes the application of indicators of ecosystem functioning in your restoration projects?



Germany (GER):

- Urban or local climatic changes
- Ecological guilds, e.g., feeding guilds
- e.g., benefits from floodplains
- The Water Framework Directive includes individual indices for assessing function

Sweden (SWE):

- Electrofishing, otter inventory, spawning inventory
- Some projects only