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Operationalising accessibility in marine pollution science communication: the Zeropol Hub case study

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Marine pollution is a major environmental challenge, and effective communication of scientific evidence is important for supporting public engagement, environmental governance, and evidence-based decision-making. Yet marine pollution communication resources are often fragmented across platforms and vary in language, format, audience orientation, and accessibility. This implementation case study describes the development and early deployment of the Zeropol Hub, an accessibility-oriented digital repository designed to curate validated science communication and educational resources on microplastics, per- and polyfluoroalkyl substances (PFAS), nutrient pollution, and underwater noise. We document the repository workflow for resource identification, screening, scientific validation, metadata classification, accessibility-oriented organisation, maintenance, and early monitoring. During the initial implementation period, the repository expanded from 71 to 103 resources, representing more than 20 languages and multiple communication formats. Web analytics provide descriptive indicators of early use and geographic reach, but do not measure user comprehension, inclusivity, discoverability, behavioural outcomes, or science-policy-society impact. The case study therefore demonstrates how accessibility principles can be operationalised as repository design and governance features, rather than demonstrating that these intended outcomes have already been achieved. The study offers a documented implementation approach that may inform development and evaluation of comparable environmental science communication infrastructures, while identifying user-centred and longitudinal evaluation as priorities for future research.

KEYWORDS
accessibility, digital repository, marine pollution, science communication, zero pollution

1 Introduction

1.1 Marine pollution and science communication

Marine pollution constitutes one of the most pressing and complex environmental challenges globally, with far-reaching consequences for ecosystem integrity, biodiversity, ecosystem services, human health, and economic sustainability. Marine pollutants, such as microplastics, chemical contaminants, nutrients and underwater noise exert cumulative pressures on marine ecosystems, threatening both ecological resilience and human well-being (Devriese et al., 2025; SAPEA, 2018). Addressing these impacts is central to international and European frameworks for environmental protection, including the United Nations Sustainable Development Goal 14 (Life Below Water), the EU Green Deal and Zero Pollution Action Plan, relevant EU environmental legal instruments and associated environmental legislation including the Marine Strategy Framework Directive (MSFD) and Water Framework Directive (WFD) (Devriese et al., 2023, 2025). Effective implementation of these policy and regulatory frameworks depends on coordinated action across science, policy, and society, supported by science communication approaches that translate complex evidence into accessible and actionable knowledge for diverse audiences (Agnew et al., 2023, 2024; Borja et al., 2025; van Leeuwen et al., 2025).

Scientific evidence plays a central role in marine governance and policy development; however, translating research into effective regulation, management, and societal action remains a persistent challenge (Dauwe et al., 2025; Devriese et al., 2023, 2025; van Leeuwen et al., 2025). Its influence depends not only on scientific quality but also on how effectively evidence can be communicated to and engaged with by policymakers and the public (Borja et al., 2025). Science communication encompasses a broad set of practices aimed at conveying scientific knowledge, methods, and findings to non-specialist audiences in ways that inform, raise awareness, engage, educate, and support evidence-based decision-making (Agnew et al., 2023; Borja et al., 2025). Within environmental and sustainability contexts, science communication plays a particularly important role in enabling informed public discourse, strengthening governance processes, and supporting behavioural and policy change (Maibach et al., 2023; Suffill et al., 2026).

Environmental policies, regulations and legislation are more likely to succeed with public support, highlighting the importance of clear communication to foster public understanding, engagement, and legitimacy (Black et al., 2019; Troya et al., 2022). The European Commission's Special Eurobarometer SP550: Attitudes of Europeans towards the Environment shows strong public concern about environmental issues, with citizens identifying pollution as one of the most serious environmental challenges and expressing support for stronger environmental protection measures (European Commission, 2020).

However, public understanding of specific marine pollution issues, e.g., sources, pathways, and impacts of MP pollution, remains inconsistent, variable and is often incomplete (Agnew et al., 2024; SAPEA, 2018). Public awareness also varies across pollutant types, with microplastics generating the greatest concern and underwater noise the least, while concern regarding specific forms of chemical pollution, such as per- and polyfluoroalkyl substances (PFAS), differs across European countries, with the highest levels of concern reported in Belgium and the Netherlands (Vaupotič et al., 2024). Such population-specific awareness often reflects a known regional pollution issue that has been highly profiled in local and national media. In contrast, a more limited understanding of marine pollution can constrain public engagement, reduce support for environmental policy, and weaken the translation of scientific evidence into societal action (Stoll-Kleemann, 2019; Suffill et al., 2026). The understanding of the drivers of public engagement and action reinforces the importance of accessible and effective science communication to support informed environmental decision-making (Agnew et al., 2023, 2024; Borja et al., 2025).

1.2 Communicating marine pollution: challenges & barriers

Despite significant advances in marine science, a persistent "knowledge–action gap" remains, which refers to the disconnect between the production of scientific knowledge and its translation into public understanding (UNESCO-IOC, 2021), societal action or policy implementation (Borja et al., 2025). While scientific knowledge may influence attitudes towards environmental matters (e.g., consumer decision making) (Bramoullé and Orset, 2018; Fernandes et al., 2020; Gelcich et al., 2014), changes in behaviour, public engagement, or regulatory uptake are not automatically achieved (Dunn et al., 2020). The disconnect arises from a combination of structural and epistemic barriers, including limited access to scientific knowledge, technical language, and mismatches between scientific outputs and stakeholder needs (Borja et al., 2025). In addition, environmental attitudes and policy support are shaped not only by knowledge but also by personal values, social norms, and existing beliefs (Fian et al., 2026; Stern, 2000).

Furthermore, marine and environmental scientists often receive limited formal training in communicating with non-academic audiences, which may constrain their ability to engage effectively with diverse public audiences and contribute to an epistemological divide between knowledge producers and knowledge users (Seys et al., 2022). These challenges are reflected in persistent disparities between scientific understanding and public awareness of several marine pollutants, including PFAS ("forever chemicals") (Suffill et al., 2025), underwater noise (Vukić et al., 2021), and eutrophication (Canfield et al., 2021), which remain comparatively less widely recognised than pollutants such as microplastics that have achieved greater public visibility (Suffill et al., 2025; Vaupotič et al., 2024).

Communicating marine pollution issues presents additional challenges, as it frequently involves conveying complex, uncertain, or politically sensitive information that may conflict with established beliefs, values, or behaviours. Effective science communication therefore requires transparency, credibility, and accessibility to foster trust and sustained engagement (Voci and Karmasin, 2024). Marine pollution research often spans multiple

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environmental pathways, evolving definitions, and changing evidence bases across pollutant types, making risks difficult to communicate clearly and consistently (SAPEA, 2018; Thompson et al., 2024). As scientific evidence develops, communicators must explain uncertainty while maintaining confidence in the evidence base and avoiding oversimplification. Communicating scientific disagreement can reduce support for mitigation actions, creating tensions between accurately representing uncertainty and maintaining engagement with potential responses (Fian et al., 2026; Wickham and Shriver, 2021). These challenges are reflected across marine pollution topics, including microplastics, PFAS, nutrients, and underwater noise, where public awareness, perceived risks, and scientific understanding continue to evolve (Agnew et al., 2024; Harclerode et al., 2021; Vaupotič et al., 2024).

The proliferation of misinformation and misleading narratives further complicates the science communication landscape. False, inaccurate or non-evidence-based information can spread rapidly through digital and social media platforms but appear legitimate (Agnew et al., 2023, 2024; Vosoughi et al., 2018). Marine pollution, especially plastic and MP pollution, has proven vulnerable to oversimplification, exaggeration, and inconsistent messaging, where such dynamics can undermine public understanding, distort risk perceptions, and erode trust in scientific institutions (Agnew et al., 2023, 2024). Addressing these challenges requires coordinated and adequately resourced communication strategies that are accessible, inclusive, and tailored to audience needs (Agnew et al., 2023; Seys et al., 2022; Zielinski et al., 2022). Bridging the knowledge–action gap depends not only on disseminating scientific information but on building trust, relevance, accessibility, and meaningful engagement across diverse societal groups (Agnew et al., 2024; Borja et al., 2025; Voci and Karmasin, 2024).

1.3 Accessibility and inclusivity in marine pollution science communication

Accessibility and inclusivity are foundational principles of effective science communication, particularly in the context of complex and societally relevant challenges such as marine pollution. Accessibility encompasses linguistic, cognitive, technical, and educational dimensions, all of which shape whether diverse audiences can understand, engage with, and use scientific knowledge (Agnew et al., 2023, 2024; Borja et al., 2025). In marine pollution contexts, where issues intersect with public health, economic activities, and environmental governance, equitable access to reliable information is increasingly recognised as essential for informed decision-making, environmental democracy, and meaningful public participation (Agnew et al., 2024; Devriese et al., 2025; Kopke et al., 2025; Rossi et al., 2024). Historically, science communication often relied on one-way dissemination practices in which scientists transmitted knowledge to relatively passive audiences (Borja et al., 2025). Contemporary approaches, however, increasingly emphasise dialogue, engagement, and responsiveness to audience needs, values, and contexts (Agnew et al., 2023; Borja et al., 2025; Horst et al., 2016; Kopke et al., 2019). This shift reflects growing recognition that science communication is not merely about transmitting information, but about enabling understanding, trust, and agency across diverse societal groups. Accessibility is therefore not an optional add-on but a structural requirement for effective science–policy–society interaction (Canfield et al., 2020; Phogat et al., 2025).

Multiple barriers continue to constrain accessibility. Technical language and disciplinary jargon can render scientific findings difficult for non-specialists to interpret, while the dominance of English in academic publishing limits inclusivity for non-English-speaking audiences (Borja et al., 2025; Seys et al., 2022). Paywalled publications and restricted access to data further exacerbate inequalities in access to scientific knowledge (Borja et al., 2025). Science communication resources are also frequently dispersed across multiple platforms, are of mixed quality and accuracy, and are not consistently adapted to the needs of different user groups, including policymakers, educators, and local communities (Agnew et al., 2023, 2024).

Addressing these barriers requires attention to several interrelated dimensions of accessibility. Linguistic accessibility involves providing multilingual resources to ensure equitable access to scientific information (Amano et al., 2021; Borja et al., 2025; Márquez and Porras, 2020). Cognitive accessibility refers to presenting complex scientific evidence in clear, comprehensible formats without compromising accuracy, where visual outputs and multimedia tools, such as infographics, videos, and interactive platforms, can support comprehension, knowledge retention and engagement (Bobek and Tversky, 2016; Franconeri et al., 2021). Educational accessibility refers to tailoring communication to audiences with varying levels of prior knowledge, learning needs and contexts. This includes different age groups, as well as students, educators, policymakers, and the general public, with the aim of enhancing ocean literacy and supporting informed decision-making (Seys et al., 2022; Zielinski et al., 2022). Technical accessibility emphasises open-access and user-oriented digital infrastructure that reduces barriers to information access and use (Borja et al., 2025).

Improving accessibility and inclusivity has been shown to strengthen public trust in science, increase engagement, and support behavioural change (Ashley et al., 2019; Stoll-Kleemann, 2019). Within marine pollution contexts, accessible communication may support public understanding of environmental risks and strengthen participation in governance processes (Agnew et al., 2024). These outcomes are particularly relevant to European environmental ambitions, including the EU Zero Pollution Agenda, which depend on accessible communication of scientific evidence across science, policy, and society (Black et al., 2019; Devriese et al., 2023, 2025). These accessibility challenges have contributed to growing interest in digital approaches that support broader dissemination, discoverability, and usability of science communication resources across diverse audiences.

1.4 Science communication infrastructure and digital repositories for marine pollution

Although traditional media (e.g., television, radio, and newspapers) continues to play an important role in informing the public about scientific and environmental issues (Keller and Wyles, 2021; Pop et al., 2023), the digitalisation of communication pathways has profoundly transformed how scientific knowledge is generated, disseminated, and accessed (Aiger et al., 2025; Diviacco and Iurcev, 2025; Krause et al., 2025; Metag et al., 2023; Rubio-Tamayo et al., 2024). While the digitalisation of communication pathways offers significant benefits, including improved efficiency in information transfer, wider reach, greater audience connectivity, and the amplification of evidence-based information, these developments are accompanied by numerous disadvantages (Agnew et al., 2023; Kopke et al., 2019; Krause et al., 2025; Metag et al., 2023). Online environments remain highly disorganised and fragmented, where reliable and unreliable information, including obsolete or misleading content, coexist across webpages, blogs, and applications, complicating the identification of trustworthy resources (Krause et al., 2025). Furthermore, digital decay continues to threaten information preservation through broken links, software obsolescence, and inactive or expired domains, reducing the accessibility and durability of online resources (Chapekis et al., 2024; Loan and Shah, 2020).

Coordinated and centralised online spaces, such as digital repositories and data portals offer practical solutions to several of these challenges by providing structured environments for the aggregation and validation of scientific information and educational resources (Seys et al., 2022). Digital repositories can be defined as organised digital systems that collect, manage, preserve, and provide access to digital resources, thereby supporting the long-term dissemination and communication of knowledge across user communities (Vrana, 2015). Such repositories support the efficient dissemination of scientific knowledge, facilitate informed decision-making, and help counter the spread of misinformation (Agnew et al., 2024; Aiger et al., 2025; Borja et al., 2025; Metag et al., 2023; Phogat et al., 2025). Furthermore, digital repositories are well suited to storing and presenting diverse information formats such as interactive tools, story maps, infographics, gamification elements, and audio-visual simulations, which can enhance understanding of complex, invisible, or geographically distant environmental issues, particularly in the context of marine pollution-related challenges (Agnew et al., 2023; Demmler and Stoll-Kleemann, 2025; Henderson and Green, 2020; Metag et al., 2023; Seys et al., 2022).

With increasing emphasis on maximising impact and achieving long-term solutions to complex socio-environmental challenges, EU research projects are increasingly adapting in how they are structured and evaluated, and how results are communicated, disseminated, and exploited (Powell and Joosse, 2024; EU, 2020). This reflects a shift from single-discipline and even multidisciplinary research, which is typically centred on peer-reviewed outputs for academic audiences, towards transdisciplinary approaches that actively involve non-academic stakeholders through operationalised processes and dedicated resources for engaging diverse audiences (Agnew et al., 2022; Borlaug and Svartefoss, 2025). As part of this shift, research projects increasingly produce curated, scientifically validated educational materials such as toolkits, interactive lesson plans, infographics, videos, audiovisual content, and newsletters. These are typically shared through project-specific websites and social media channels, apps, and other dedicated infrastructures. This expanding communication ecosystem enables interaction across scientists, institutions, communicators, and public audiences through multiple formats and channels, including communication infrastructures developed within European Union-funded research projects. However, each tool and platform presents distinct advantages and limitations, requiring careful selection to ensure alignment with communication objectives (Aiger et al., 2025; Krause et al., 2025; Portman et al., 2025).

Despite this expanded communication ecosystem, research projects have a finite lifecycle, including their associated engagement platforms and social media channels. While peer-reviewed publications generally remain discoverable through journal websites, bibliographic and citation databases such as Web of Science, academic search engines such as Google Scholar, reference management platforms such as Mendeley, and academic social networking and user-controlled document hosting platforms such as ResearchGate or Academia.edu, access to these other communication materials remains vulnerable to digital decay over time (Chapekis et al., 2024). This raises particular challenges for maintaining sustained access to project-specific science communications and educational materials and outputs after research project completion, which is often limited, uncertain, and difficult to ensure. Digital catalogues and data platforms such as EMODnet[1], UNEP's Global Plastics Hub[2] or Belgium's Coastal Portal[3] can support a wide range of stakeholders, including students, citizen scientists, community groups, and policy makers, among others (Szüdi et al., 2022). In parallel, digital repositories and archival infrastructures, such as Zenodo and Copernicus, facilitate the storage, sharing, and long-term preservation of research outputs and datasets, while also functioning as interoperable metadata infrastructures that connect data across platforms and user communities. These systems support both broader engagement and long-term preservation of digital materials (Geetha et al., 2016; Vrana, 2015), ensuring that research outputs remain accessible beyond the lifecycle of individual research projects. Therefore, institutional repositories such as the Marine Data Archive (MDA)[4], together with their discovery and access interfaces such as the Integrated Marine Information System (IMIS)[5], can play a key role in strengthening the dissemination, long-term preservation, accessibility, and reuse of marine scientific knowledge resources.

Research on marine pollution communication increasingly emphasises the role of structured and accessible digital infrastructures for supporting public understanding, engagement, and evidence-informed decision-making (Agnew et al., 2023). Digital repositories, marine data portals, and coastal WebGIS platforms provide mechanisms for organising, preserving, and presenting scientific and educational materials through searchable and user-oriented interfaces (Kopke and Dwyer, 2016; Martín Míguez et al., 2019; O'Dea et al., 2011). However, despite growth in digital communication approaches, persistent barriers remain. Communication materials are often distributed across project websites, institutional platforms, and temporary dissemination channels, creating challenges for

[1]https://emodnet.ec.europa.eu/en
[2]https://globalplasticshub.org/
[3]https://www.kustportaal.be/en
[4]https://marinedataarchive.org/
[5]https://www.vliz.be/en/imis

discoverability, accessibility, reuse, and long-term preservation. Language barriers and differences in audience orientation further limit practical access to marine pollution knowledge (Borja et al., 2025; Boucquey et al., 2019).

Although repositories and data infrastructures exist, relatively few centralised systems are designed specifically to curate validated, multilingual science communication and educational resources across multiple marine pollution topics. This gap motivates the present implementation case study of the Zero Pollution Online Hub (Zeropol Hub; https://zeropolhub.eu/), developed within SOS-ZEROPOL2030. The objective of this study is to document how accessibility-oriented principles were translated into a practical repository architecture and governance workflow, and to describe the Hub's early implementation using repository-development, dissemination, and web-analytics indicators. The study does not test whether the Hub improves user comprehension, inclusivity, discoverability, behaviour, or policy outcomes because such analyses require dedicated user-centred and longer term evaluation. Rather, the contribution is an applied account of how resource identification, scientific validation, metadata classification, accessibility-oriented organisation, repository integration, maintenance, and early monitoring can be operationalised within marine pollution science communication infrastructure. Figure 1 situates this contribution within the overall conceptual logic of the study, linking the communication challenges identified in the literature to the accessibility framework informing Hub development, its operationalisation through repository design and governance, and the implementation indicators examined in this case study. Importantly, the framework also distinguishes these implementation indicators from user-, behavioural-, and policy-level outcomes that fall beyond the scope of the present study and require future evaluation.

2 Methods

2.1 Study design and methodological approach

A descriptive digital-repository implementation case study design was adopted to document the development, implementation, and early deployment of the Hub within the Horizon Europe-funded SOS-ZEROPOL2030 project. The unit of analysis was the Hub as a communication infrastructure, including its resource-curation workflow, classification framework, repository architecture, maintenance procedures, dissemination activities, and early web-use indicators. Repository content focused on four marine pollution categories: PFAS, microplastics, nutrients, and underwater noise. The methodological workflow comprised repository development, resource identification and collation, scientific validation, accessibility-oriented classification, repository integration, and monitoring of early dissemination and usage indicators. Accessibility was operationalised in this study as observable repository design and classification features across linguistic, cognitive, technical, and educational dimensions. These implementation characteristics were not treated as direct measures of user comprehension, perceived usability, inclusivity, or communication effectiveness. Likewise, web analytics were used descriptively to characterise early use and geographic reach rather than as causal evidence of improved discoverability or engagement outcomes.

2.2 Hub development and repository architecture

Repository implementation followed a modular architecture designed to support resource organisation, classification, and retrieval (Figure 2). The platform was implemented as open access, without registration requirements or paywall restrictions, and designed to support access across desktop and mobile environments and compatibility across commonly used browsers. Materials were organised according to pollutant type, resource format, target audience, and language. Metadata tagging and structured classification systems were implemented to support filtering, navigation, and retrieval. Repository architecture included structured navigation pathways and metadata fields to enable users to browse and retrieve content according to pollutant category, communication format, language, and intended audience. Supported formats included infographics, videos, lesson plans, reports, policy briefs, and interactive media.

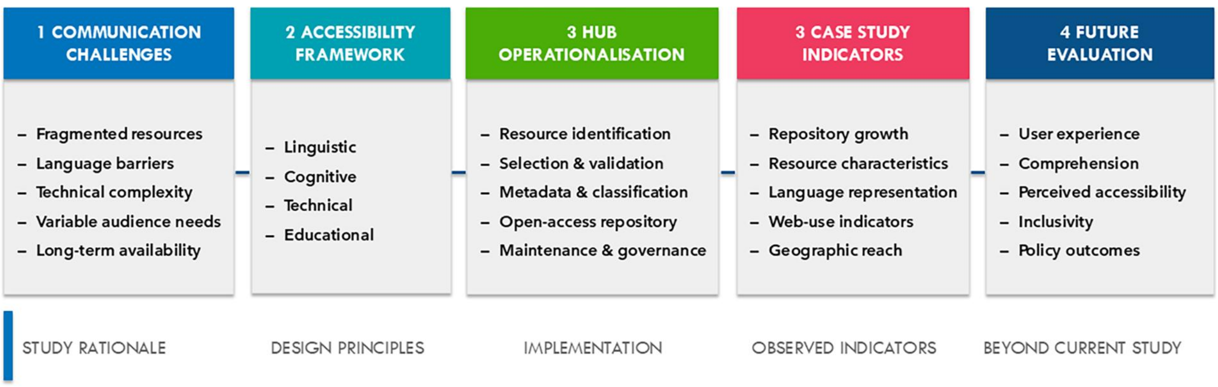

FIGURE 1
Conceptual framework of the Zeropol Hub implementation case study, linking identified marine pollution communication challenges and accessibility dimensions to repository operationalisation, initial implementation indicators, and outcomes requiring future evaluation.

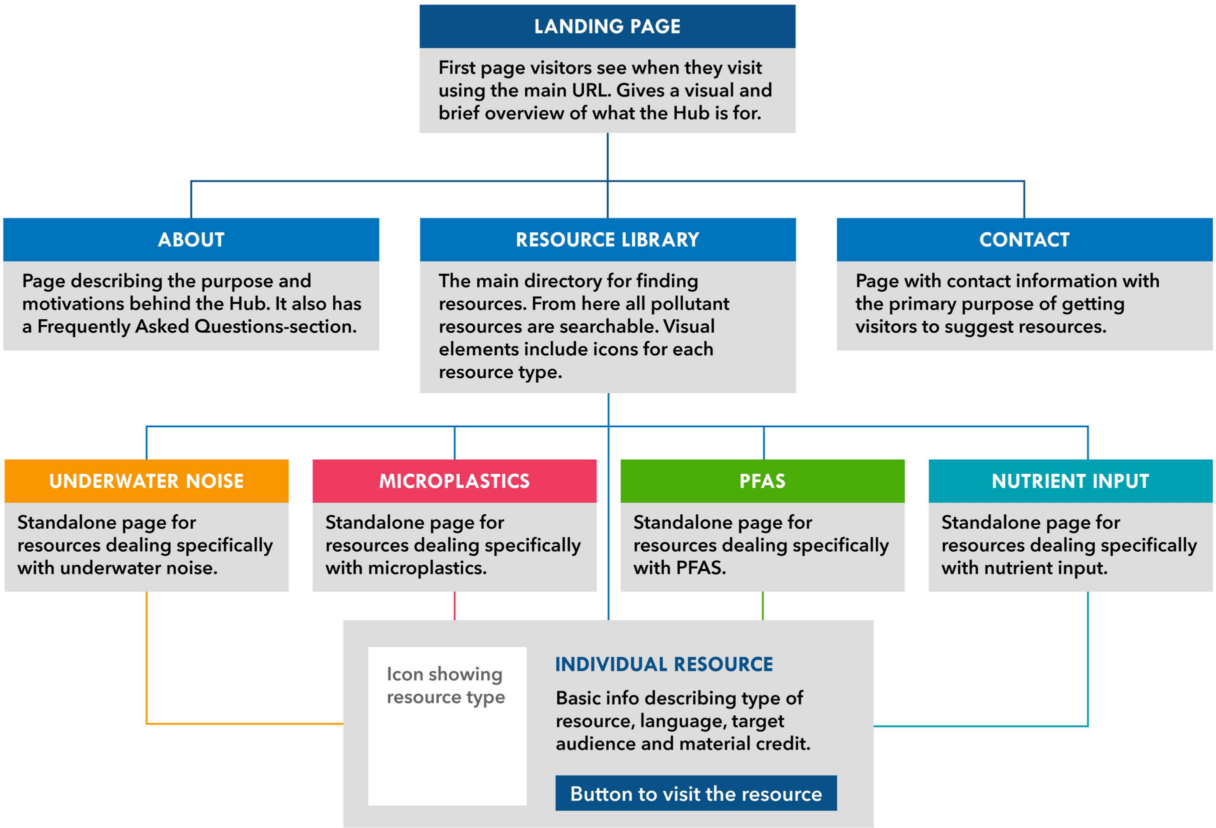

FIGURE 2
Schematic showing the complete site architecture of the Hub with descriptions of the content and intent of each page.

2.3 Resource identification, selection, and validation

The identification, selection, validation, and organisation of resources followed a structured multi-phase process designed to ensure scientific reliability, educational relevance, and accessibility.

2.3.1 Phase 1: resource identification

Resources were identified through broad internet searches, initially conducted using the Google search engine with search terms relevant to each of the four marine pollution categories (PFAS, microplastics, nutrients, and underwater noise). Searches targeted publicly available science communication and educational resources hosted by research project websites, institutional repositories, educational platforms, governmental and intergovernmental organisations, and non-governmental or civil society organisations (NGOs/CSOs). Examples included resources hosted by organisations such as NOAA, the European Environment Agency, and MIO-ECSDE (Mediterranean Information Office for Environment, Culture and Sustainable Development). Relevant outputs from European research projects were also considered, and additional resources were identified through contributions from SOS-ZEROPOL2030 consortium partners and wider research networks.

To improve transparency and reproducibility, resource identification should be understood as a structured curation process rather than a systematic literature review. Searches targeted publicly available communication and educational outputs relevant to the four focal pollutants and prioritised institutional and scientific provenance. Candidate resources were logged before screening so that source, pollutant topic, format, language, intended audience, URL, and subsequent verification status could be recorded consistently.

2.3.2 Phase 2: resource selection and screening

Selection criteria were developed to ensure credibility, educational relevance, and accessibility. Included resources were required to:

(i) provide educational information related to one or more of the four marine pollutant categories (PFAS, microplastics, underwater noise, and nutrients);
(ii) originate from verified institutional or scientific sources;
(iii) be available without paywalls or restricted access requirements; and
(iv) provide educational or science communication value for at least one target end-user group.

Resources considered promotional, commercially biased, or lacking scientific objectivity were excluded.

2.3.3 Phase 3: scientific validation and database organisation

Selected resources were compiled in a centralised database and organised by pollutant type, contributing consortium partner, date, title, descriptor, format/type, target audience/end user, web link, and verification status. Scientific validation was undertaken by five consortium scientists with disciplinary expertise relevant to each pollutant category. Independent validation focused on whether the scientific content was consistent with the current evidence base, appropriately represented the pollutant issue for its intended communication purpose, and did not contain evident scientific inaccuracies or misleading claims. A form was used to gather the expert's assessment which determined the inclusion status of reviewed resources. Classification and validation status were recorded in the resource-management system before repository integration.

2.3.4 Phase 4: repository integration and metadata assignment

Following validation, resources were transferred to the Hub and assigned structured metadata fields for classification and retrieval. Metadata categories included pollutant type, resource format (e.g., factsheet, infographic, lesson plan, policy brief), language, and intended target audience, which includes age groupings, policymakers, and general public. Descriptive text was included for each entry to provide contextual information such as type of resource, language, suitability for audience type and material credit (Figure 3) as provided by the resource developer, host, or owner of the resources. Additional contextual metadata were included where available and varied according to resource type. Examples included video duration and geographical focus (Figure 4). Where a resource was re-hosted rather than linked to its original external source, redistribution was limited to materials for which the applicable licence permitted re-hosting or permission had been obtained from the resource owner or rights holder.

2.3.5 Phase 5: ongoing maintenance and quality assurance

Procedures were established to support repository reliability and continuity during the project implementation period through continued identification of emerging resources and periodic review of existing content. Quality-assurance activities included verification of links, identification of outdated materials, and maintenance of repository functionality. The internal resource-management system recorded metadata for each resource, including pollutant category, resource format, language, intended audience, source information and validation status, supporting consistent classification, repository integration and quality assurance. Bi-monthly verification procedures and a Hub management manual supported standardised resource identification, validation, classification, and maintenance processes. These procedures represent mechanisms intended to support continuity; the present study does not provide evidence of long-term sustainability beyond the observed implementation period.

2.4 Accessibility and classification framework

The Hub implemented a structured accessibility framework encompassing linguistic, cognitive, technical, and educational

FIGURE 3
Screenshot illustrating the descriptive text included for each resource entry to provide contextual information.

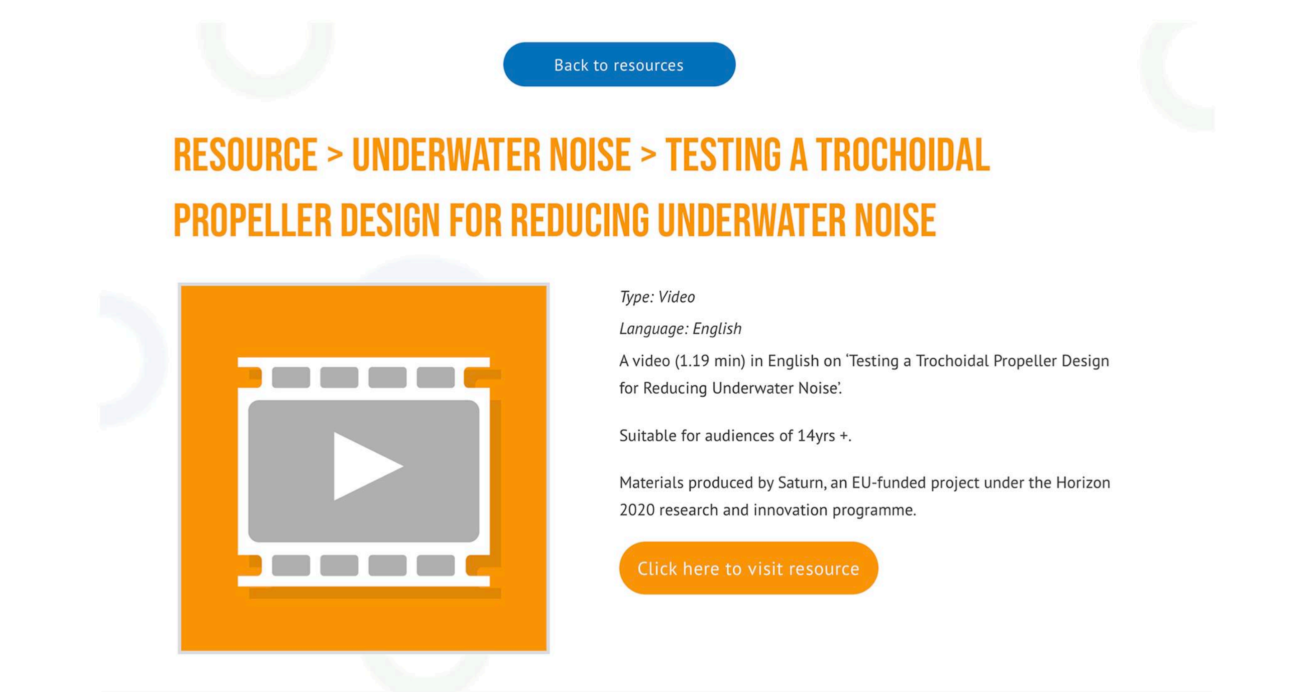

FIGURE 4
Screenshot illustrating the inclusion of additional descriptive text, specifically for video resources, where the duration of the video is indicated.

dimensions to guide resource organisation, classification, and discoverability (Table 1). Accessibility dimensions were used as classification criteria during repository integration and metadata assignment. Collectively, the framework provided a structured approach for organising repository resources and assigning metadata across accessibility dimensions. The framework was subsequently used to support repository implementation and evaluation.

2.5 Monitoring and evaluation of repository implementation

Following the soft launch of the Hub in February 2025, monitoring procedures were implemented to describe repository development, early website use, geographic reach, and dissemination during the initial deployment period. Repository-development metrics were derived from internal resource-management records and included resource growth, pollutant coverage, resource-format diversity, and linguistic representation. Dissemination monitoring documented presentations at scientific and stakeholder events and other project outreach associated with repository deployment. The internal resource-management system additionally recorded metadata for each resource, including pollutant category, resource format, language, intended audience, source information and validation status, thereby supporting consistent classification, repository integration and subsequent quality-assurance procedures. Bi-monthly checks assessed the continued availability of external links and identified outdated or inaccessible resources.

Website activity was monitored primarily using Simple Analytics, a privacy-oriented web-analytics platform that does not use cookies or persistent visitor identifiers. Simple Analytics data were available from May 2025 and were used for the website-use and geographic indicators reported in this study through April 2026. For comparison and supplementary server-level monitoring, AWStats log-file analytics were available from January 2025. Because the two platforms use different measurement approaches, the descriptive results reported below are identified according to the source metric and are not interpreted as directly interchangeable measures of individual users or sessions.

Within Simple Analytics, the platform's "visitors" metric is privacy-preserving and does not track an individual across sessions; pageviews record requests to individual pages and can therefore exceed the visitor count. Recorded access to a selected Hub resource or pollutant-category page was treated as a page request recorded by Simple Analytics. The platform filters likely bot traffic using data-centre IP-address lists without retaining visitor IP addresses; AWStats separately identifies and excludes traffic classified as robots/spiders from its visitor tables. Some residual bot traffic may nevertheless remain. Country attribution in Simple Analytics is inferred from the visitor device time zone rather than stored IP-address geolocation and should therefore be interpreted as approximate. AWStats derives country from IP-address information and may be affected by VPN use. Simple Analytics does not require cookie consent for its privacy-preserving measurements; users are informed of the analytics tools through the Hub privacy statement.

These analytics describe recorded website activity only. They do not identify users' motivations, comprehension, satisfaction, navigation success, demographic characteristics, or downstream use of information, and country-level attribution should not be interpreted as representative audience sampling. Internal/team

TABLE 1 The hub accessibility and classification framework.

Accessibility dimension	Accessibility barrier	Repository implementation	Accessibility objective
Linguistic	Dominance of English-language scientific communication limiting reach and inclusivity	Inclusion and categorisation of multilingual resources, enabling users to identify materials available in different languages	Support access to scientific and educational content across linguistic groups
Cognitive	Complexity of scientific information and variation in prior knowledge	Inclusion of materials using clear language and visual communication formats, including infographics, videos, and interactive resources; classification according to communication format	Support interpretation of environmental information across different knowledge levels
Technical	Barriers related to institutional access, financial restrictions, and technological usability	Prioritisation of open-access resources, compatibility across devices and browsers, and exclusion of paywalled or registration-restricted materials	Support usability and reduce practical barriers to access
Educational	Difficulty identifying materials appropriate for different audiences and use contexts	Classification and descriptive organisation according to intended audience (e.g., by age group or type of target audience)	Support identification of resources appropriate to different educational and communication contexts

FIGURE 5
Timeline of Hub soft launch and dissemination activities (February 2025–February 2026).

traffic was not separately documented as excluded in the information available for this revision and is therefore not assumed to have been removed.

3 Results

3.1 Hub deployment and dissemination

The Hub (https://zeropolhub.eu/) was soft-launched online in February 2025 and provided a centralised, open-access repository containing educational and science communication resources relating to four marine pollution categories: microplastics, PFAS, nutrients, and underwater noise. Following deployment, dissemination activities were undertaken to increase awareness of the Hub (Figure 5). In May 2025, the Hub was presented during a SOS-ZEROPOL2030 workshop at the European Maritime Day event in Cork, Ireland, introducing the repository to participants from marine science, industry, governance, policy, and stakeholder sectors. In October 2025, the Hub was presented to the European Marine Board Communication Panel, involving marine science communication experts from across Europe. From early 2026 onwards, the Hub was promoted through the SOS-ZEROPOL2030 project website and associated social media channels.

3.2 Repository growth and resource characteristics

3.2.1 Repository growth

Following its online deployment in February 2025, the Hub underwent continued expansion through addition of marine pollution science communication resources. At the point of soft launch, the repository contained 71 individual resources spanning the four focal pollutant categories: microplastics, PFAS, nutrients, and underwater noise. By October 2025, the repository had expanded to 103 resources (Table 2), representing an increase of approximately 45% during the initial implementation period. Repository growth continued through the further inclusion of educational and science communication materials through resource identification and collation, scientific validation and accessibility-oriented classification.

3.2.2 Distribution by pollutant category

Resources were distributed across all four marine pollution categories during the initial implementation period, with representation varying according to the availability of identified materials and source contributions. In October 2025, underwater noise constituted the largest repository category ($n = 36$; 35%), followed by PFAS ($n = 26$; 25.2%), microplastics ($n = 24$; 23.3%), and nutrients ($n = 17$; 16.5%) (Table 2).

3.2.3 Resource format diversity

The repository included a diverse range of educational and science communication formats. Resource types included infographics, factsheets, videos, lesson plans, reports, policy briefs, podcasts, interactive resources, educational toolkits, animations, websites, and downloadable communication materials. Formats represented visual, textual, audiovisual, interactive, and downloadable resource types.

3.3 Accessibility features and repository structure

Repository resources were organised and classified according to linguistic, educational, technical, and cognitive accessibility dimensions. Repository implementation included multilingual resources, audience-based categorisation, metadata-supported navigation, and multiple communication formats. The accessibility features implemented across these dimensions are described below.

3.3.1 Linguistic accessibility

Repository resources were available in more than 20 languages at the time of analysis, with multilingual content represented across all four pollutant categories and language availability varying between categories and resource types. Resources relating to microplastics demonstrated broad linguistic representation, with materials available in 19 languages, while several underwater noise communication resources included multilingual subtitles. Table 3 summarises examples of multilingual accessibility features represented within the Hub.

3.3.2 Educational accessibility

Repository resources were classified according to intended audience categories. Included audience categories comprised children across different age groupings, policymakers, and adult members of the general public. Hub resources included school-oriented lesson plans, visual learning materials, policy-focused communication outputs, and introductory resources designed for non-specialist audiences. Examples of audience-based categorisation are summarised in Table 4.

TABLE 2 Distribution of resources by marine pollution category.

Pollutant	Number of resources	Percentage of repository
Underwater noise	36	35%
PFAS	26	25.2%
Microplastics	24	23.3%
Nutrient pollution	17	16.5%
Total	**103**	**100%**

Bold values used for total values.

TABLE 3 Examples of multilingual accessibility features represented within the hub.

Accessibility feature	Example implementation
Multilingual resources	Materials available in >20 languages
Subtitled audiovisual materials	Underwater noise videos with multilingual subtitles
Language categorisation	Metadata filtering by language

TABLE 4 Target audience and example of resource focus within the Hub.

Audience category	Example resource focus
Children (age-grouped)	Introductory educational materials
Students	Learning materials
Educators	Lesson plans and teaching materials
Policymakers	Policy briefs

3.3.3 Technical and cognitive accessibility

Repository access was provided without registration requirements or paywall restrictions and supported use across devices and browsers. Where external resources became unavailable or inaccessible, downloadable versions were hosted within the repository only where the applicable licence permitted redistribution or where permission to re-host the material had been obtained from the resource owner or rights holder. Materials for which redistribution rights could not be established were not re-hosted.

Metadata categorisation and filtering systems enabled users to search and navigate resources according to pollutant type, language, format, and intended audience. Descriptive metadata accompanying each resource included contextual information such as format, duration, geographical relevance, and source organisation. Cognitive accessibility was further supported through the provision of multiple communication formats (Section 3.2.3) alongside descriptive metadata to accommodate different information and learning preferences.

3.4 Early user engagement and repository reach

Early website-use and reach indicators were described using web analytics and dissemination monitoring during the initial implementation period. These analytics are reported as descriptive indicators of recorded website activity and are not treated as direct measures of accessibility, discoverability, user comprehension, inclusivity, or communication effectiveness.

3.4.1 User engagement metrics

Between May 2025 and April 2026, Simple Analytics recorded 252 visitors under the platform's privacy-preserving visitor metric and 1,433 pageviews. Activity across the pollutant-specific resource libraries is shown in Figure 6 using the Simple Analytics visitor metric. The underwater-noise library recorded the highest activity, followed by microplastics, PFAS, and nutrients. These differences describe observed website traffic during the monitoring period and should not be interpreted as evidence of comparative public interest, accessibility, discoverability, or communication effectiveness because acquisition pathways, user characteristics, and exposure to dissemination activities were not controlled.

3.4.2 Most accessed resources

Recorded access varied across pollutant categories and communication formats. In Table 5, recorded access represents a page request to the relevant Hub resource page captured by Simple Analytics; it does not represent a verified individual user or a measure of downstream engagement with the linked resource. Several of the resources with the highest recorded access counts related to underwater noise and microplastics. These rankings are descriptive and may reflect multiple factors, including repository composition, external search visibility, dissemination, or pre-existing user interest; the available analytics do not permit these explanations to be distinguished (Table 5).

3.4.3 Geographic reach and multilingual resource use

Simple Analytics recorded website activity attributed to multiple countries during the May 2025–April 2026 monitoring period. Country was inferred from the visitor device time zone rather than stored IP-address geolocation and should therefore be interpreted as approximate. The largest share of attributed visitors was from Ireland, followed by Portugal, the United States, and the United Kingdom (Figure 7). Non-English resources also received recorded accesses, including the Dutch underwater-noise website Geluidsoverlast in de Noordzee (15 accesses), the Dutch interactive media resource Herrie achter de horizon (13), the German-language microplastics factsheet Mikroplastik Merkblatt (9), and the underwater-noise infographic Anleitung zur Verringerung des Unterwasserlärms durch Schiffe (9). These observations demonstrate recorded use of multilingual resource pages but do not establish whether multilingual provision improved inclusivity or accessibility for particular user groups.

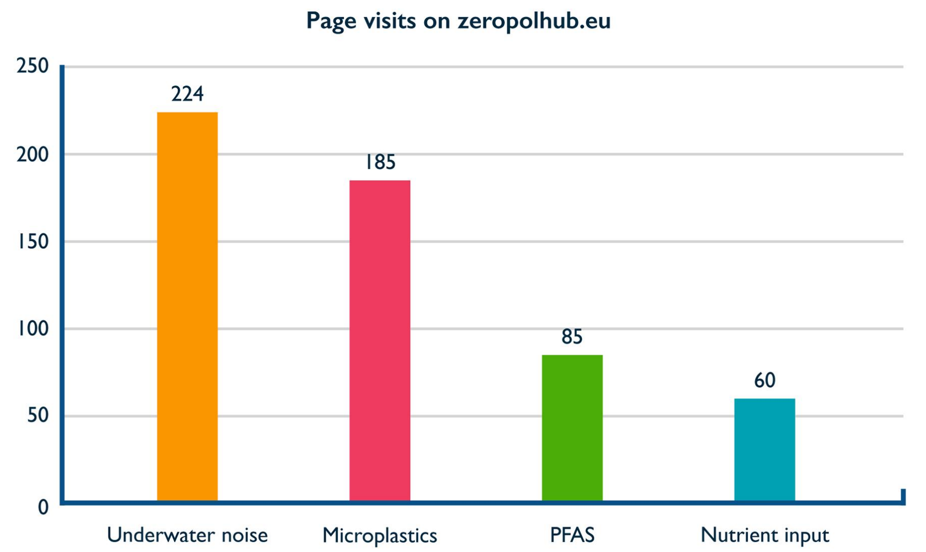

FIGURE 6
Recorded activity across pollutant-specific resource libraries between May 2025 and April 2026, based on the simple analytics “visitors” metric as defined in Section 2.5.

TABLE 5 Most accessed repository resources during the initial monitoring period (May 2025–April 2026).

Resource title	Pollutant category	Resource type	Resource format	Recorded accesses
How to reduce underwater noise from shipping	Underwater noise	Educational resource	Infographic	79
Slowing down ships leads to much quieter oceans	Underwater noise	Communication resource	Video	20
Natural processes affecting distribution and fate of microplastics	Microplastics	Scientific communication resource	Infographic	15

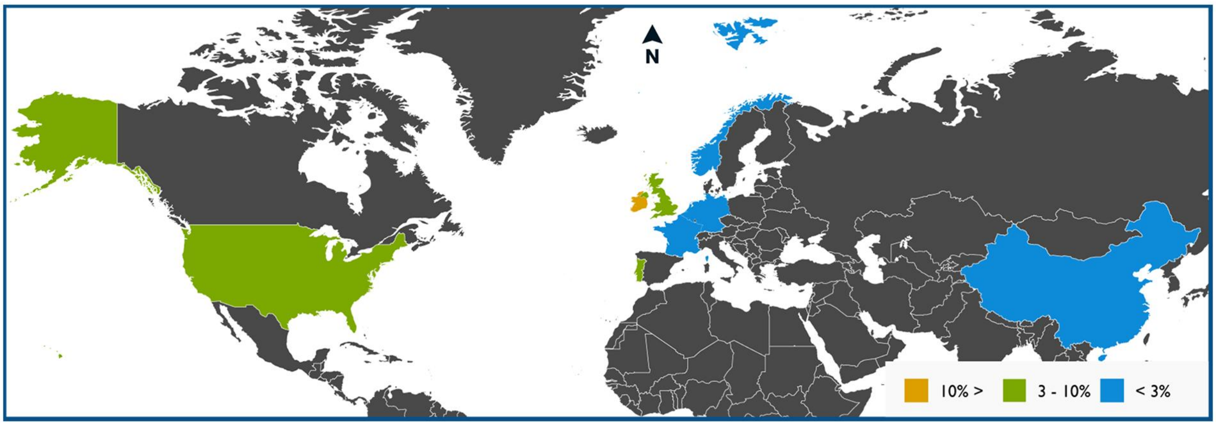

FIGURE 7
Geographic distribution of visitors attributed by simple analytics during the initial monitoring period (May 2025–April 2026). Country attribution is inferred from the visitor device time zone and is therefore approximate. The highest proportion of attributed visitors was from Ireland (64%), followed by Portugal (9%), the United States (7%), and the United Kingdom (4%). Additional visitors were recorded from Germany (3%), The Netherlands (3%), Norway (2%), Belgium (1%), France (1%), and China (1%).

4 Discussion

4.1 Operationalising accessibility through repository infrastructure

This implementation case study documents how accessibility considerations identified in the literature were translated into the design and early operation of a digital repository through the Zeropol Hub. The evidence presented concerns implemented repository features and governance procedures rather than measured improvements in accessibility outcomes. Previous research has identified persistent barriers to marine pollution science communication, including fragmented communication environments, language constraints, technical barriers to access, differences in how environmental topics and communication resources are represented and discovered, and challenges in translating scientific evidence into usable formats (Agnew et al., 2023, 2024; Borja et al., 2025; Seys et al., 2022). The Hub provides a practical example of an infrastructure designed in response to these challenges. The methodology translated linguistic, educational, cognitive, and technical accessibility considerations into operational procedures, while the results document their implementation through multilingual provision, audience categorisation, metadata-supported navigation, multiple communication formats, scientific validation procedures, and open-access architecture.

Repository implementation provides a practical example of how accessibility dimensions identified were translated into repository design. Linguistic accessibility was implemented through multilingual resource inclusion and filtering (>20 languages); educational accessibility through audience categorisation; cognitive accessibility through multiple communication formats; and technical accessibility through open-access architecture and metadata-supported navigation. Repository growth from 71 to 103 validated resources should be interpreted primarily as evidence that repository content can remain dynamic and expandable during deployment rather than as evidence of communication effectiveness or long-term sustainability. The increase illustrates that communication materials distributed across projects and institutions can be identified, validated, and integrated through structured curation processes. At the same time, growth introduces governance challenges. Maintaining accessibility over time requires periodic review of repository composition, removal or replacement of outdated materials, verification of external links, and continued metadata management to ensure that increasing volume does not reduce usability or navigability. These requirements align directly with the procedures described in Section 2.3 (Phase 5).

Accordingly, accessibility in this case study is interpreted as a set of repository design characteristics intended to reduce practical barriers to locating and using communication resources, rather than as a measured improvement in user understanding, usability, or engagement. Multilingual provision was used to address linguistic barriers, audience categorisation to support educational accessibility, varied formats to address different information preferences, and open-access implementation to reduce technical access constraints. Whether these features achieve their intended effects for different audiences remains an empirical question for future user-centred evaluation.

4.2 Discoverability as a distinct dimension of accessibility in practice

While accessibility was a central objective of repository development, the implementation results suggest that discoverability represents an additional and distinct consideration for science communication infrastructure. Access to information does not necessarily ensure that users can locate relevant content efficiently or identify resources suited to their needs. To reflect this, the repository incorporated metadata structures, filtering systems, audience categorisation, pollutant-specific organisation, and multilingual navigation intended not only to increase availability of resources but also to support discoverability. This distinction is particularly relevant in the context of the barriers identified in the literature review, which highlight that environmental communication challenges often arise not from a complete absence of information but from fragmentation, inconsistent organisation, and difficulties locating reliable materials across dispersed communication environments (Borja et al., 2025). Repository implementation suggests that discoverability mechanisms may therefore be as important as accessibility measures in shaping practical use of communication outputs.

Patterns observed across repository-development metrics, website analytics, and dissemination monitoring illustrate early use of the implemented repository features but do not validate discoverability as an outcome. Linguistic accessibility was operationalised through inclusion of resources in more than 20 languages and supported through language filtering and repository organisation. Recorded access to Dutch- and German-language materials confirms that non-English resources were used. However, because acquisition pathways and user needs were not measured, it cannot be determined whether users found these materials through repository navigation, external search engines, referrals, or language-specific searches, nor whether multilingual provision reduced a barrier for those users.

Educational and cognitive accessibility were similarly reinforced through resource diversity and audience categorisation. Materials were organised for children, students, educators, policymakers, and public audiences and included visual, audiovisual, textual, and interactive formats. The prominence of visual and concise communication formats among the most highly accessed resources in the Hub aligns strongly with wider observations in the literature that digital science communication increasingly relies on multimodal formats to support comprehension across diverse audiences (Agnew et al., 2023; Borja et al., 2025).

Early web-use metrics provide a descriptive account of repository activity rather than a direct measure of discoverability or engagement quality. Between May 2025 and April 2026, the Hub recorded 252 visitors and 1,433 page views. These data show that repository pages were accessed during early deployment, but they do not establish how users arrived, whether navigation was successful, how long or meaningfully resources were used, or whether access produced learning or other communication outcomes.

Variation in engagement across pollutant categories provides further insight. Interestingly, underwater-noise resources recorded the highest levels of access despite literature identifying underwater noise as a comparatively less publicly recognised marine pollution issue (Vaupotič et al., 2024; Vukić et al., 2021). The higher engagement with underwater-noise resources may reflect several interacting factors. One interpretation is that repositories help surface less publicly visible pollution topics by reducing fragmentation. However, an alternative explanation is differential competition within digital search environments e.g., compared to more heavily represented topics such as microplastics or PFAS, underwater-noise resources may face less competition in search indexing and therefore achieve greater visibility. This pattern may also reflect users with pre-existing interest or professional engagement seeking specialised information. The observations highlight that discoverability increasingly depends not only on repository architecture but also on how external search ecosystems, including search engines and AI-supported retrieval systems identify, prioritise, and surface repository content. Repository usability therefore depends partly on metadata quality, indexing practices, and search visibility beyond the repository itself.

At the same time, accessibility-oriented repositories cannot fully compensate for inequalities in underlying communication ecosystems. Differences in repository composition across pollutant categories could reflect broader variation in availability of communication outputs and suggest that repository approaches may need to be complemented by targeted communication development where resources remain limited. Taken together, these findings suggest that repositories may influence environmental science communication efforts, not only by improving access but by shaping what information becomes visible, searchable, and discoverable within complex information environments.

4.3 Governance and science communication stewardship

Beyond documenting resource availability, the Hub case study contributes by describing the governance processes used to select, validate, organise, and maintain science communication resources. The operational workflow, including resource identification, inclusion criteria, scientific validation, metadata assignment, quality assurance, and maintenance protocols, extends the analysis from interface features toward communication stewardship.

Governance in this context refers to the processes that determine how communication resources are curated, classified, updated, and sustained over time. Accessibility may increase opportunities for use and discoverability may influence whether information is found, but governance influences whether information remains reliable, organised, and available. This distinction is particularly relevant in marine pollution communication contexts where concerns around information quality, evidence credibility, and long-term availability remain persistent challenges (Agnew et al., 2024; Krause et al., 2025). These challenges are also reflected in literature emphasising the need for sustained institutional coordination to support long-term marine knowledge infrastructures (Borja et al., 2025). Repository implementation therefore suggests that accessibility, discoverability, and governance are interconnected but distinct functions of marine pollution communication infrastructure. The governance approach adopted within the Hub aimed to support consistency across pollutant categories and audience groups while maintaining scientific integrity and repository usability. Although repository success was not formally evaluated through user outcomes, implementation demonstrates that structured governance procedures can support consistency, reduce risks associated with outdated information, and maintain repository usability during early deployment. This case study contributes to wider discussions around marine pollution knowledge infrastructures by illustrating that communication effectiveness may depend not only on producing materials but also on sustaining the organisational systems through which materials remain locatable, accessible and usable over time.

4.4 Sustaining accessibility-oriented communication infrastructures

A further issue emerging from both the literature and the implementation process concerns the sustainability of accessibility-oriented communication infrastructures beyond individual project lifecycles. Previous work has highlighted how communication outputs developed through funded projects frequently become difficult to locate, inaccessible, or disconnected from dissemination pathways over time, especially after the project has ended (Chapekis et al., 2024; Loan and Shah, 2020). These challenges are consistent with broader discussions on the fragmentation of marine knowledge systems and the need for longer-term structural approaches to communication infrastructure (Borja et al., 2025). In response, repository implementation through the Hub incorporated maintenance procedures, governance protocols, periodic verification, and structured metadata management. Long-term sustainability also requires recognising that discoverability occurs within competitive digital environments. Topics with extensive online coverage may compete against large volumes of existing content, reducing visibility of individual repositories despite high-quality materials. Conversely, repositories may play a particularly important role for emerging or less visible marine pollution topics where reliable resources are comparatively limited.

From this perspective, accessibility can be treated as a continuing organisational responsibility rather than a one-time publication characteristic. The present study documents maintenance and governance mechanisms implemented during the project period; it does not demonstrate that these functions will persist after active project support ends. Although developed specifically for marine pollution, elements of the implementation approach such as structured curation, accessibility-led classification, multilingual organisation, metadata-supported navigation, and governance procedures, may be relevant to other environmental communication contexts. However, their transferability should be evaluated rather than assumed.

4.5 Limitations and future directions

Several limitations should be considered when interpreting these findings. First, this is an initial implementation case study rather than an outcome evaluation. Repository indicators and web analytics describe development and recorded use but cannot determine educational outcomes, changes in awareness, perceived accessibility, inclusivity, navigation success, policy influence, behavioural impacts, or causal effects on science-policy-society interaction. Second, repository composition reflected the availability of existing communication materials and partner contributions; differences across pollutant categories therefore may influence traffic patterns and should not be interpreted as indicators of relative issue importance. Third, accessibility and discoverability were operationalised through design and implementation characteristics rather than direct user testing. Fourth, web analytics provide aggregate behavioural traces and do not identify motivations, user profiles, search pathways, satisfaction, comprehension, or the representativeness of users. Fifth, the observation period is insufficient to demonstrate long-term sustainability. Finally, the resource-identification process was designed for applied repository curation rather than as a systematic review; reproducibility therefore depends on transparent documentation of the operational search, screening, validation, and maintenance procedures.

Future research should therefore move beyond implementation metrics and use longitudinal and user-centred methods to test the outcomes that the present repository design is intended to support. Relevant approaches include usability testing, task-based navigation studies, surveys or interviews with defined audience groups, analysis of acquisition pathways, and measures of comprehension, perceived accessibility, resource usefulness, and subsequent knowledge use. Such work would allow future studies to distinguish repository availability from discoverability and implemented accessibility features from demonstrated accessibility and inclusivity outcomes.

5 Conclusion

The Zeropol Hub case study documents how accessibility-oriented principles can be operationalised through resource curation, scientific validation, metadata, multilingual organisation, open access, and maintenance procedures within a marine pollution science communication repository. Early repository and web-analytics data demonstrate implementation and recorded use, but do not establish improvements in accessibility, inclusivity, discoverability, comprehension, or communication effectiveness. The principal contribution is therefore an applied basis of implementation for subsequent user-centred and longitudinal evaluation of whether these design features achieve their intended outcomes.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

KK: Methodology, Investigation, Supervision, Data curation, Conceptualization, Writing – review & editing, Funding acquisition, Formal analysis, Project administration, Writing – original draft, Visualization. SA: Investigation, Writing – review & editing, Validation, Methodology, Formal analysis, Data curation. TH: Formal analysis, Writing – review & editing, Investigation, Software, Data curation, Methodology, Visualization. LD: Investigation, Data curation, Writing – review & editing, Validation. NV: Investigation, Validation, Writing – review & editing. TM: Investigation, Validation, Data curation, Writing – review & editing. RR: Writing – review & editing, Investigation, Validation, Data curation. SP: Writing – review & editing, Validation, Investigation. AB: Writing – review &

editing, Data curation, Investigation, Validation. TV: Writing – review & editing, Validation, Investigation, Data curation.

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Conflict of interest

Author TM was employed by SEAMOHT Ltd.

The remaining authors declare that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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