D5.1 Knowledge hub v1.0 (prototype) published

Deliverable No: [D5.1]
Work package: [WP5]

Official delivery date: [30.09.2025]
Actual delivery date: [23.09.2025]

Dissemination level: Public

Funded by the European Union

Project: 101157886 | HORIZON-MISS-2023-OCEAN-01-04 | www.procleanlakes.eu

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Version	Date	Author(s)
0.2	23.09.2025	ALTFACTOR

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Executive Summary

The D5.1 Knowledge Hub v1.0 is a web-based platform that brings together scientific tools, citizen contributions, and educational resources to advance lake restoration, protection, and sustainable management. The prototype demonstrates a modular and scalable solution, integrating user management, content delivery, and interactive features within a modern technology stack. A React and TypeScript frontend is combined with a NestJS backend delivering robust API services. The architecture follows domain-driven design principles, ensuring clear separation of concerns and enabling both present functionality and future expansion.

1.Introduction

The ProCleanLakes D5.1 Knowledge Hub v1.0 represents a significant advancement in environmental conservation technology, specifically designed to address the complex challenges of lake restoration and protection across Europe. This comprehensive digital platform serves as a bridge between scientific research, policy implementation, and community engagement, creating a collaborative ecosystem where diverse organizations and stakeholders can work together toward sustainable water resource management. By integrating cutting-edge technology with user-centered design, the platform transforms complex environmental data into actionable insights, making advanced conservation tools accessible and usable for stakeholders with different levels of technical expertise. The development of this platform was guided by a clear vision to create more than just an information repository, but rather a dynamic, interactive environment that actively supports decision-making processes and fosters meaningful engagement with lake conservation efforts.

1.1. Tasks (Objective)

The platform was developed with several core objectives in mind, each addressing specific aspects of the project's vision. The primary focus was on creating a centralized repository for lake-related information, research findings, and best practices in environmental conservation. This involved implementing structured content organization with intuitive categories, tags, and advanced search functionality to ensure users could easily locate relevant information. The development team prioritized building a system that would serve as a living library of knowledge, where information could be continuously updated and expanded as new research and data became available.

Stakeholder engagement remains a cornerstone of the project, with the platform designed to facilitate active participation from diverse user groups, including researchers, policymakers, local communities, and environmental activists. While the initial plan included discussion forums, the focus has evolved to emphasize the Replication Assistance Guideline Tool (RAGT) as the primary engagement mechanism. This tool enables structured knowledge sharing and collaboration, allowing stakeholders to document, access, and apply best practices in lake conservation. The platform supports interactive features such as commenting on guidelines, sharing implementation experiences, and connecting with experts, creating a dynamic environment for collaborative problem-solving. This approach

ensures that valuable insights and practical knowledge can be effectively captured and disseminated, even without traditional discussion forums, while still fostering a sense of community and shared purpose among users.

Data visualization emerged as a key component of the platform's objectives. The development team recognized that raw environmental data, while valuable, often remains inaccessible to non-experts. To address this, the platform incorporates sophisticated tools for presenting complex environmental data in accessible formats. Interactive maps provide geographical context, while dynamic charts and dashboards help users understand lake conditions, track trends over time, and identify potential areas of concern. These visualization tools are designed to be both informative and intuitive, allowing users to explore data according to their specific interests.

The educational aspect of the platform was given equal importance in the project's objectives. The development team created an application that enables the integration of collections of structured learning materials and resources, with the goal of educating users about lake ecosystems, conservation techniques and sustainable practices. These resources were designed to be accessible to a wide range of users, from school students to environmental professionals, with content presented in various formats to accommodate different learning styles and preferences.

1.2. Objectives of the Work

The technical implementation of the ProCleanLakes D5.1 Knowledge Hub v1.0 was guided by several key objectives that ensured the platform's effectiveness, reliability, and long-term viability. Scalability was a key design requirement, ensuring the platform could handle growing datasets and user volumes without sacrificing performance. This was achieved through efficient database design, optimized API responses, and a robust infrastructure capable of handling significant traffic and data processing demands.

Usability formed another cornerstone of the technical implementation. The development team prioritized creating an intuitive user interface that would be accessible to users with varying levels of technical expertise. The responsive design approach guaranteed a consistent and user-friendly experience across different devices and screen sizes, from desktop computers to mobile phones, recognizing that users might need to access the platform in various field conditions.

Security considerations were paramount throughout the development process. The platform incorporates robust authentication and authorization mechanisms to protect sensitive information and ensure that users only have access to appropriate features and data. Role-based access control was implemented to manage different levels of permissions, while comprehensive data validation helps prevent security vulnerabilities. These measures ensure that both user data and the integrity of the platform's information remain protected.

Performance optimization was another critical objective that influenced technical decisions. The application was carefully designed to deliver fast loading times and smooth interactions, even when handling complex data visualizations or processing large datasets. This involved implementing efficient data fetching strategies,

optimizing frontend performance, and minimizing unnecessary resource usage. The result is a platform that remains responsive and reliable, even as the volume of data and number of users continue to grow.

Maintainability was also taken into consideration in the platform's architecture and coding practices. The codebase was structured using modular design principles, with clear separation of concerns and consistent coding standards. Comprehensive documentation was created to support future development efforts, and the system was designed to be easily extensible, allowing for the addition of new features and functionality as the platform evolves. This forward-looking approach ensures that the ProCleanLakes D5.1 Knowledge Hub v1.0 will remain a valuable resource for years to come, capable of adapting to changing needs and technological advancements in the field of environmental conservation.

2. Outline of the Deliverable

The implementation encompasses several key components:

2.1. Frontend Architecture

Component Library: Built with React and TypeScript, featuring reusable UI components that maintain consistency throughout the application.

State Management: Utilizes React Query for efficient server state management, caching, and data synchronization.

Routing: Implemented with React Router to provide seamless navigation without requiring full page reloads.

UI/UX: Features a responsive design using Tailwind CSS, with careful attention to accessibility and user experience principles.

2.2. Backend Services

API Layer: RESTful API built with NestJS, following REST principles and providing clear, consistent endpoints.

Authentication: Session-based authentication system using secure HTTP-only cookies, Passport.js, and a Prisma-backed session store for access control.

Database: MySQL with Prisma ORM for type-safe database operations and migrations.

File Management: Comprehensive file upload and storage system with support for various file types and sizes.

2.3. Core Features

User Management: Complete user registration, authentication, and profile management system.

Content Management: Tools for creating, editing, and organizing articles, documents, and media.

Private Messaging: Communication between users with support for file attachments.

Data Visualization: Interactive charts and maps for presenting environmental data.

3. The significance of a web presence

In today's digital age, a robust web presence is not just beneficial but essential for any large-scale environmental initiative. The ProCleanLakes D5.1 Knowledge Hub v1.0 serves as the digital heart of the project, creating a virtual space where science, policy, and community action converge. This online platform breaks down traditional barriers to information access and collaboration, enabling real-time interaction between diverse stakeholders regardless of their physical location. By establishing a persistent, always-available digital interface, the project ensures that lake conservation efforts can continue uninterrupted, with data and knowledge shared openly among researchers, policymakers, and local communities most affected by water management decisions. The web platform's ability to present complex environmental data in accessible formats transforms abstract scientific concepts into tangible insights, empowering users at all levels of expertise to participate meaningfully in conservation efforts.

3.1. Centralized Knowledge Repository

The platform's architecture has been thoughtfully designed to support the future development of a comprehensive knowledge repository. The current implementation establishes a solid foundation that will enable seamless integration of centralized knowledge management features in upcoming versions. The modular design and scalable infrastructure ensure that as the need arises, the system can efficiently aggregate and organize environmental data from diverse sources, including government agencies, research institutions, and citizen scientists. The existing database structure includes fields and relationships that will support advanced search functionality, categorization, and tagging systems. This forward-thinking approach means that when the centralized knowledge repository is implemented, it will be able to present a unified view of lake ecosystems by connecting previously fragmented information sources, all while maintaining the platform's current performance and user experience standards.

3.2. Community Building

The platform's community-building features create a vibrant ecosystem where knowledge sharing and collaboration can flourish. Through the articles section, users can share insights, research findings, and practical experiences related to lake conservation. The comment functionality enables meaningful dialogue and knowledge exchange between scientific experts and community members, fostering a deeper understanding of lake ecosystems. User-generated content empowers individuals to contribute their local knowledge and observations, enriching the collective understanding of environmental challenges. The platform also supports the formation of special interest groups that focus on specific conservation topics, connecting organizations and members who might not otherwise have opportunities to collaborate. By facilitating these connections and knowledge-sharing opportunities, the platform strengthens the collective capacity to address complex environmental challenges and promotes a shared commitment to lake conservation.

3.3. Data Democratization

The platform's approach to data democratization represents a significant advancement in environmental governance. By translating complex scientific data into intuitive visualizations and plain-language explanations, the platform makes critical information accessible to non-experts without sacrificing scientific rigor. The platform's educational resources help users understand how to interpret environmental data, building data literacy within the broader community. This approach to data democratization ensures that all stakeholders—from policymakers to local residents—can access the same high-quality information when making decisions that affect lake ecosystems. The platform also provides tools for citizens to contribute their own observations and measurements, creating a more comprehensive and participatory approach to environmental monitoring. This two-way flow of information helps build trust between different groups of users and creates a more inclusive decision-making process.

3.4. Continuous Learning and Capacity Building

Planned interactive dashboards will allow users to explore data, adjusting parameters to see how different factors affect lake health. Educational resources are also part of the envisioned features, helping users understand how to interpret environmental data and fostering data literacy within the broader community. This planned democratization of information is intended to level the playing field, ensuring that all stakeholders—from government officials to local residents—will have access to the same high-quality information when making decisions that affect lake ecosystems. In future iterations, the platform will also provide tools for citizens to contribute their own observations and measurements, creating a more comprehensive and participatory approach to environmental monitoring. This two-way flow of information is expected to build trust between different groups of users and create a more inclusive decision-making process.

3.5. Enhanced Decision-Making and Policy Development

The platform's comprehensive data management and analysis tools provide decision-makers with the information they need to develop evidence-based policies and management strategies. By integrating data from multiple sources and presenting it in clear, actionable formats, the platform may help identify trends, predict potential issues, and evaluate the effectiveness of different interventions. The platform also facilitates more transparent and inclusive decision-making processes by making relevant data and analysis available to all users. This transparency helps build public trust in environmental management decisions and creates opportunities for meaningful public participation in the policy development process. By providing a common information base for all members, the platform helps align conservation efforts across different jurisdictions and sectors, creating more coordinated and effective approaches to lake management.

4. Structure

4.1. Frontend Structure

The frontend of the ProCleanLakes platform is built with a focus on user experience and performance. The application follows a component-based architecture, where each piece of the interface is a self-contained unit that can be reused throughout the platform. The layout is designed to be intuitive, with a consistent navigation system that helps users find what they need quickly. The interface is fully responsive, automatically adjusting to different screen sizes and devices. Interactive elements like forms, maps, and data visualizations are implemented using modern web technologies to ensure smooth performance. The design system includes a carefully chosen color palette, typography, and spacing that create a professional and accessible user experience.

4.2. Backend Structure

The backend of the platform is built to be robust and scalable, capable of handling large amounts of data and many simultaneous users. It processes all the behind-the-scenes operations that make the platform function, such as user authentication, data storage, and complex calculations. The system is designed with security in mind, implementing measures to protect sensitive information and prevent unauthorized access. The architecture allows for easy updates and additions of new features as the platform grows. Performance optimizations ensure that pages load quickly and that data-intensive operations don't slow down the user experience.

The platform uses REST APIs for communication between components, ensuring scalability and interoperability.

5. Sections

5.1. Public-Facing Sections

The platform features several public sections accessible to all visitors without authentication:

Homepage serves as the digital front door, offering an overview of the platform's purpose and key features. It includes dynamic statistics about lake monitoring efforts and showcases featured content to engage new visitors.

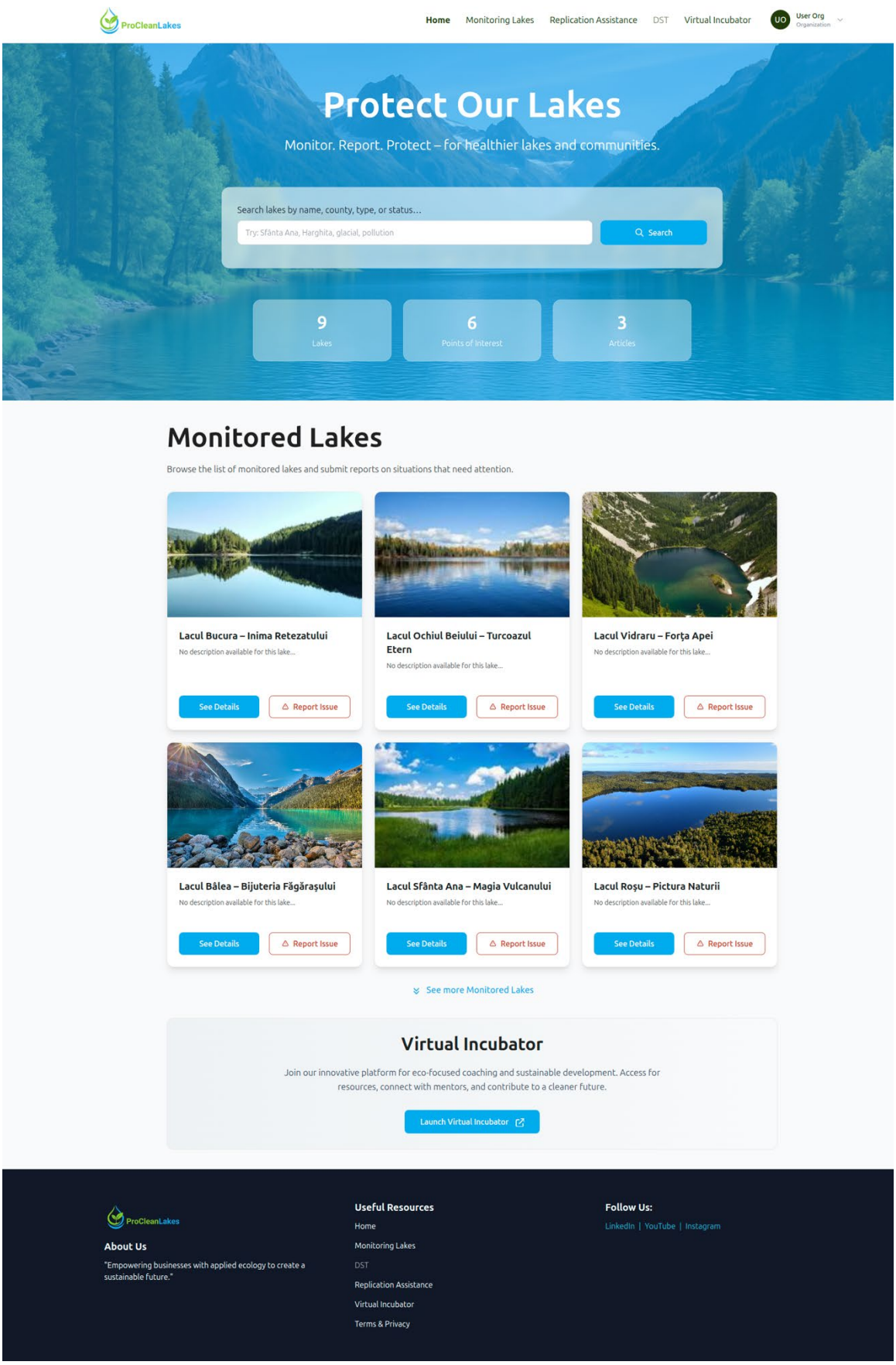

Figure 1 - Home Page

Monitored Lakes (/map-list) provides an interactive map interface where users can explore monitored lakes. The current project structure is designed to support future enhancements, such as representing each lake with key metrics, allowing for quick visual assessment of water quality and ecosystem health across different regions.

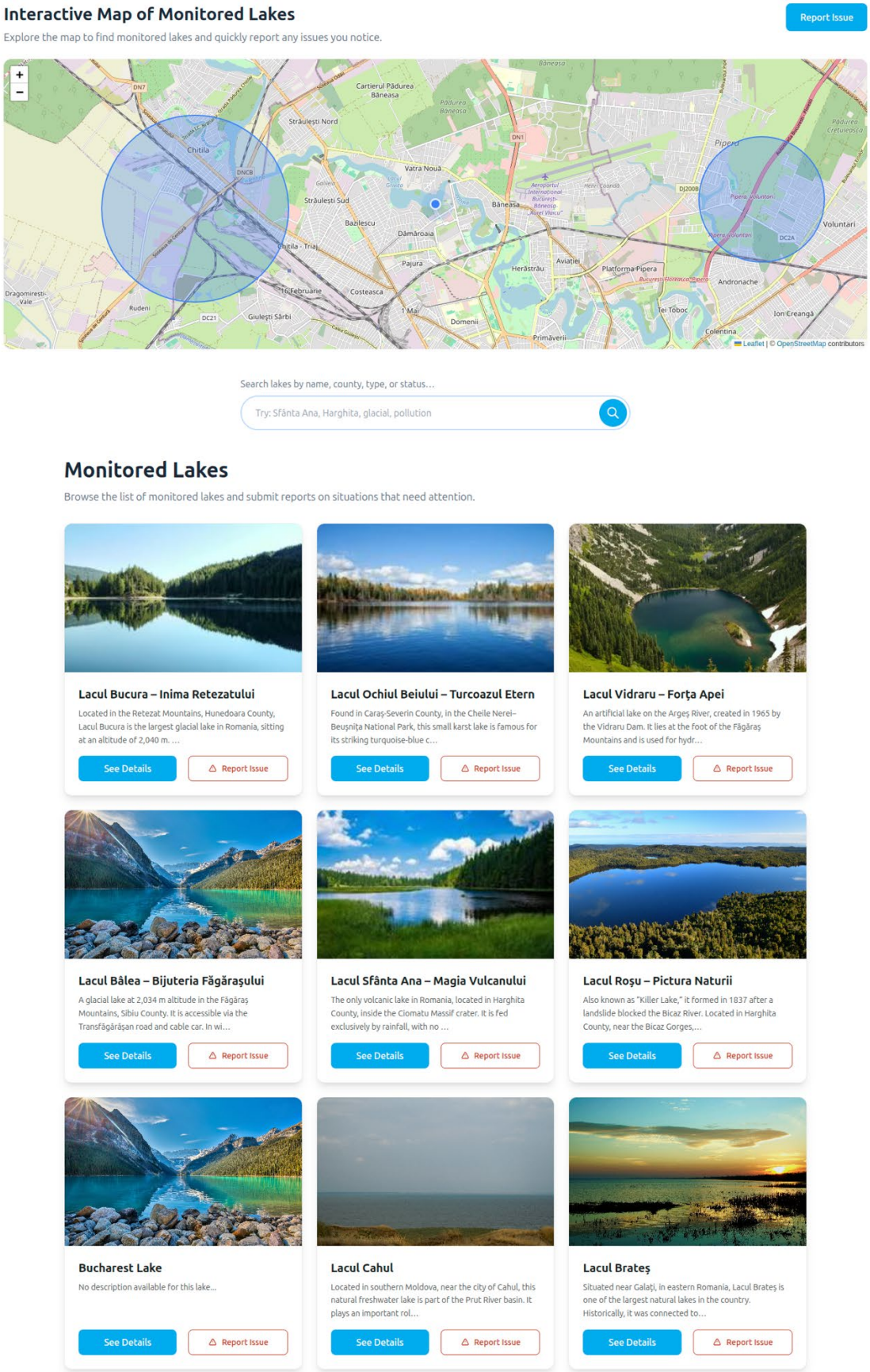

Figure 2 - Monitored Lakes

Lake Details (/lakes-detail/:id) is designed to offer in-depth information about each specific lake. While the current version does not yet include all features, the project structure is built to easily support future enhancements such as historical data trends, recent measurements, and conservation status—ultimately serving as a comprehensive resource for researchers and concerned citizens alike.

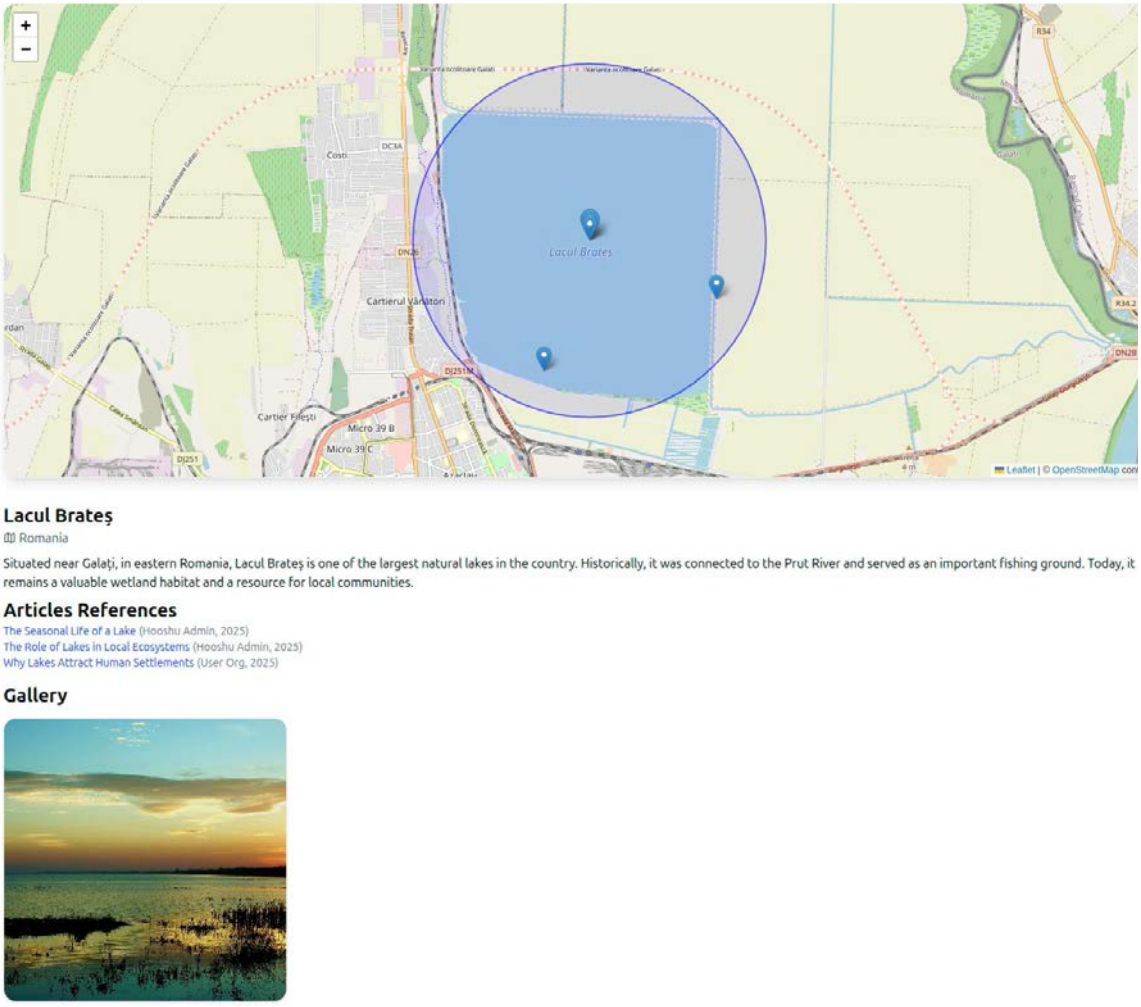

Figure 3 - Lake Details

Points of Interest (/view-pois/:lakeId) highlights significant locations around each lake, such as monitoring stations, recreational areas, and conservation sites, providing context about human and environmental interactions with the water body. In addition, citizens can contribute by marking their own points of interest, helping to capture observations and insights about the lake from a community perspective.

Replication Assistance Guideline Tools (/articles) serves as a repository of educational content, research findings, and best practices in lake conservation, organized for easy navigation and reference.

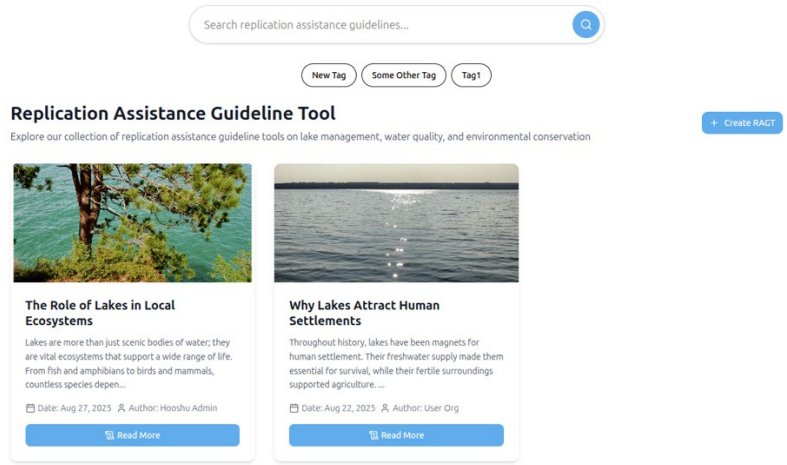

Figure 4 - Replication Assistance Guideline Tools

5.2. User Account Management

The authentication system includes:

Login/Registration (/login, /register) provides secure access to personalized features while the profile management section (/profile/edit) allows users to update their information.

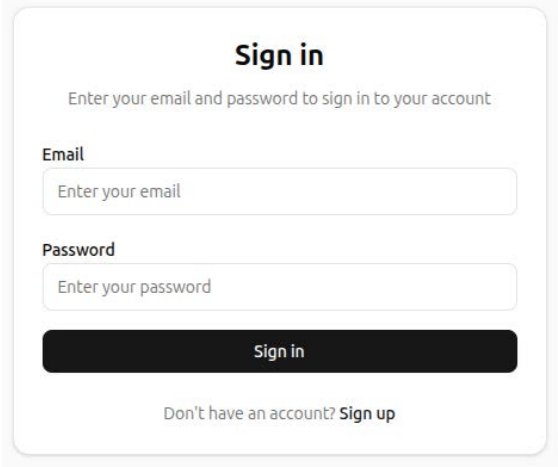

Figure 5 - Login

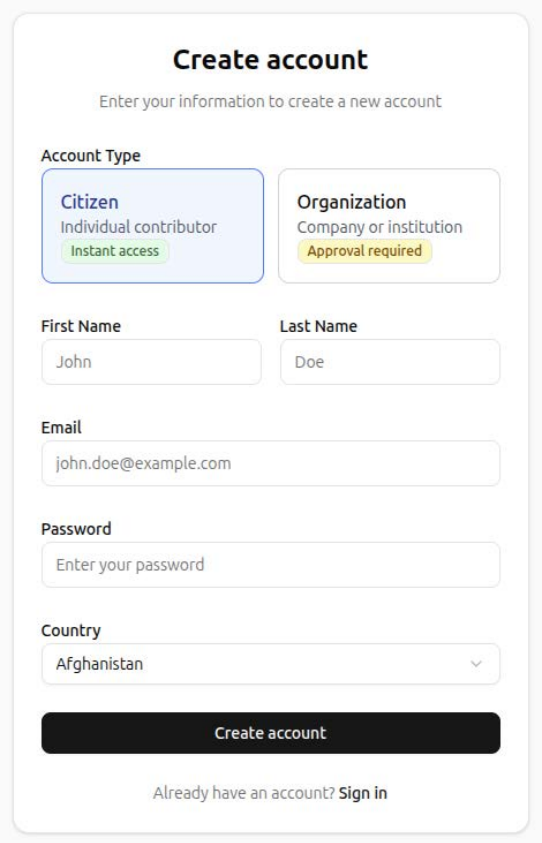

Figure 6 - Registration

5.3. Dashboard & User-Specific Features

The platform offers role-based dashboards:

User Dashboard (/dashboard/my-dashboard) provides personalized overviews with quick access to relevant lakes, recent activities, and important updates.

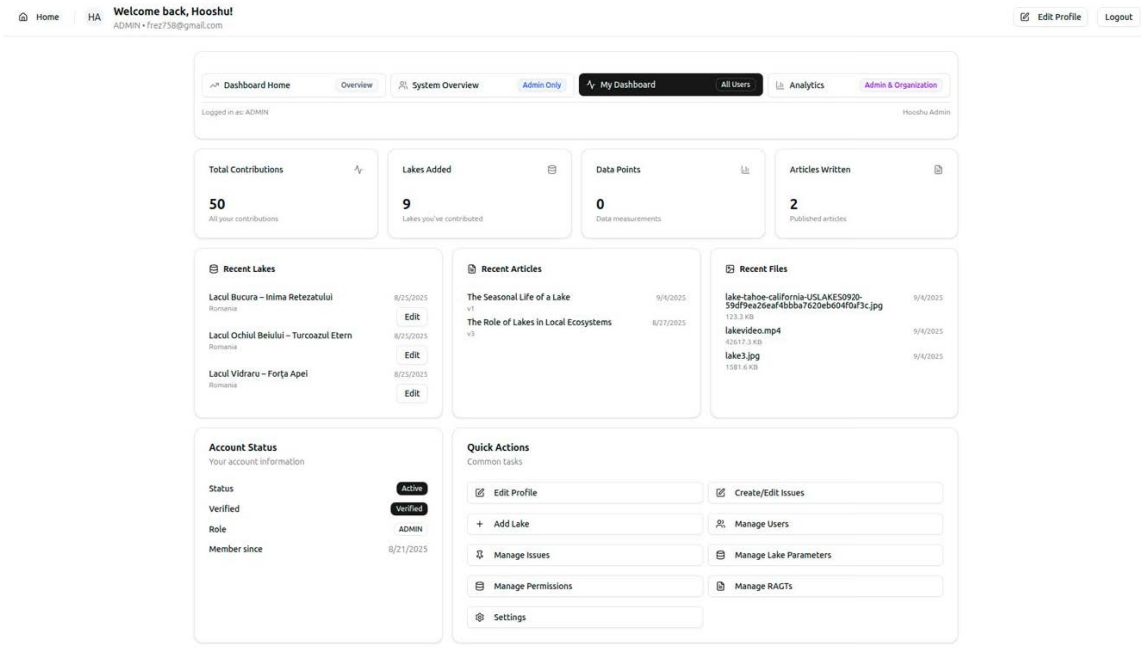

Figure 7 - Personal Dashboard

Analytics Dashboard (/dashboard/analytics) is designed to provide advanced data visualization tools for users with appropriate permissions, enabling detailed analysis of environmental trends and patterns. While not yet fully implemented, the current project structure allows these capabilities to be integrated seamlessly in a future release.

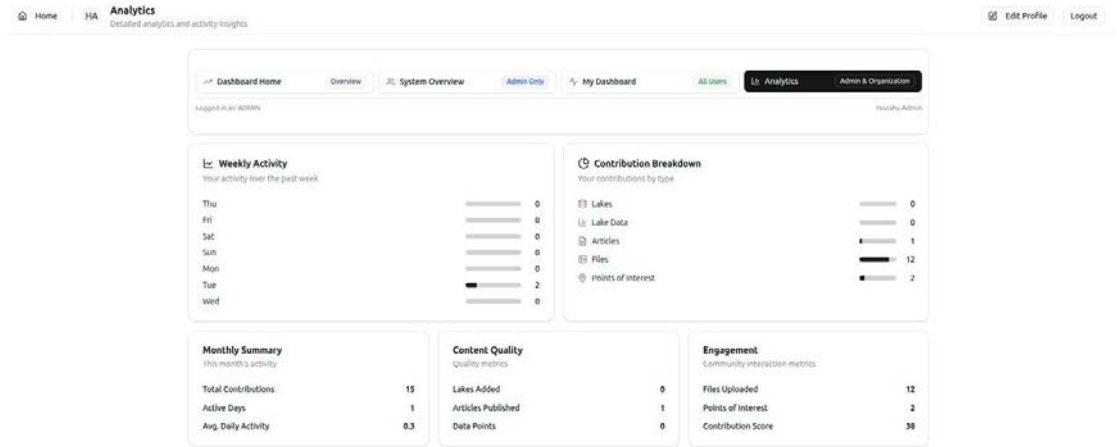

Figure 8 - Analytics Dashboard

System Overview (/dashboard/system-overview) is an administrative panel for platform monitoring and management, accessible only to administrators.

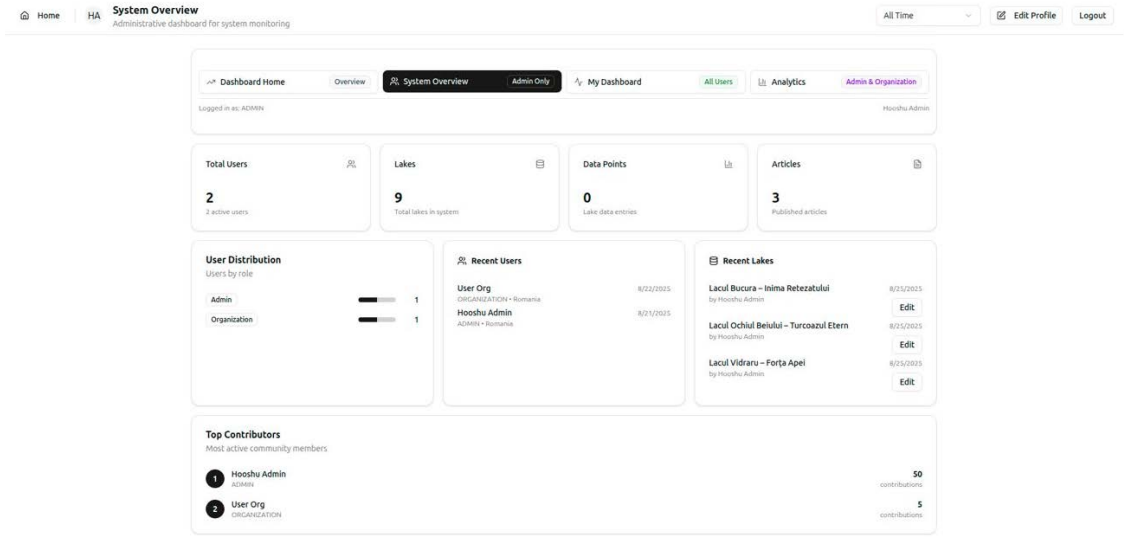

Figure 9 - System Overview Dashboard

5.4. Content Management

The platform includes robust content management capabilities:

RAGT Management (/articles/create, /articles/edit/:id) allows authorized users to create and update educational content with media integration. While rich text formatting is not yet available, the project structure is designed to support its seamless implementation in a future release.

Issue Reporting (/report-issue) enables users to report environmental concerns or technical problems, with tracking and management capabilities.

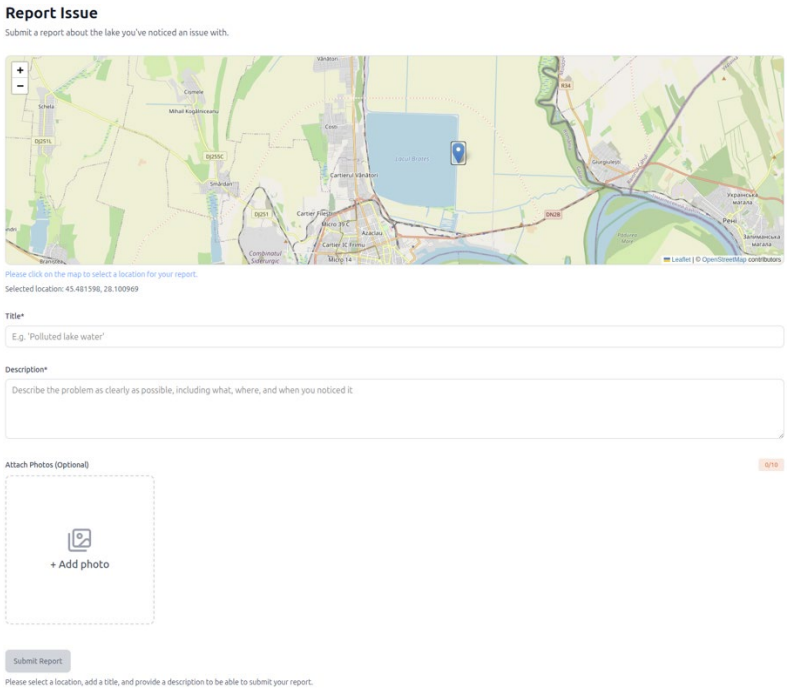

Figure 10 - Report Issue (Observation)

5.5. Administrative Features

The administrative section (/admin/) includes comprehensive tools for platform management:

Lake Management (/admin/lakes, /admin/manage-lakes) provides interfaces for adding, editing, and categorizing monitored water bodies.

User Management (/admin/users, /admin/permissions) allows administrators to manage user accounts, roles, and permissions.

Content Moderation (/admin/articles) offers tools for reviewing and managing published content.

Lake Parameters Management (/admin/lake-parameters) provides tools for creating, editing, and deleting lake parameter definitions, with usage tracking and delete protection.

5.6. Communication Tools

The platform facilitates interaction through:

Messaging System (/messages, /messages/new, /messages/:id) enables private communication between users, supporting both one-on-one conversations.

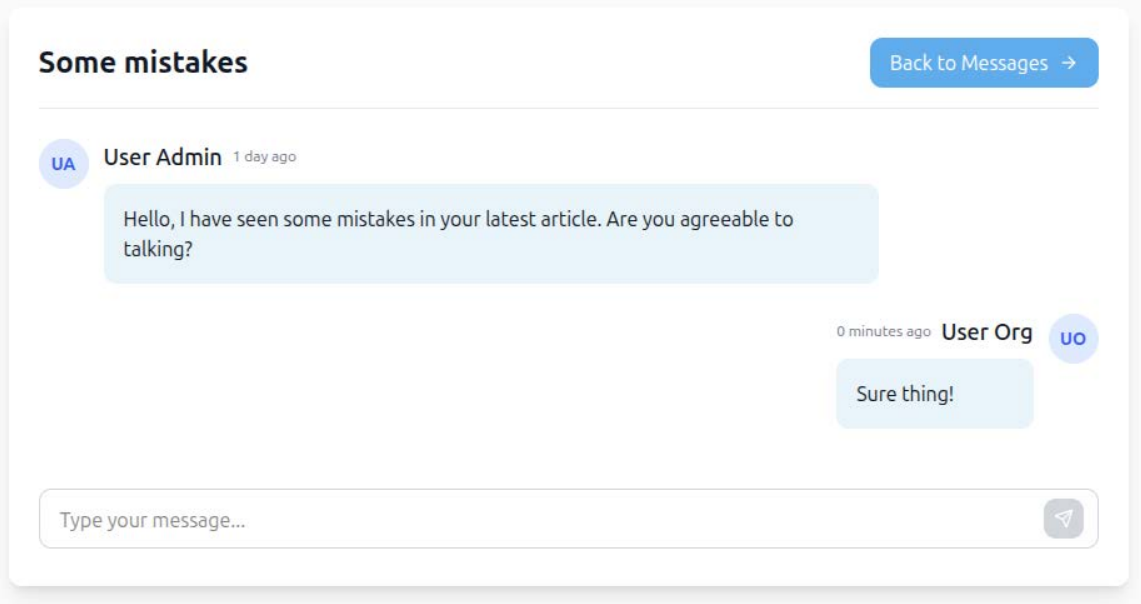

Figure 11 - Private Chat

5.7. Additional Features

Terms and Privacy (/terms) provides legal documentation and platform policies.

Point of Interest Management (/dashboard/pois-create-edit) allows for the creation and editing of points of interest related to monitored lakes.

This comprehensive routing structure demonstrates a well-thought-out platform that balances public information sharing with powerful tools for collaboration and management, all while maintaining appropriate access controls and user experiences tailored to different roles and needs.

6. Browser Compatibility

The ProCleanLakes D5.1 Knowledge Hub v1.0 has been designed with a structure that allows for seamless functionality across a wide range of web browsers and devices in future iterations. While full cross-browser testing and optimization have not yet been implemented, the prototype has so far been tested on Chromium-based browsers such as Google Chrome and Brave, where it performs reliably.

The project architecture has been intentionally developed to support easy extension toward broader compatibility, including other major browsers like Mozilla Firefox, Apple Safari, and Microsoft Edge. This ensures that in future releases, the

platform can be adapted with minimal effort to provide consistent access to environmental data and features across diverse technologies and connection qualities.

The responsive design already in place enables the prototype to adjust layouts and functionality based on screen size and device capabilities, laying the groundwork for an optimal viewing experience on desktops, laptops, tablets, and smartphones. As the platform evolves, progressive enhancement techniques and browser detection can be integrated to ensure that users on older or less common browsers are not excluded, while also guiding them toward the best possible experience.

7. Feature development

The development of the ProCleanLakes D5.1 Knowledge Hub v1.0 has followed a structured approach to ensure that all features meet user needs while maintaining technical excellence. The platform's feature set has been carefully prioritized based on user requirements, technical feasibility, and strategic importance to the project's conservation goals.

7.1. Current Implementation Status

The platform currently provides a solid foundation for the Decision Support Tool (DST) Prototype, with the project structure intentionally designed to support seamless expansion in future releases. At this stage, the focus has been on building the underlying architecture that will enable data collection, visualization, and analytical capabilities.

Although the full DST functionality is not yet implemented, the current structure has been designed to support seamless integration of upcoming features such as:

- Data collection infrastructure for water quality parameters
- Data visualization tools
- User interface components to support future DST features

This approach ensures that when development progresses, these capabilities can be added efficiently without requiring major architectural changes.

7.2. Planned DST Development

The next phase of development will focus on enhancing the DST with advanced analytical capabilities, including:

- Predictive modeling for water quality trends
- Scenario analysis tools for restoration planning
- Integration with external data sources for comprehensive ecosystem assessment
- Customizable reporting features for different stakeholder groups

7.3. Core Functionality Foundation

The platform has been designed with a solid architectural foundation that enables the future implementation of advanced lake monitoring tools. While features such as tracking water quality parameters, viewing historical data trends, and receiving alerts about significant changes in lake conditions have not yet been implemented, the current project structure is built to support their seamless integration in upcoming releases.

This foundation includes a robust data management system capable of handling large volumes of environmental data and optimized for fast query performance, ensuring that when these features are introduced, they can operate efficiently and reliably.

7.4. User Engagement and Collaboration

User engagement features have been designed to foster collaboration and knowledge sharing among the platform's diverse user base. These currently include comments, private messaging between users, and tools for community science data collection. The platform also provides administrative tools that allow moderators and administrators to manage content, users, and system settings efficiently.

7.5. Security and Access Control

Security has been a primary consideration throughout development, with features such as role-based access control, data encryption, and secure authentication mechanisms protecting sensitive information and ensuring that users only have access to appropriate features and data. The platform's modular architecture allows for the seamless integration of the enhanced DST features as they become available in future updates.

7.6. Future Roadmap

The development team has outlined a clear roadmap for the DST's evolution, with planned releases that will introduce increasingly sophisticated analytical tools and modeling capabilities. These future enhancements will be designed to work seamlessly with the existing platform infrastructure while providing additional value to users involved in lake conservation and management.