FERRO

Fostering European Lake Restoration

Deliverable D1.4 – Scoping Paper

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1 Table of Contents

2 Summary

This scoping paper has been developed as an additional deliverable of the Horizon Europe FERRO project to clarify the differences and synergies between work packages (WP) 3 and 4 and to establish their clear connections to the demonstration and experimental sites work packages (WP5/6/7/8/9). It aims to define the project's scope and boundary conditions, including common definitions and geographical limitations while clarifying the methodologies and distribution of activities within WP3 and WP4. The paper also delineates the distinctions and linkages between deliverables D3.3 Lake Restoration Database and D4.3 Dashboard Monitoring Restoration Lakes. By providing this clarity, the scoping paper ensures streamlined coordination and effective integration across the project's work packages.

3 Introduction

The **FERRO project** aims to advance circular and nature-based restoration of natural lakes through a structured framework of 10 work packages: 8 scientific and 2 administrative (Fig. 2). The administrative work packages—**Project Management (WP1)** and **Project Communication, Dissemination, and Exploitation (WP2)**—provide crucial support to all scientific activities. The scientific work packages are organized into four pillars:

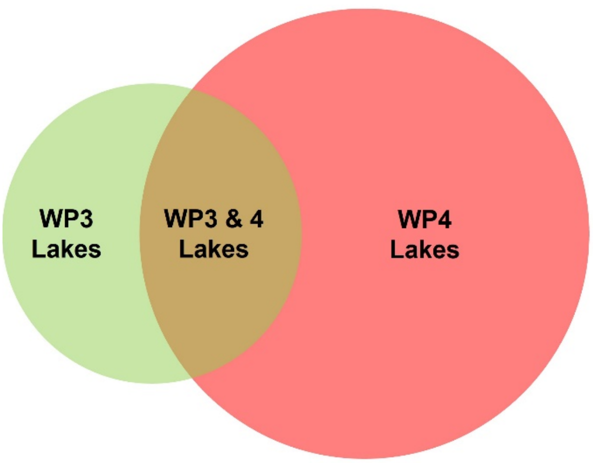
1. **Pillar 1: Classification and Prioritization of Lakes for Restoration (WP3 and WP4)**
2. **Pillar 2: Catchment-Oriented Solutions (WP5 and WP6)**
3. **Pillar 3: In-Lake-Oriented Solutions (WP7, WP8, and WP9)**
4. **Pillar 4: Transfer of Knowledge (WP10)**

WP3 (Lake Restoration Database) and WP4 (Remote sensing-based classification and monitoring) are pivotal to the project and form the backbone of Pillar 1. WP3 focuses on building a comprehensive database of previously restored lakes, providing historical insights into successful and unsuccessful restoration strategies, and offering critical decision support for restoration planning. WP4 complements WP3 by leveraging remote sensing to classify lakes based on their vulnerability to eutrophication, prioritize them for restoration, and monitor the long-term impacts of restoration efforts. This remote sensing-based approach extends beyond the temporal and spatial limitations of traditional in-situ monitoring methods.

The integration and synergy between WP3 and WP4 extend to all other pillars. During the implementation of **catchment-oriented solutions (Pillar 2)** and **in-lake-oriented solutions (Pillar 3)**, WP3 informs decision-making by offering lessons learned from past restoration projects, while WP4 provides real-time monitoring capabilities to track restoration outcomes. Similarly, for **knowledge transfer (Pillar 4)**, both WP3 and WP4 play a critical role in ensuring that insights and methodologies are effectively disseminated to stakeholders and applied in practice.

This **scoping paper** highlights the uniqueness of WP3 and WP4, their synergies, and their connections to the demonstration and experimental site work packages (WP5/6/7/8/9). It establishes the project's scope and boundary conditions, including standardized definitions and geographical limitations. Furthermore, it outlines the methodologies and distribution of activities in WP3 and WP4, ensuring clear differentiation between their roles and deliverables. By fostering alignment and coherence across work packages, this document aims to facilitate effective implementation and integration of solutions while supporting the project's overarching restoration and knowledge dissemination goals.

Figure 1 illustrates the integration and synergies of WP3 and WP4, underscoring their central role in supporting the project's scientific and practical objectives.



WP3: Restored lake database (independent of surface area)
WP3 focuses on historical data and insights from previously restored lakes. It provides a retrospective view of past restoration efforts, highlighting what has succeeded or failed, including estimates of restoration costs and associated challenges.

WP4: Classification (>0.5 km² surface area)
WP4 addresses current and future restoration needs by focusing on the classification of lake vulnerability to eutrophication, thereby prioritizing lakes for restoration. It harnesses the power of remote sensing to monitor the effects of eutrophication and assess the impacts of restoration efforts in lakes.

Intersection of WP3 and WP4 Lakes
Together, WP3 and WP4 enhance decision-making for lake restoration. WP3's historical database informs WP4's prioritization process by integrating lessons learned from past restoration projects. In turn, WP4 demonstrates how remote sensing can support and enhance the long-term monitoring of restoration efforts documented in WP3, creating a synergistic framework for restoration planning and evaluation.

Figure 1. Integration and Synergies Between WP3 and WP4 Lakes for Restoration Planning and Monitoring

4 Project Scope and Boundary Conditions

4.1 Definitions

- **Lake:** In the scope of WP3, the term lakes encompass all water bodies, including both natural lakes and human-made lakes such as reservoirs and impoundments, to ensure a comprehensive approach to lake restoration and management.
- **FERRO lake restoration database** is a structured repository and decision-support tool designed to assist lake managers and scientists in selecting and evaluating restoration measures. By leveraging data and experiences from past projects, it enables informed decision-making. The database format varies based on the collected data, ranging from a simple Excel database to a robust DBMS like MySQL, PostgreSQL, or MongoDB, ensuring efficient data management and analysis.

- **Lake suitable for remote sensing monitoring** is a standing body of water with a minimum surface area of 0.5 km² in a suitable shape, ensuring adequate data quality for analysis using satellite sensors. Smaller lakes may be considered if high-resolution remote sensing (satellite or airborne) technology is employed.
- **Classification scheme of lakes and their catchments for prioritization for restoration** is based on a holistic framework approach (previously applied in Politi et al., 2024, adapted in FERRO) to evaluate lakes regarding eutrophication risk. The approach utilizes spatially and non-spatially explicit (inter)national datasets from various sources to characterize and score several metrics/indicators in the lake catchment and the water body, aiming to assess an overall eutrophication risk score for each site.
- **Dashboard for monitoring impact of restoration measures** is a web-based interactive tool that displays data and information in a tailored way. The FERRO Dashboard will provide quick overviews of selected lakes using maps and graphs to demonstrate how remote sensing, combined with in-situ and auxiliary data, can support lake restoration monitoring.

4.2 Geographical boundary

WP3 and WP4 will be restricted to EEA38 + Horizon Europe (Mainland Europe), see Table 1

Table 1. Geographical Scope: EEA38 + Horizon Europe (Mainland Europe Focus)

Category	Countries
EU Member States (27)	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France (continental), Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden
Non-EU EFTA Countries (4)	Iceland, Norway, Liechtenstein, Switzerland
Candidate and Potential Candidate Countries (7)	Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, Serbia, Turkey
Other Horizon Europe Associated Countries (2)	UK, Ukraine
Excluded Countries	Horizon Europe-associated countries outside Europe: Canada, Israel, Morocco, New Zealand, and Tunisia

4.3 Temporal Scope

This section outlines the temporal framework for WP3 and WP4, focusing on the timeline and deliverables, as illustrated in the project's Gantt chart (Figure 2). The tasks within these work packages are distributed across the project duration (2024–2028) to ensure a structured and phased approach to achieving the deliverables.

Work Package Tasks	2024		2025				2026				2027				2028	
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
WP3. Review of lake restoration of European lakes.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Task 3.1 Identifying restoration data sources and preparing metrics template**. (D3.1)**	■	■	■	■	■											
Task 3.2 Data collection and data extraction publications, and grey literature. **(D3.2)**					■	■	■	■	■	■	■	■	■	■		
Task 3.3 Creating and testing a database on lake restoration. **(D3.3)**								■	■	■	■	■	■	■	■	■
WP4. Remote sensing-based classification and monitoring	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Task 4.1 Data collection and processing related to lakes and lake catchments. **(D4.1)**	■	■	■	■												
Task 4.2 Implementation catchment wide assessment tool. **(D4.1)**			■	■	■	■	■	■								
Task 4.3 Generation of satellite-based water quality products for restoration lakes. **(D4.2)**			■	■	■	■	■	■	■	■	■	■	■	■	■	■
Task 4.4 Implement and run dashboard for monitoring impact for restoration measures. **(D4.3)**									■	■	■	■	■	■	■	■

Figure 2. WP3 and WP4 Gantt chart

5 Distinguishing WP3 and WP4

5.1 Overview of WP3 and WP4

Table 2 gives an overview of the aspects of WP3 and WP4

Table 2. Comparison of WP3 and WP4

Aspect	**WP3: Database of Previously Restored Lakes**	**WP4: Remote Sensing-Based Classification and Monitoring**
Objectives	To review restoration literature and create a database of previously restored EU lakes based on various sources of data in order to help those involved in restoration to make informed decisions.	To provide a lake- and catchment-related classification scheme for lake eutrophication vulnerability and water quality information derived from satellite data to 1) support classification and prioritization of lakes for restoration and 2) demonstrate how remote sensing can be used to monitor the impact of restoration activities in space and time.
Data Sources	- Restoration data survey - Scientific publications - Grey literature	- Satellite-based datasets (e.g., Copernicus Sentinel-3 OLCI) - Catchment-related and Earth Observation (EO) based datasets from, e.g., Copernicus services and existing lake and catchment databases.
Metrics Collected	- **Lake Morphometry:** Depth, surface area, volume - **Restoration metrics:** technique (s), duration - **Nutrient Monitoring:** Pre- and post-restoration data on nitrogen and phosphorus concentrations - **Algal Metrics:** Chlorophyll concentrations, algal blooms - **Financial and Social Metrics:** Restoration costs, societal impacts (e.g., recreational value, stakeholder involvement).	- **Catchment Datasets:** E.g., land use, population density, soil type, river network and lake outflow (Politi et al. 2024) - **Lake Datasets:** e.g., lake mean depth, lake surface area and volume, thermal stratification, rate of annual water exchange (Politi et al. 2024) - **Other datasets:** e.g., remote sensing-derived chlorophyll-a concentrations and cyanobacteria risk index.
Output	**Database:** - A decision-support database that equips lake managers with information to make better-informed choices when selecting restoration techniques.	**Web map:** - For classification and prioritization of lakes for restoration. **Dashboard:** - For a remote sensing-based system towards long-term monitoring of restoration impact.

5.2 Uniqueness of WP3 and WP4

Key Differences:

1. **Primary Focus**:
    - WP3 focuses on **historical in-situ-based and other data** of previously restored lakes.
    - WP4 focuses on **current and future restoration needs**, relying heavily on **remote sensing** and lake and catchment characteristics.
2. **Metrics**:
    - WP3 emphasizes **in-situ data and financial/social impacts** of past restoration efforts.
    - WP4 emphasizes **vulnerability to eutrophication classification** and **remote sensing-based monitoring** of restoration impacts.
3. **Target Lakes**:
    - WP3 works with lakes that have already been restored.
    - WP4 works with lakes larger than 0.5 km^2 and which are available in the water quality products of the Copernicus Global Land Service to determine their vulnerability to eutrophication and prioritize restoration.

5.3 Synergy Between WP3 and WP4

Despite their distinct goals and methodologies, WP3 and WP4 are **highly complementary**. Together, they can create **meaningful insights** to enhance decision-making for lake restoration:

1. **Integrated Insights**:
    - WP3 provides historical benchmarks and proven strategies for restoration.
    - WP4 offers tools to identify lakes at the highest risk and monitor future restoration impacts.
2. **Improved Decision-Support**:
    - WP3's database can inform WP4's prioritization by integrating lessons learned from past restorations.
    - WP4's satellite-derived monitoring can support the long-term success of restoration approaches.

3. **Holistic Approach**:
   - Combining the **retrospective perspective** of WP3 with WP4's **forward-looking, multi-data dashboard** enables a comprehensive framework for restoration planning and assessment.

5.4 Integration of WP3 and WP4 with Demonstration and Experimental Sites (WP5-9)

All demonstration site lakes will be included in both the restoration database (WP3) and the dashboard (WP4). The experimental site lake will be part of WP3 but is too small to be effectively monitored using remote sensing data in WP4.

6 Conclusion

By maintaining their unique focus, WP3 and WP4 avoid overlap while working together to provide a **comprehensive decision-support system**. WP3 equips lake managers and scientists with insights from past successes, while WP4 empowers them to prioritize vulnerable lakes and monitor restoration efforts in real time. Together, these work packages create a synergistic framework that ensures effective, data-driven lake restoration strategies across the EU.

7 References

Politi, E., M. E. J. Cutler, L. Carvalho, and J. S. Rowan. 2024. A global typological approach to classify lakes based on their eutrophication risk. Aquatic Sciences.

8 Annex

8.1 WP 3 Description

Work package number	WP3 (Leader: UFZ; Participants: All; Duration: M1-M48)
Work package title	Review of lake restoration of European lakes.

Objectives

To review restoration literature and create a database of previously restored EU lakes based on various sources of data in order to help those involved in restoration to make informed decisions.

KPI 3.1 Development of a database on lake restoration in the EU (Task 3.1., 3.2 and 3.3; D3.1, 3.2, and 3.3)

Description of work

We want to create a lake restoration database (for the consortium member countries). This detailed database will help the restoration community decide on restoration measures appropriate for their lakes by using the vast experiences collected in past projects.

Task 3.1 Identifying restoration data sources (published and unpublished) and preparing templates for the key restoration metrics. *(Leader: UFZ; Participants: All; Duration: M1-M15)*

We create a protocol for lake restoration metrics focusing on Lake Catchment characteristics (e.g., land use), lake morphometry, use of the lake, water quality parameters (e.g., nitrogen, phosphorus, and chlorophyll concentration), restoration method, year of restoration, cost of restoration, etc. The protocol we also integrate remotely sensed data and a list of restored lakes will be identified for inclusion in Task 4.1 (WP4).

Task 3.2 Data collection from authorities and data extraction from scientific publications, and grey literature. *(Leader: UFZ; Participants: All; Duration: M13-M42)*

The aim is to collect as much data available on restoration because there is a strong bias towards the publication of studies showing restoration success. Published data will be searched via search engines, e.g., Google Scholar and Web of Science. Grey literature is produced by individuals or organizations outside commercial and academic publishers. We will establish a protocol to identify sources of grey literature on lake restoration, mainly focusing search for government reports, conference proceedings, and graduate dissertations. In addition, a list of restoration experts (academic and non-academic) and organizations will be created based on internet search. The experts and organizations will be asked if they have grey literature on lake restoration; a follow-up questionnaire will be sent to those who affirm the availability of unpublished restoration data. **(D3.1)**

Task 3.3 Creating a data base on lake restoration. *(Leader: UFZ; Participants: All; Duration: M25-M48)*

The purpose of the database is to help lake managers decide on restoration measures appropriate for their lakes by using the vast experiences collected in past projects. We will determine the data types, relationships between the data, and the type of queries to be performed on the data. The database will create an appropriate database management system (DBMS), e.g., MySQL, PostgreSQL, Microsoft SQL Server, and Oracle. The database schema will be designed, implemented, and populated with data. The database will be internally (consortium members) and externally tested (selected restoration users for the restoration community). **(D3.2)**

8.2 WP 4 Description

Work package number	WP4 (Leader BC; Participants All; Duration: M1-M48)
Work package title	Remote sensing-based classification and monitoring

Objectives

To provide catchment-related and water quality information derived from satellite data for 1) support classification and prioritization of lakes for restoration and 2) monitor the impact of restoration activities in space and time.

KPI 4.1: Minimum number of lakes included in the lake characterization assessment (Task 4.2; D4.1) = 400

KPI 4.2: Map of European lakes showing the FERRO classification output (Task 4.2; D4.1) = 1

KPI 4.3: Minimum number of FERRO demonstration sites, for which a time series of satellite data will be processed and integrated into the dashboard to showcase the potential of monitoring restoration measures (Task 4.3, 4.4, and 10.3; D4.2 and 4.3) = 2

Description of work

For WP4, objective 1) is mainly addressed by tasks 4.1-4.2 and objective 2) by tasks 4.3-4.4.

Task 4.1 Data collection and processing related to lakes and lake catchments *(Leader: BG; Participants: BC; Duration: M1-M12).* Based on the definition and requirements derived from WP3 and the metrics of the methodology (Politi *et al.* 2023, in review), several catchment related and EO based datasets shall be identified and downloaded from e.g. Copernicus services and existing Lake data bases. In addition, high chlorophyll-a concentration and cyanobacteria risk index products will be generated from Copernicus data (Sentinel-3) by own processing and used as indicator within the classification and prioritisation tool. Formatting and fit for purpose storage of all datasets will be necessary. This will be performed using xcube environment that leads to a harmonized spatial-temporal data set which can be easily analysed. Previously restored EU lakes will be included identified in Task 3.1 WP3 **(D4.1)**

Task 4.2 Implement catchment wide assessment tool for a number of pre-selected lakes *(Leader: BC; Participants: BG; Duration: M7-M25).* Based on the generated datasets in Task 4.1 and adopted from Politi *et al.* (2023 in review), metrics will be generated and scores will be applied, leading to a classification scheme of lakes for prioritisation for restoration. Results will be visualized via a dashboard for interactive analysis of the classification results. The selected lakes in the project will be used for verification of our assessment of restoration needs. **(D4.1)**
Output: Lake classification and prioritisation tool

Task 4.3 Generation of satellite based water quality products for restoration lakes *(Leader: BG; Participants: BC; Duration: M7-M48).* Archived and Near Real Time Sentinel-2 MSI and Sentinel-3 OLCI data will be used to produce water quality information (Chl-a, cyanobacteria occurrence, turbidity, Secchi Depth) supporting the FERRO restoration actions in the project. Archived data will serve as reference to be compared with current status and for show casing, data will be produced for lakes that already have undergone measures. During the restoration actions, NRT information will be generated and sent to all project stakeholders through a service, which will provide recent and updated information about the lake status, support planning and monitoring of the effects of the actions and to assess the sustainability of the implemented measures after. As for Task 4.1 all generated data will be cubed (xcube) per restoration site. In addition, information sheets can be produced and/or an online viewer implemented. The viewer provides easy access, visualization of and to work with the datasets included in the cube. **(D4.2)**

Task 4.4 Implement and run a dashboard for monitoring impact of restoration measures (Leader: BC; Participants: BG; Duration: M25-M48). A dashboard will be developed that compiles the information collected from the different activities: water quality from EO, in-situ data, and other auxiliary data if needed (e.g., meteorological data). The dashboard will provide a fast overview of the situation in a lake in graphs as a support for restoration partners and related stakeholders to make decisions. The dashboard will be published on a cloud server and access will be opened for project partners and stakeholders and maintained until the end of the project. **(D4.3)**

Output: Dashboard for impact monitoring