

The Changing Status of Freshwater Biodiversity Monitoring in the UK

Thackeray, S. J.¹, Spencer, M.², Bowler, D.², Burris, D.³, Fletcher, M.⁴,
Fournier, I.², Jones, J. I.⁵, Lavictoire, L.⁶, Mackay, E. B.¹, Moorhouse, H.
L.¹, Ormerod, S. J.⁷, Pearce-Higgins, J. W.⁸, & Johnes, P. J.⁹

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¹UK Centre for Ecology & Hydrology, Library Avenue, Bailrigg, Lancaster, LA1 4AP, UK

²UK Centre for Ecology & Hydrology, Benson Lane, Crowmarsh Gifford, Wallingford, OX10 8BB, UK

³Natural England, UK.

⁴Natural England, Penrith, UK.

⁵School of Biological and Behavioural Sciences, Queen Mary University of London, London, UK.

⁶Freshwater Biological Association, The Ferry Landing, Far Sawrey, Ambleside, Cumbria, LA22 0LP

⁷Cardiff School of Biosciences/Water Research Institute, Martin Evans Building, Cardiff University, Museum Avenue, Cardiff CF10 3AX

⁸British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU.

⁹School of Geographical Sciences, University of Bristol, University Road, Bristol BS8 1SS

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1. Background

National Capability for UK Challenges (NC-UK) is a major UKCEH research programme that delivers long-term and national-scale data, understanding, tools, and partnerships to the UK environmental community. Freshwater biodiversity is a priority area of focus for NC-UK. In the UK, inland waters have great ecological, socioeconomic and cultural value but are also impacted by multiple environmental stressors. To fully understand the current status of the UK freshwater environment, we need to improve the coordination of monitoring, analysis and evidence provision. We report on a survey and workshop that enabled diverse stakeholders to share knowledge on UK freshwater biodiversity monitoring, identify gaps, and explore collaborative opportunities. This work supported NC-UK's aims to strengthen cross-sector engagement to build a collective "voice", improve the coherence of monitoring and analysis, and inform more effective and inclusive responses to freshwater biodiversity change, loss and positive management.

2. Summary

- Freshwater ecosystems are highly biodiverse and provide wide-ranging benefits to wellbeing, economy and national security. However, they are impacted by multiple, interacting stressors including habitat disturbance and modification; anthropogenic land-use change; overexploitation; long-standing and emergent pollutants; climate change; and the introduction of invasive non-native species.
- Despite signs that some elements of UK freshwater ecosystems have been recovering from historic sanitary and industrial pollution, particularly in urban areas, recent data indicate that these positive trends have stalled. In some regions, especially rural areas, there is evidence of degradation.
- To understand present status and recent trends, we must be able to detect and quantify the impacts of the changing mix of stressors acting upon UK freshwater ecosystems. This vital knowledge requires effective monitoring, research, and interpretation, to inform public and political debate and guide evidence-based action.
- To guide future efforts in monitoring and analysis of UK freshwater ecosystems, we surveyed community views on the status of biodiversity monitoring in these habitats followed by an online workshop that brought together experts in freshwater biodiversity and water quality.
- Through this engagement, we assessed how well current UK monitoring approaches provide the evidence needed to detect and understand freshwater ecosystem changes linked to multiple stressors.
- Our survey was completed by 149 respondents, representing multiple sectors (especially universities and research institutes, Government agencies, and public bodies) across England, Scotland, Wales, and Northern Ireland.
- Survey respondents recognised the diversity of organisations that play an important role in gathering, analysing and interpreting freshwater biodiversity data in the UK, including major contributions from research institutes, universities, Government agencies, and non-Governmental organisations.
- Considering the breadth of freshwater monitoring that is currently undertaken in the UK, respondents' views suggested some important imbalances. Specifically, respondents perceived that lowland running and (larger) standing waters are better monitored than upland fresh waters, ponds, and wetland habitats. It was also suggested that microbial communities, benthic and planktonic algae, zooplankton and aquatic plants are less well monitored than macroinvertebrates, fish, and wetland birds. Respondents also believed that current monitoring is least effective at indicating impacts of emerging contaminant pollution, hydrometeorological extremes, and climate change trends, compared to other stressors.
- Survey respondents perceived that a lack of funding for data collection and analysis is a major barrier to our understanding of patterns and drivers of change in UK freshwater biodiversity. Related to this, the current availability and coverage of biodiversity and stressor data were thought to be constraints to the current evidence base.
- In both the survey and the subsequent workshop, diverse monitoring approaches were identified as having the potential to fill important gaps in our understanding of UK freshwater

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biodiversity change, especially established approaches based upon taxonomic surveys, molecular/eDNA-based approaches, and citizen science. Acoustic and image-analysis approaches were also suggested, as were approaches that deliver information on animal movements and energy flows within food webs.

- There exist a wide range of approaches for monitoring, detecting and quantifying chemicals of concern in fresh waters, to understand organism exposure. In our workshop, participants recognised the potential of passive integrative samplers, microfluidics, advanced analytical techniques, automated bankside sampling, and sensor technologies to deliver vital data. In addition, analyses of chemical concentrations in species tissues can provide direct measures of chemical bioavailability and uptake for some substances. It was recognised that all techniques have strengths and weaknesses. As such, the integration of novel and established techniques would be well justified.
- Workshop participants highlighted the importance of gathering data on specific aspects of the physical environment. Specifically, techniques that allow landscape-scale mapping of freshwater habitats, as well as hydrological regimes and associated sediment mobilisation processes.
- The workshop discussion session highlighted several key considerations for the integrated analysis of freshwater stressor and ecological response data. These included the need to account for multiple interacting stressors that may be correlated with each other, spatial and temporal mismatches among data sets and lags in ecological responses, and differences in data collection methods. However, several analytical approaches were identified that could address these challenges.
- We need indicators to effectively monitor ecosystem change, deterioration, and restoration success. In workshop breakouts, the key attributes of vital freshwater ecosystem indicators were discussed: sensitivity to specific pressures, relevance to goals of monitoring, ability to detect multiple stressor effects, practicality of measurement and interpretation, scalability across time and space, and usefulness for decision-makers and stakeholders.
- Through the engagement activities within this project, we identified a clear desire within the UK freshwater community for a more integrated monitoring and analysis system. To enable this, we need to have a better overview of the current UK freshwater monitoring landscape, for clear leadership in taking this ambition forward, and investment that will support collaboration around this goal. We identified a need for a shared digital infrastructure, to enable data discoverability and integration to underpin this community effort.
- Through the survey and workshop, it was apparent that the community recognises that no single method will deliver a holistic understanding of freshwater ecosystem change; rather that multiple approaches deliver useful and complementary information. We should not see novel monitoring methods as replacements for more established approaches.
- Finally, there was recognition of the need to improve narratives around the fundamental importance of freshwater monitoring in the UK, so that the public and policy makers understand that this vital research is key to guiding management, conservation and restoration efforts.

3. Introduction

We are in the midst of a global freshwater biodiversity crisis (Reid *et al.*, 2019; Tickner *et al.*, 2020). In the UK, as is the case globally, there is a history of freshwater ecosystems being impacted and degraded by multiple stressors such as climate and land-use change, habitat alteration, species introductions, and both long-standing and emerging pollutants. These stressors interact with each other in complex ways, making it challenging to understand the drivers of freshwater ecosystem change (Jackson *et al.*, 2016; Birk *et al.*, 2020). High quality and comprehensive ecological data are key to developing this understanding, and using this as an evidential basis for regulation, conservation, and restoration.

In the UK, there are signs of recovery in some aspects of freshwater biodiversity (e.g. river macroinvertebrate richness and abundance) following action on historic sanitary and industrial pollution (Pharoah *et al.*, 2023; Qu *et al.*, 2023; Burns *et al.*, 2023). However, recent data suggest that these positive trends have stalled, with some regions showing signs of further degradation (Johnson *et al.*, 2026). Among vertebrates, some fishes, especially migratory species, are in severe decline (Cefas, EA & NRW, 2025; IFM 2023). For wintering waterbirds, an indicator based upon 16 species has shown population decline over the last ~20 years. The proportion of lakes, rivers and estuaries at good or high ecological status, under the Water Framework Directive (WFD) has not improved over the last decade and varies markedly from 16% in England, 31% in Northern Ireland, 40% in Wales and ~66% in Scotland (Burns *et al.*, 2023). However, many biotic groups have been insufficiently characterised under existing monitoring programmes to allow robust conclusions to be drawn with respect to trajectories and drivers of change.

It is vital that we assess how well-equipped we are to monitor freshwater biodiversity change in the UK, in a holistic sense, and to attribute such changes to the many stressors acting on UK fresh waters. This will allow us to identify priority actions for the UK freshwater monitoring and analysis community. Towards this goal, we present the outcomes of a survey and workshop that enabled us to explore multi-sectoral stakeholder perceptions of the current state of freshwater biodiversity monitoring in the UK. This work gathered views on:

- Organisations that have a key role in monitoring and analysis for UK fresh waters.
- Variations and potential biases in our current evidence base, with respect to spatiotemporal scales of data collection, and coverage of habitat types, species groups, and environmental pressures.
- The potential role of novel monitoring and analysis approaches in helping us to detect and understand change.
- The extent to which public and political narratives are evidence-based.

4. Methods

4.1 Pre-workshop survey

To assess community views on the current state of freshwater biodiversity monitoring throughout the UK, we created an online survey. The survey was designed as a mixture of categorical (multiple choice and Likert scale) and open questions (allowing free text responses). Questions were designed to assess community perceptions regarding which organisations play major roles in monitoring and interpreting freshwater data, which freshwater systems and taxa are most and least well monitored, which environmental stressors are least well captured by current monitoring frameworks, the spatial and temporal scales of current understanding, and the potential role of varied monitoring approaches (see Appendix).

The survey was designed by a project steering group (Appendix Table A1), with a multi-sector membership (academic, research, regulatory, charitable, and government advisory). We used UKCEH-approved software JISC, the online survey tool designed for academic research, education, and public sector organisations. The link to the survey was distributed to participants via organisational and Steering Group personal social media accounts (LinkedIn, BlueSky), and professional networks.

Free-text responses to open questions were summarised using Microsoft 365 Copilot. The survey received Favourable Ethical Opinion from the UKCEH Human Research Ethics Committee (HREC0094).

As part of the pre-workshop survey, respondents were asked about their motivations for attending the subsequent workshop (Figure 1). The most frequent responses to this question were to understand the latest developments (60%), learn something new (58%), or connect with others in the field (57%) highlighting the demand for knowledge sharing and capacity building across the freshwater monitoring community.

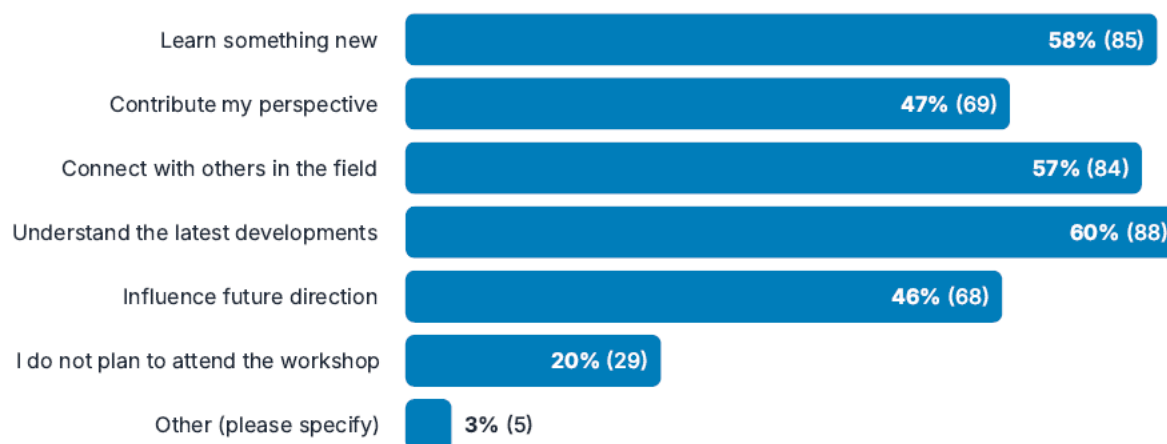


Figure 1. The main goals respondents identified for attending the workshop.

4.2 Workshop

4.2.1 Overview

To further engage the community in discussing the current state of UK freshwater biodiversity monitoring, we held an online workshop on the 12th of November 2025. Potential attendees could self-nominate to attend the event, by following a weblink circulated alongside the pre-workshop survey.

The stated aims of the workshop, shared in advance, were:

- To understand how well-equipped we are to detect and understand the effects of pollutants on the status of UK freshwaters.
- To guide priority actions for monitoring freshwater biodiversity and freshwater ecosystem quality in the UK.

The workshop was facilitated by the project steering group and partners at [Countryside](#), and was hosted on Zoom. Attendance at the workshop was limited to 50, to allow for effective facilitation and manageable breakout group sizes. Initially, the workshop was over-subscribed, and applications to attend were screened to select a final attendee list that maximised the diversity of organisations and sectors represented. The full programme for the workshop is in the Appendix.

4.2.2 Invited presentations

The first part of the event comprised a series of short presentations from invited representatives of the academic, regulatory, and voluntary sectors. These presentations were designed to ‘set the scene’ and provoke discussions in subsequent break-out sessions. Speakers were identified by the project steering group. The topics addressed by these speakers were:

- Our current understanding of freshwater biodiversity trends, and the pressures it faces, in the UK.
- Community views on UK freshwater biodiversity monitoring and analysis, based upon the pre-workshop survey.
- What’s working, what’s missing, and what’s next in freshwater biodiversity monitoring and analysis from academic, regulatory, and voluntary sector perspectives.
- The potential of novel monitoring tools in delivering more advanced understanding of change over shorter to longer timescales.

4.2.3 Break-out discussion sessions

The workshop included two break-out discussion sessions, which allowed participants to explore and elaborate on themes raised during the earlier presentation sessions. The first such session was on the topic of “exploring the current and potential roles of emerging monitoring technologies”. For this, workshop attendees were split into five break-out groups, each covering one of:

- Novel approaches to biological monitoring (e.g. earth observation/remote sensing, molecular approaches, acoustics, image analysis)
- Novel approaches to measuring chemical stressors (e.g. sensors for chemistry, passive samplers, molecular chemistry)

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- Novel approaches for monitoring the physical environment (e.g. earth observation/remote sensing, sensors for temperature, light, noise, flow)
- Innovative modelling/analytical approaches for the interpretation of freshwater ecosystem data
- Developing fit-for-purpose freshwater ecosystem indicators, in a multi-stressor world

Participants were given the opportunity to select one of these topics (and break-out groups) prior to the event, according to their interest and expertise. Each group was assigned a facilitator, a scribe, and space on a workshop Mural board, to capture outputs from their discussions. During the break-out session, attendees were invited to identify specific technologies and approaches, name them on Mural sticky notes, and place these notes on a simplified “systems diagram” (Figure 2) to indicate what new understanding could be delivered by each approach. They were then invited to record the level of readiness of that approach, its key limitations and uncertainties, and the time and space scales over which it would deliver knowledge.

In the second workshop break-out session, participants were encouraged to consider “opportunities to better integrate established and novel monitoring approaches, and key enablers and challenges to this vision”. For this session, participants were randomly assigned to break-out groups, to consider the following questions:

- What are the key enablers of a more integrated monitoring network?
- What are the main barriers to such integration?
- With respect to an integrated network, what can we already achieve and what could your organisation contribute?
- Who else needs to be involved in making this work?

The results of these discussions were also recorded by posting sticky notes in “enablers”, “barriers”, “resources” and “partners” comment boxes on the workshop Mural board. To conclude the workshop, participants heard one final presentation on an example of a vision for a “National Capability Integrated Environmental Monitoring Network”, and there was an opportunity to consider the alignment between this vision and the views expressed in the second break-out session.

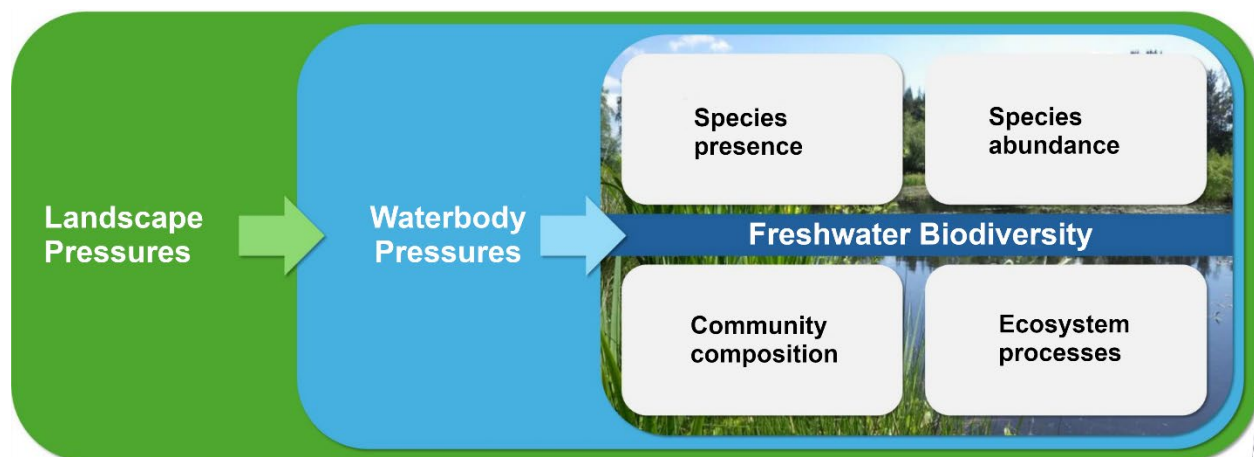


Figure 2. Template “systems diagram” upon which participants could place sticky notes representing different monitoring and analysis technologies and approaches, according to their ability to deliver information on different aspects of the connected terrestrial-freshwater ecosystem.

Ethical considerations were central to the design and delivery of the workshop. Prior to participating, all attendees were provided with an information sheet outlining the purpose of the workshop, what participation entailed, how their data would be used, and their right to withdraw at any time. Participants provided formal consent by accepting the invite to the Teams appointment, as well as by providing consent via a Teams form. Participation in all engagement activities was voluntary, and individuals were free to decline to answer any question. Data were recorded and stored securely, and identifying information was removed during analysis to protect participant confidentiality. Any quotes presented in this report have been anonymised to avoid attribution to any specific individual or organisation. No sensitive personal data were collected, and the project team took care to ensure that participation posed no foreseeable risk to individuals.

4.3 Illustration of survey and workshop outcomes

We commissioned Rebecca Roberts ([Envirovisuals](#)) to create murals depicting the major themes arising from the survey and workshop. The use of an alternative medium to display the results of the community discussions was undertaken to increase the accessibility of our findings, and the impact of communications arising from our work.

5. Results

5.1 Pre-workshop survey

5.1.1 Respondent information

In total, 149 respondents completed the pre-workshop survey. Most of these (71%) worked in England, with 11% working in Scotland and 9% working in Wales (Figure 3). Multiple sectors were represented in the survey responses (Figure 4), with university affiliations being the most common (26% of respondents), followed by Government agencies, non-Governmental public bodies and research institutes (13 – 14%). The survey also captured views from the private sector, with a combined 14% of respondents from commercial businesses and water companies. Twenty-seven percent of respondents selected “other” affiliations, though many of these related to consultancies, environmental non-Governmental organisations, the charity sector, and community and conservation groups.

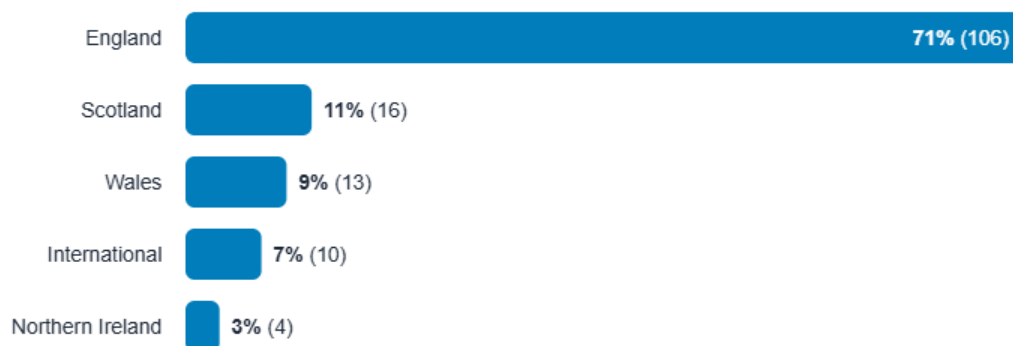


Figure 3. Survey respondents' working location across the UK nations.

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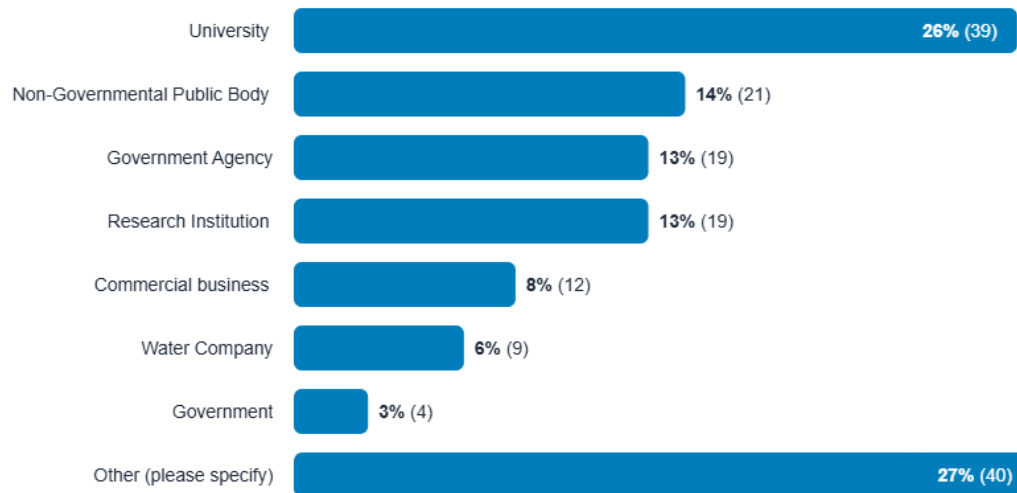


Figure 4. Distribution of survey respondents by organisational affiliation.

Over half (59%) of survey respondents described their role as an environmental or ecological researcher, and citizen scientists were also well represented (21%). Data scientists, campaigners, regulators and water/asset/land managers each accounted for <10% of the total responses (Figure 5). “Other” roles included consultancy, policy, monitoring, conservation, and project management/coordination. Twenty-three percent identified themselves as Early Career Researchers (ECRs).

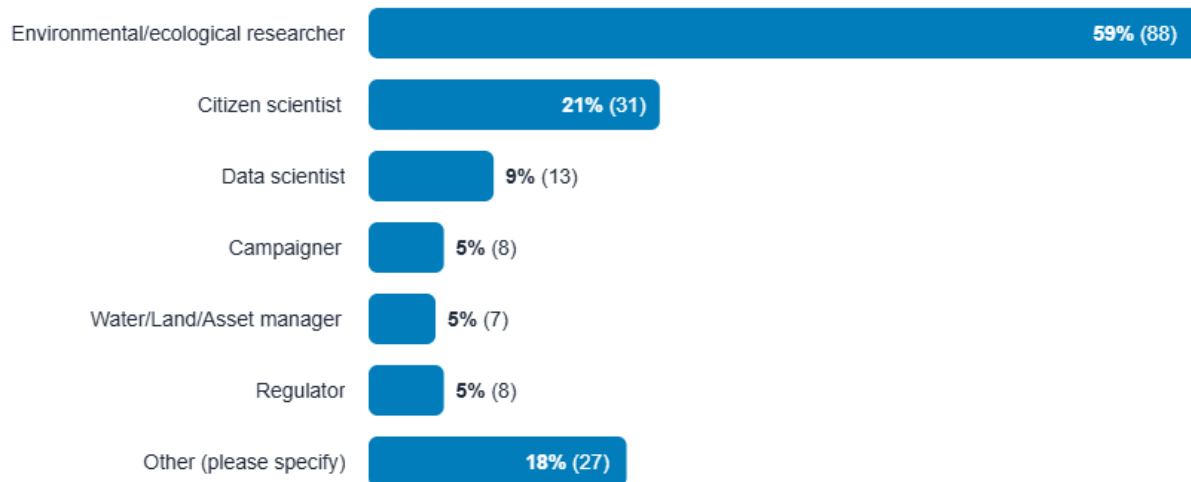


Figure 5. Survey respondents' roles.

5.1.2 Perceived roles in monitoring, analysis and interpretation

Based upon their knowledge and experience, respondents perceived that several different sectors play a major role in gathering UK freshwater biodiversity data, with Government agencies, research institutions, non-Governmental organisations, and universities all being suggested in over 60% of responses (Figure

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6). Free-text responses elaborated upon these selections, collectively recognising the importance of UK regulators (Environment Agency, Scottish Environment Protection Agency, Natural Resources Wales and Northern Ireland Environment Agency), as well as Natural England, NatureScot, Defra, FERA and Cefas in gathering data. Survey respondents suggested that statutory agencies gathered the most accessible, standardised, long-term datasets, though this role was declining due to budget cuts over the last 5-10 years. Amongst research institutions, UKCEH was specifically identified for its role in gathering freshwater biodiversity data (e.g. Upland Waters Monitoring Network and Cumbrian Lakes), alongside specific universities such as St Andrews, Aberdeen, Cardiff, and Glasgow).

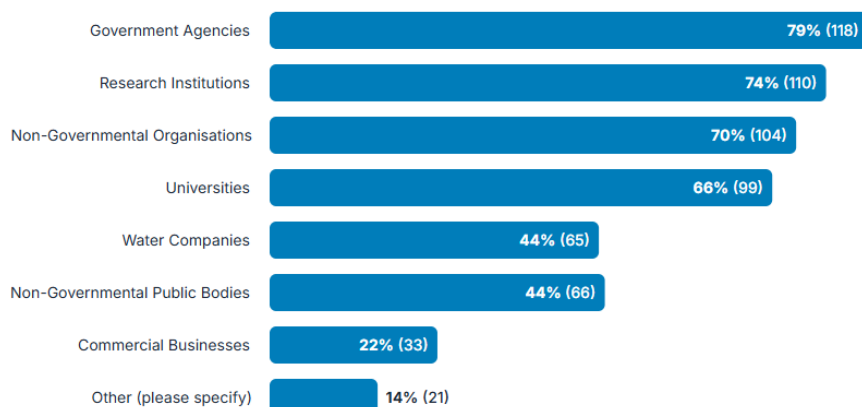


Figure 6. Survey responses indicating which organisations are perceived to play a major role in gathering freshwater biodiversity data in the UK (multiple selections permitted).

Though less frequently selected, both water companies and commercial businesses were perceived to play a major role in data gathering (44% and 22% of respondents, respectively). Consultancies were specifically mentioned in free text responses (e.g. APEM, Ricardo) in recognition of their role in collecting data for water companies, planning applications, and environmental impact assessments. Water company data collection, primarily for their assets, was believed to be significant though respondents commented that these data were often collected by consultancies and were not openly available.

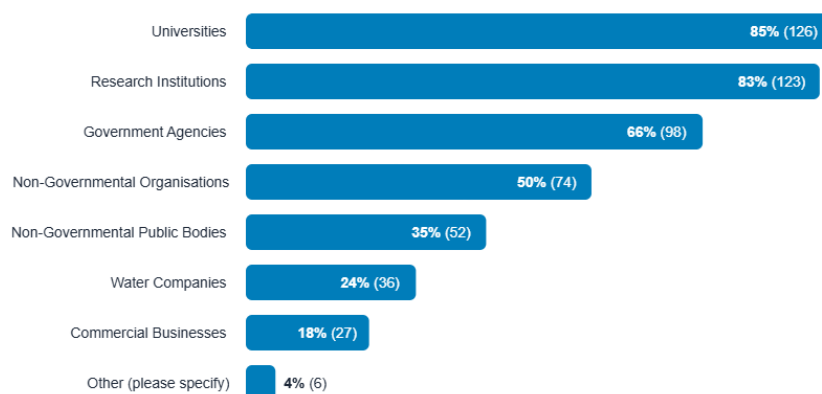


Figure 7. Survey responses indicating which organisations are perceived to play a major role in analysing and interpreting freshwater biodiversity data in the UK (multiple selections permitted).

In addition to this, citizen scientists/volunteers, community groups, angling clubs, rivers trusts, and wildlife trusts were all thought to make an important contribution to data collection as well. This was felt especially important for data on selected water quality parameters, macroinvertebrates, and wetland birds

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(in the case of the Wildfowl and Wetlands Trust and RSPB). The role of the Freshwater Biological Association was also specifically mentioned. However, the observation was made that NGO data could be narrow in taxonomic scope and of variable quality. A growing role for citizen science in delivering freshwater data was suggested, potentially filling monitoring gaps that have opened due to funding cuts and reduced capacity in other organisations.

When re-framing the question to ask for perceptions of which organisations play a major role in analysing and interpreting, rather than collecting, freshwater biodiversity data, Government agencies, research institutions, non-Governmental organisations, and universities remained the most frequently selected (Figure 7). However, the number of respondents selecting research institutions and universities increased (83 – 85%), while the number selecting non-Governmental organisations and Government agencies decreased (50 – 66%). Respondents discriminated between analysis for statutory reporting, shaped by policy requirements (Government agencies), and deeper analyses supported by research projects (universities and research institutes).

Important challenges were identified by survey respondents. Firstly, it was perceived that current monitoring efforts are fragmented and uncoordinated, rather than integrated, standardised and strategic. Secondly, there was a view that important data are not always made openly available. Thirdly, there were concerns that many organisations lack the time, funding and expertise needed to fully analyse and interpret the data that are collected.

5.1.3 Perceived representation of ecosystem types

Lowland streams and rivers were perceived to be the most well monitored freshwater ecosystem types (76% of respondents selected this option, Figure 8), followed by lowland lakes and reservoirs (39%). It was suggested that this is because of a combination of statutory requirements (Water Framework Directive), and a combination of these sites being impacted by wastewater discharges, water companies having a responsibility to assess impacts, and the fact that these systems often support both recreational uses and associated commercial interests. However, despite these relative assessments, some respondents also commented that no freshwater ecosystem types are currently “well monitored” in absolute terms.

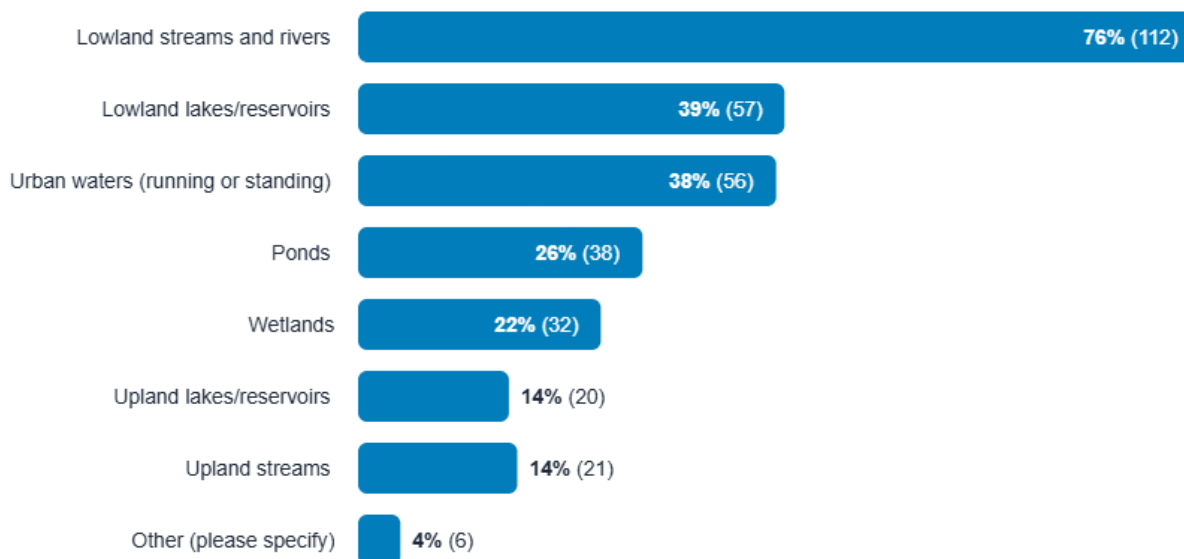


Figure 8. Survey respondents' perceptions of which freshwater ecosystem types are most well monitored for their resident biodiversity in the UK (multiple selections permitted).

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In contrast, upland streams (59%), wetlands (54%), ponds and upland lakes and reservoirs (47%) were thought to be least well monitored (Figure 9). Alongside these selections, free text responses suggested that small water bodies (springs, seeps, ditches), headwaters, canals, wet woodlands and riparian habitats are also poorly monitored. Respondents suggested that some monitoring initiatives (Upland Waters Monitoring Network, NCEA Small Streams Network, voluntary riverfly monitoring) contribute to filling these gaps, though they do not fully compensate for them. Ponds were perceived to be especially poorly monitored, notwithstanding activities such as eDNA great crested newt surveys, and the work of some specifically named organisations (Natural England, the Freshwater Habitats Trust, UKCEH).

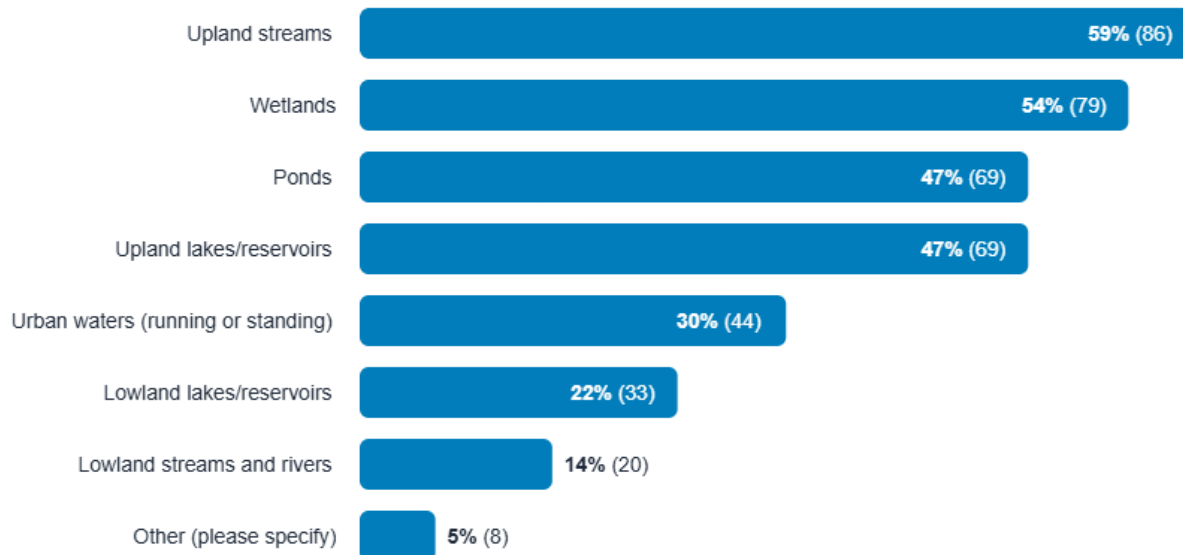


Figure 9. Survey respondents' perceptions of which freshwater ecosystem types are least well monitored for their resident biodiversity in the UK (multiple selections permitted).

A potential source of disagreement was over urban waters, with similar numbers of respondents perceiving them to be well monitored (38%) and poorly monitored (30%). There was recognition, however, that these locations are exposed to chronic pollution and could be the focus of citizen science monitoring.

Overall, survey respondents perceived that current monitoring may be biased towards flowing waters, larger and more accessible water bodies, and areas where there are more people.

5.1.4 Perceived representation of species groups

Survey participants were asked to reflect on which species groups are understudied, given current freshwater biodiversity monitoring in the UK (Figure 10). Microbial communities were highlighted in 61% of responses, followed by benthic and planktonic algae, zooplankton and aquatic plants (all selected by $\geq 40\%$ of respondents). In contrast, macroinvertebrates, fish, and wetland birds were highlighted less frequently (all $\leq 28\%$). Additional "other" groups that were highlighted as understudied included mammals, amphibians and parasites.

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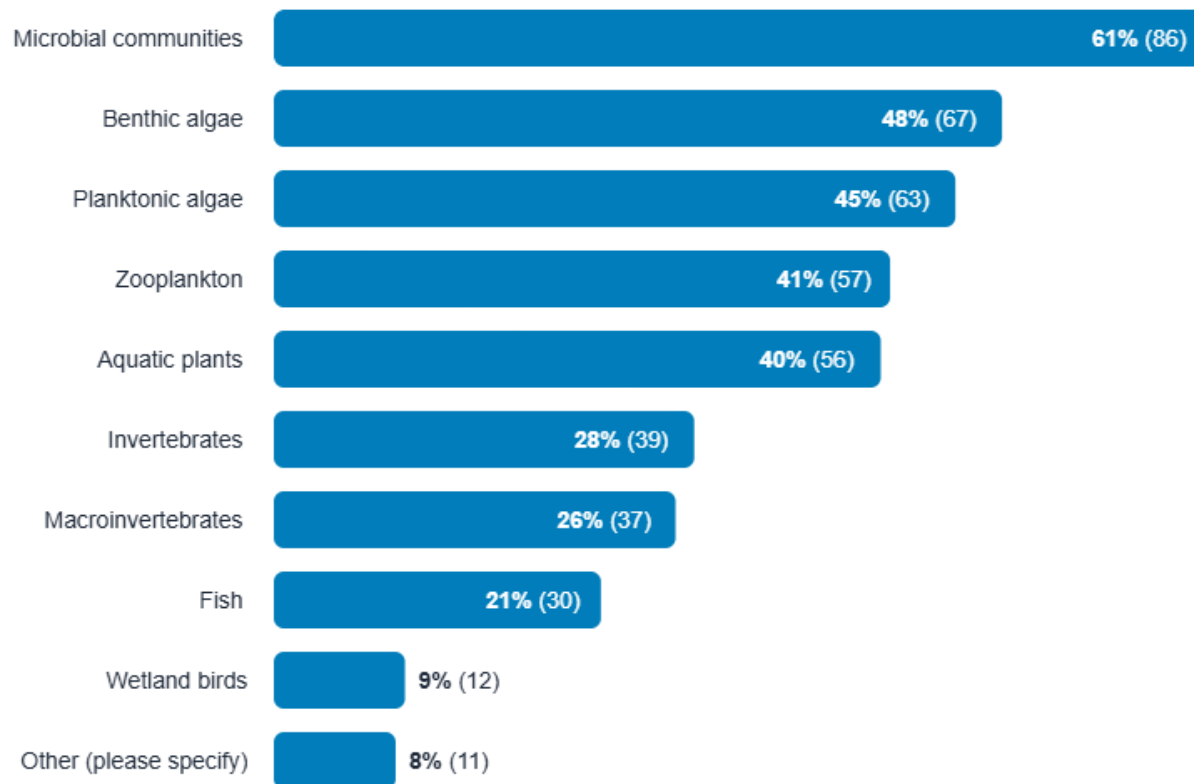


Figure 10. Survey respondents' perceptions of which freshwater species groups are most understudied in the UK (multiple selections permitted).

In free text responses, survey participants elaborated on these perceptions. In the specific case of benthic algae, it was thought that, while benthic diatoms are included in statutory monitoring, other benthic algal groups are largely neglected. Associated benthic micro- and meiofauna were also perceived to be poorly monitored. Responses suggested that plankton composition data are often missing, and that we currently lack assessment tools based upon these taxa. It was suggested, however, that molecular monitoring tools offer an opportunity to improve current understanding of microbial and biofilm communities. With respect to invertebrates, molluscs were felt to be poorly served by current UK monitoring. For aquatic plants, a distinction was made between current monitoring of specific nutrient response metrics, and the need for a more comprehensive assessment of taxonomic and functional composition, and abundance. For freshwater fish it was thought that, alongside reduced statutory monitoring effort, there are practical challenges to effective monitoring in some habitats (e.g. upland streams and deep lakes). Some secretive waterbird species also pose practical challenges to effective observational monitoring and might be better represented through the introduction of eDNA or other techniques.

Responses to the question of species group coverage exposed several high-level challenges for current UK biodiversity monitoring. Specifically, respondents perceived 1) a lack of (and declines in) taxonomic expertise for many freshwater species groups, 2) expense (time and money) and logistical/practical challenges in monitoring some groups compared to others, 3) the absence of robust assessment tools based upon many species groups, especially those that fall outside of Water Framework Directive protocols, 4) insufficient foundational ecological knowledge of some groups, 5) difficulties in robustly monitoring highly mobile, secretive or colony forming species, and 6) taxonomic biases in monitoring as a result of the aforementioned issues. Importantly, there was recognition of the need for an ecosystem-scale approach, incorporating functional indicators of ecosystem processes, and of food web structure.

5.1.5 Perceived representation of pressures

Impacts of emerging contaminant pollution, hydrometeorological extremes, and climate change trends were frequently perceived as being poorly indicated by our current approach to freshwater biodiversity monitoring (Figure 11, 78%, 58%, and 48% of respondents, respectively). A considerable proportion of survey respondents felt that this could be said of the impacts of agrochemicals, habitat alteration and non-native species (38 – 44%) too. A smaller proportion of respondents felt that the impacts of nutrient and metal pollution were poorly captured by current monitoring efforts (27 – 29%).

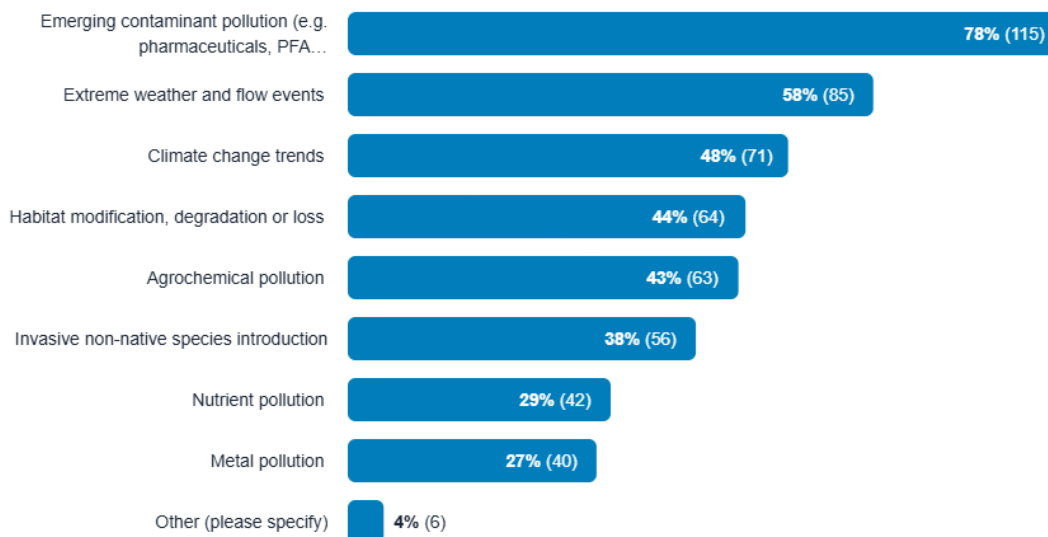


Figure 11. Survey respondents’ views on which types of environmental stressors are currently underrepresented or poorly indicated by existing freshwater biodiversity data in the UK (multiple selections permitted).

In their elaboration of these responses, survey respondents perceived PFAS (per- and polyfluoroalkyl substances i.e. “forever chemicals”), pharmaceuticals, cyanobacterial metabolites, pesticides, microplastics, tyre/brake dust, sediments, hydrocarbons, metals, and sludge as contaminants of particular concern, and that there is currently insufficient understanding of the direct and indirect impacts of such materials. Urban storm water/combined sewer overflows (CSOs) were specifically suggested as stressors that current monitoring fails to fully capture. Furthermore, it was felt that regulatory frameworks do not keep pace with the increasing diversity of recognised contaminants. Insufficient temporal monitoring resolution was seen as a key barrier to understanding the impacts of extremes such as floods, drought, and heatwaves. Participants perceived that major habitat losses have not been effectively monitored, and that provisions for “modified waterbodies” in current regulatory frameworks mask important ecological degradation.

A key concern was that these stressors do not occur in isolation. Freshwater ecosystems are instead exposed to multiple co-occurring pressures, causing considerable challenges in isolating causes of freshwater biodiversity change. Related to this, it was perceived that many current biodiversity indicators are designed to be sensitive to nutrient and dissolved oxygen concentrations specifically, rather than other stressors. Combined with a lack of long-term baseline data in many locations, our ability to detect biodiversity trends across the UK was seen to be undermined.

5.1.6 Reflections on spatiotemporal scales of monitoring and interpretation

Survey responses indicated a perceived scale dependence in our ability to quantify and understand changes in freshwater biodiversity. Specifically, it was believed that our ability to understand change diminishes from finer to coarser spatial scales. Fifty-one percent of respondents believed that we are well-equipped to understand change at the scale of individual river reaches and water bodies, and 46% at the scale of individual catchments. Corresponding figures were 36% at UK country scale (i.e. England, Scotland, Wales, Northern Ireland) and 19% at UK-scale. Despite these relative assessments, several respondents believed that, in absolute terms, we cannot robustly quantify and understand change at any scale, due to a lack of political will, funding cuts, reduced monitoring efforts overall, and the patchiness and lack of coordination of current monitoring across the UK. This latter point necessitates the non-trivial task of integrating data from multiple sources, which differ in key attributes such as spatial coverage, collection methods, and taxonomic resolution. It was also noted that, even at smaller spatial scales, there is a great degree of variability in monitoring effort and coverage, and that such work is often short-term in nature and under-resourced.

In relative terms, survey respondents felt that we are more able to quantify change at longer temporal scales (decadal 37%, year-to-year 61%, seasonally 34%) than at shorter ones (monthly 8%, less than monthly 2%). As before though, in absolute terms, there was a strong sentiment that we are not well-equipped to quantify and understand change at any temporal scale. A caveat to the apparent support for our ability to quantify and understand change at year-to-year scales is that, for some water bodies, sampling is only repeated every 3 - 6 years (with a specific mention of EA river monitoring). Furthermore, changing methodologies, taxonomic resolution, monitoring site location, and periodic funding cuts (the latter leading to data gaps) were identified as undermining robust long-term assessment across the UK. Indeed, some respondents stressed the importance of long-term monitoring sites for climate impact detection, and the need to protect such activities. There was recognition that finer-scale, seasonal monitoring is being undertaken for only some taxonomic groups (e.g. phytoplankton, benthic diatoms, invertebrates), and at certain well-studied sites. As such, we are currently unable to quantify biodiversity responses to intense, short-term pressures (e.g. flow extremes, pulses in pollutant exposure) and changes in seasonal organism behaviour (phenological change) across the whole UK.

5.1.7 Barriers and opportunities to fill knowledge gaps

Funding constraints were perceived as a major barrier to our understanding of patterns and drivers of change in UK freshwater biodiversity (Figure 12), with respect to support for both data collection (82% respondents) and analysis (77%). Related to these funding cuts, biodiversity and stressor data availability and coverage were suggested by many respondents (43 – 58%) as barriers. As before, participants commented that current monitoring is often not at sufficient spatial or temporal resolutions to understand change and fails to capture change in specific ecosystem types (e.g. small water bodies and headwater streams). Indeed, when participants were asked whether they agreed with the statement “*sufficient effort has been maintained over the long term to monitor freshwater ecosystems*” on a Likert scale of 1 (strongly disagree) to 10 (strongly agree), only 1% of responses were higher than 7, and the mean score was 3.6.

Approximately one third of respondents also perceived barriers associated with data quality, and the availability of tools for analysis and visualisation. Key aspects of data quality included variability in sampling and laboratory analysis procedures over time, lack of interoperability among data sets (and co-ordination of data collection and publication), lack of co-ordination of biodiversity and stressor data, and difficulties in interpreting data without having specialist insights from those that collected it. This latter point is an important caveat to the open availability of agency data sets online and, indeed, data access was viewed as a barrier by 46% of respondents.

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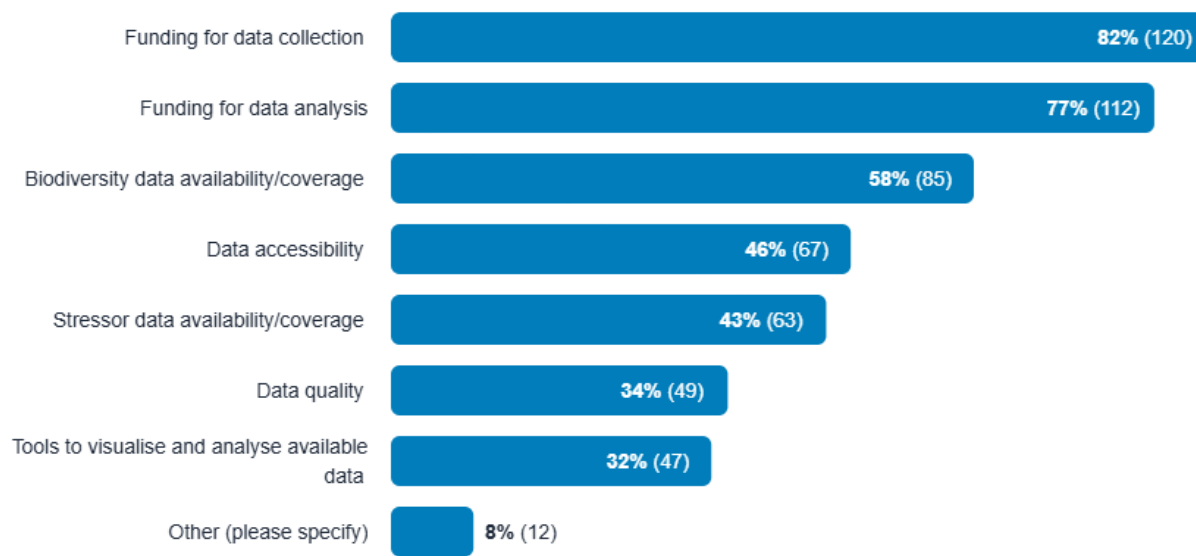


Figure 12. Survey respondents' views on the major barriers to understanding the trends and drivers of freshwater biodiversity change in the UK (multiple selections permitted).

In addition to these observations, it was suggested that national-scale data analysis and interpretation could risk masking important catchment-scale drivers of change, and that monitoring schemes should “evolve” to address emerging pressures and challenges. Further, it was suggested that a lack of understanding is not the key barrier to addressing biodiversity decline, rather political and regulatory action on known issues.

Most respondents felt that there was the potential for established taxonomic surveys, eDNA/molecular approaches or citizen science to help us fill important gaps in our understanding of freshwater biodiversity change (Figure 13; 72, 79, 67% of respondents, respectively). Forty-three percent also felt that remote sensing offers this potential. Other technological approaches (passive and active acoustics, image analysis/computer vision) were selected less frequently ($\leq 31\%$).

Survey participants indicated that a continuation of established approaches (some disliked the use of the term “traditional” due to a perceived negative framing) is essential for continuity in biodiversity assessment and provides reliable abundance data, which not only allows for trend detection and early warnings, but also provides a means to validate/calibrate newer approaches. Molecular monitoring approaches were seen as especially valuable for detecting hard-to-capture and understudied species, offering the potential for catchment-wide presence-absence information, and at high frequency. However, some important uncertainties were perceived; gaps in taxonomic coverage, a lack of abundance/biomass estimation, issues with false positive and negative detections, comparability with established approaches, and perceived issues with the reliability of workflows. For these reasons, molecular methods were viewed as complementary to established ones, rather than as a replacement.

The perceived value of citizen science was in expanding the spatial coverage of monitoring, while engaging local people with biodiversity monitoring. However, it was perceived that data quality depends heavily on training, benchmarking, and expert oversight (with BTO-type approaches recognised as good practice). There was agreement that citizen science should complement, but not replace, professional surveys, and concern that a reliance of citizen science may mask cuts to funding for agency monitoring.

Participants commented on the potential of image analysis, acoustics, and remote sensing, though noted that these methods currently have a narrow taxonomic scope, or are insufficiently developed for broad

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biodiversity assessment. It was also noted that they generate large volumes of data that require AI/machine learning type approaches for robust interpretation.

A strong overarching theme was that no single method will deliver a holistic understanding of change and that there is a need to integrate different data types. All approaches offer value, and we should view the diversity of current methods as a strength. There were some important parallel considerations though, in that we must not over-rely on technological solutions compared to on-the-ground ecosystem understanding and connection with nature, we need to cherish and rebuild our UK taxonomic skills base, and we need to be mindful of variable levels of trust in different data sources.

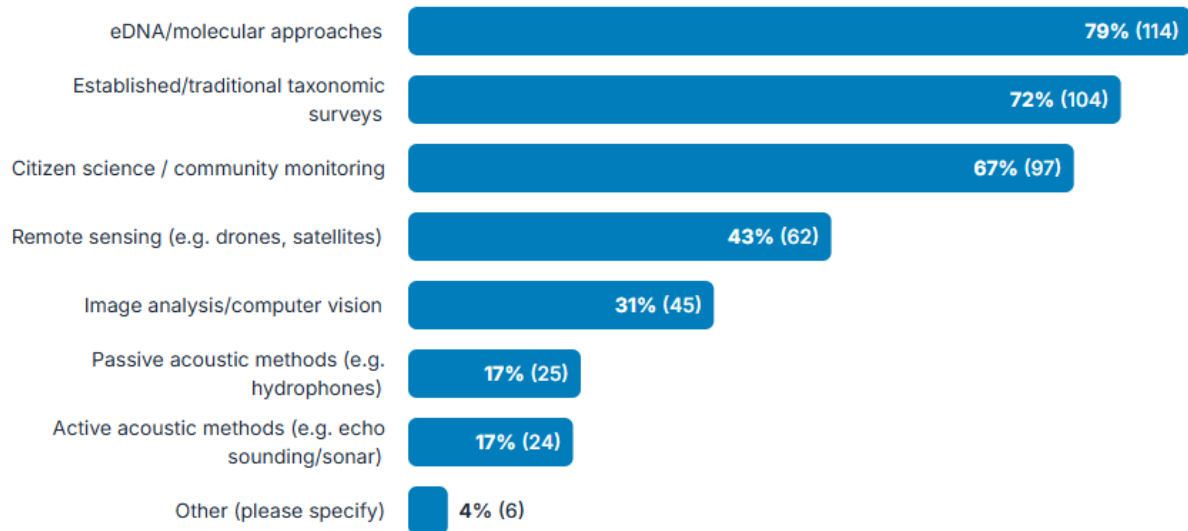


Figure 13. Survey respondents' views on which monitoring approaches will most help fill important gaps in our understanding of freshwater biodiversity change in the UK (multiple selections permitted).

5.1.8 Reflections on public and political narratives

Survey respondents showed great variance in their level of agreement with the statement “*public discourse on the state of freshwater ecosystems in the UK is well informed by available scientific evidence*” (Figure 14). On a Likert scale of 1 (strong disagreement with the statement) to 10 (strong agreement), individual responses covered the whole scale, however the mean score was 4.25 and 63% of respondents scored their agreement as between 3 and 5, indicating that many tended to disagree that public discourse on the state of UK fresh waters was well informed by evidence, to some extent.

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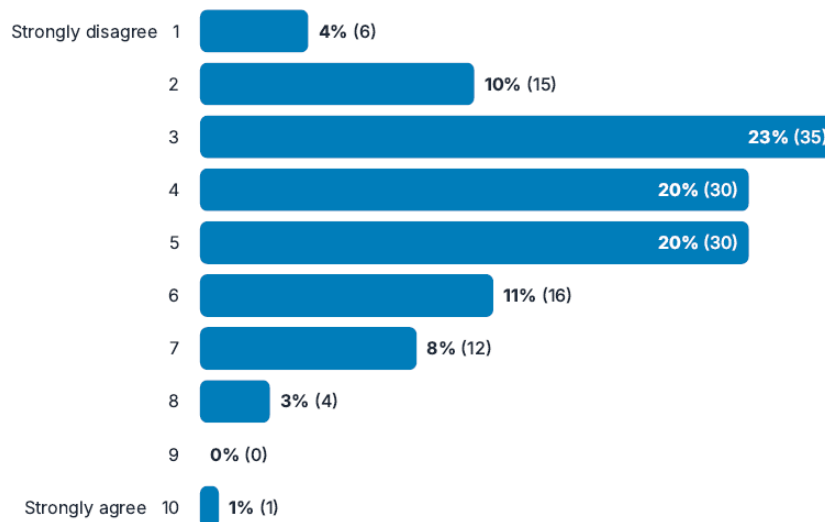


Figure 14. Survey respondents' agreement with the statement: "Public discourse on the state of freshwater ecosystems in the UK is well informed by available scientific evidence."

Elaborating on these responses, survey participants suggested that public discourse on these issues can be poorly informed, selective and distorted. It was felt that media narratives were overly simplistic, focusing on single issues such as sewage (e.g. combined sewer overflows), and missing the concomitant impacts of the wider range of additional stressors and sources. In addition, it was recognised that much of the messaging that reaches the public focuses on rivers, with little on other types of freshwater ecosystems. There was concern that (social) media influencers play a role in promoting overly simplistic and alarmist narratives, sometimes with little evidential backing. Furthermore, there was concern about media bias, with negative stories about UK fresh waters being more likely to receive media attention than more positive ones (such as long-term recovery in river invertebrate communities). However, there was a recognition that, behind this, there are key difficulties associated with scientific evidence being inaccessible or too complex to be readily interpretable by the wider public. As such, there is a perceived need for better translation of complex research findings into balanced and publicly accessible messages. This may require improvements and upskilling in science communication, recognising that activists and influencers are often more skilled in this area. Survey respondents perceived an important challenge with respect to public trust in water quality/ecological narratives, as this has diminished in some contexts in recent years (e.g. communications from water companies and regulators, suspected political influence on messaging).

Agreement scores were more widely distributed when survey respondents were asked to consider the statement "*in the UK, policymakers' understanding of the state of freshwater ecosystems is well informed by available evidence*" (Figure 15). There was no strong agreement with this statement, with no individual responses exceeding 8 on the Likert scale. Twenty percent of respondents neither agreed nor disagreed with the statement (score of 5/10) and 56% gave scores lower than this, indicating some degree of disagreement.

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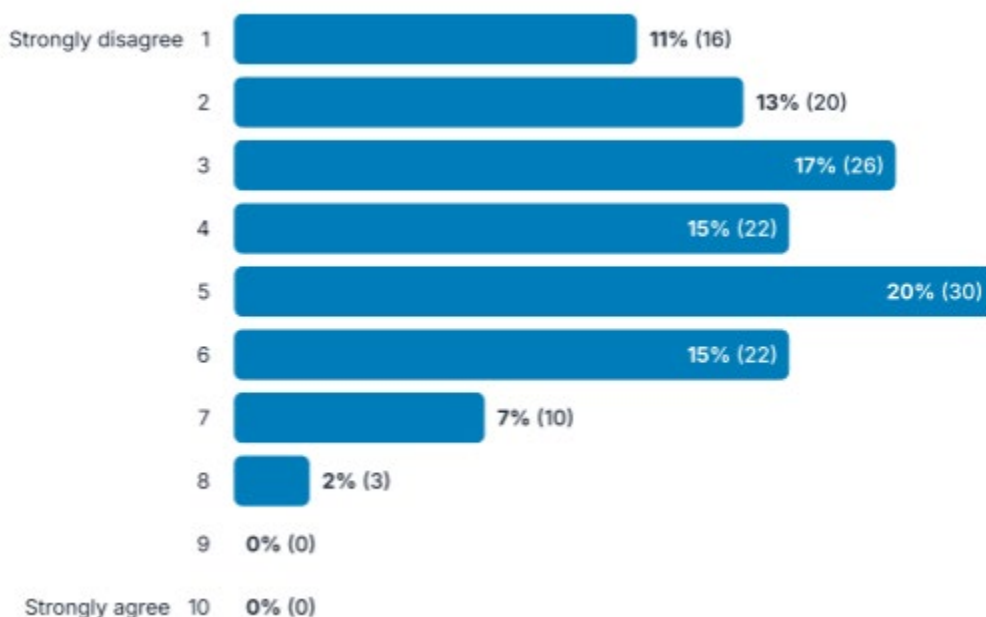


Figure 15. Survey respondents' agreement with the statement: "In the UK, policymakers' understanding of the state of freshwater ecosystems is well informed by available evidence".

The justifications behind these scores were complex, though general sentiments suggested a perception that policymakers were, at best, partially informed by scientific evidence, and that they may use evidence ineffectively and/or selectively. Further, it was perceived that they prioritise responses to political, economic and public concerns, electoral considerations and media pressure over environmental issues (despite the interdependencies within the socioecological system). There were also concerns about the political influence of particularly powerful sectors (e.g. business, water companies, and agriculture). As for the case of public discourse, it was suggested that the available evidence on the state of fresh waters may be too complex and difficult to interpret to be readily used to guide and inform policy. This results in a significant gap between scientific understanding and policy impact. However, it was acknowledged that, while Parliamentary level understanding is generally low, there are some civil servants who are more knowledgeable with respect to the state of the UK freshwater environment. Even in these cases, it was suggested that evidence-based policy implementation may be limited by political will, funding, and long-term commitment (beyond electoral cycles).

5.1.9 Additional comments from survey respondents

Finally, survey respondents were offered the opportunity to share additional thoughts that they had not already offered in response to earlier questions. Several key themes arose in these comments, and there were commonalities with issues raised in response to earlier questions. Strong concerns were once again raised with respect to a long-term reduction in statutory freshwater monitoring effort, a pattern which will reduce statistical power in associated data analyses and undermine our collective ability to detect trends at UK scale. Long-term monitoring was viewed as vital, and yet underfunded.

Participants also suggested that improvements could be made to the accessibility of freshwater datasets, reporting that several key data sources are not fully open access, limiting collaboration and innovation (e.g. industry data sets and Environmental Impact Assessments). A need for long-term data stewardship was suggested, especially for short-term, project-specific datasets. Respondents felt that the UK lacks an

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integrated data framework, bringing together agency, research institute, academic institution, and citizen science datasets in a standardised way. Associated with this, some participants suggested the important role that citizen science data sets can play in understanding the status of UK fresh waters, and that these initiatives can uncover issues missed by statutory monitoring (the EA-funded Freshwater Invertebrate Network was specifically mentioned).

A strong perception that came through was that much of the current messaging on the status of UK fresh waters reflects river habitats, and not the wider freshwater landscape. Ponds (including ephemeral ones) were suggested to be particularly understudied and undervalued. There was also recognition that lake ecosystems are under pressure, with poor controls on catchment nutrient pollution, and many in deteriorating condition, with legacy pollutants from past catchment practices, stored in lake sediments, continuing to drive ecosystem damage. It was also suggested that estuarine, transitional, and coastal waters are understudied. In addition to these perceived habitat biases, some participants identified stressors that require more monitoring effort and understanding (e.g. the wider impacts of cyanobacterial blooms on ecosystems, changes to freshwater connectivity in the landscape).

Survey participants shared important concerns regarding political commitment to monitoring, conserving and restoring freshwater ecosystems in the UK. Here, it was felt that political parties lack a shared commitment to biodiversity protection, that environmental issues lose out to short-term economic considerations and the priorities of powerful sectoral groups, and that policy narratives can strip away legal protections (with current legislation perceived as weak). As a result, it was suggested that, even in cases where there is clear evidence of pollution, there is no guarantee of remedial action. It was also felt that sources of pollution that are already well-known cannot currently be eliminated or effectively treated. It was suggested by some that policy change requires better public awareness of the underlying issues (and future implications), which in turn relies upon effective scientific communication. However, it was noted that a careful balance needs to be struck between the need for scientific certainty on patterns and drivers of change, and the need for urgent action on biodiversity loss.

5.2 Workshop

The workshop was attended by fifty representatives from 21 academic institutions, research organisations, consultancies, charities, regulators, water companies, and Governmental bodies (Table 1).

Table 1. Organisations represented at the workshop.

Organisations Invited	Organisations Attending
<ul style="list-style-type: none"> • Affinity Water • Anglian Water • Angling Trust • Bristol Water • Canal & River Trust • Cardiff University • Chairs Aquatic Interest Group of CIEEM • CIEEM • Department for Environment, Food and Rural Affairs (DEFRA) • Department for Infrastructure – Rivers Directorate • Earthwatch 	<ul style="list-style-type: none"> • APEM Ltd • Amphibian and Reptile Conservation Trust • Bristol Water • British Trust for Ornithology • Cardiff University • Countryside • Earthwatch • Edinburgh Napier University • Environment Agency • Freshwater Biological Association (FBA) • Freshwater Habitats Trust • Natural England (NE)

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<ul style="list-style-type: none">• Environment Agency (EA)• Freshwater Biological Association (FBA)• Freshwater Habitats Trust• Institute of Fisheries Management• Lake District National Park Authority• Manchester Metropolitan University (MMU)• Met Office• National Groundwater Level Archive• Natural England (NE)• Natural Environment Research Council (NERC)• Natural Resources Wales (NRW)• Non-marine Isopod Recording Scheme• Northumbrian Water• Northern Ireland Environment Agency (NIEA)• Plymouth Marine Laboratory• Queen Mary University of London (QMUL)• British Hydrological Society• River Restoration Centre• Riverfly / Freshwater Biological Association• Scottish Environment Protection Agency (SEPA)• Scottish Government• Severn Trent Water• South Cumbria Rivers Trust• Southeast Water• South Staffs Water• Southwest Water• Southern Water• Thames Water• The Rivers Trust• University College London (UCL)• University of Essex• University of Kent• University of Loughborough• University of Plymouth• University of Sheffield• United Utilities• Wessex Water• West Wales Biodiversity Information Centre• Westcountry Rivers Trust• Welsh Government• Welsh Water• Wild Trout Trust• Wildfowl & Wetlands Trust (WWT)• Wyre Rivers Trust• Yorkshire Water• UK Centre for Ecology & Hydrology (UKCEH)	<ul style="list-style-type: none">• NatureScot• Queen Mary University of London (QMUL)• Severn Trent Water• UK Centre for Ecology & Hydrology (UKCEH)• University of Bristol• University of Exeter• University of Glasgow• University of Leeds• Welsh Government
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5.2.1 Exploring the roles of emerging technologies and approaches

Novel approaches to biological monitoring

Workshop participants identified a wide range of monitoring technologies that could provide useful information on species presence, species abundance, community composition, or ecosystem processes, with a different mixture of approaches being judged as relevant to different levels of ecological organisation.

- **Molecular monitoring approaches.** The potential of molecular monitoring techniques was recognised for all four levels of ecological organisation (species presence, species abundance, community composition, ecosystem processes). Targeted eDNA assays (using droplet digital or quantitative PCR) were identified as appropriate for single species detection (Mauvisseau *et al.*, 2019), and it was noted that in some cases (e.g. river and lake fish communities) species abundance/biomass can be estimated by such means as well (Perry *et al.*, 2025). For quantification of community composition (relative abundances), eDNA metabarcoding was repeatedly recognised as a useful approach (Lawson Handley *et al.*, 2019; Hallam *et al.*, 2021), and participants suggested several molecular techniques that could also yield insights into ecosystem processes. These included RNA analyses to investigate microbial gene regulation, population genetics and genomics, and the use of metabarcoding data to derive functional and ecological network metrics (Blackman *et al.*, 2022).
- **Acoustic monitoring approaches.** Workshop participants suggested that passive acoustics (deployment of hydrophone technologies, and associated analysis of recorded sounds/soundscapes) can be used for monitoring of species presence and community composition (Bolgan *et al.*, 2018; Lawson *et al.*, 2024; Bolgan 2025). In the former case, the current development of classifiers to enable single species detection was noted. In addition to passive acoustics, well-designed active hydroacoustic surveys (echo sounding) were recognised for their ability to provide accurate estimates of fish abundance and size in lakes, and some large rivers (Winfield *et al.*, 2007).
- **Image acquisition and analysis.** Underwater camera deployment, and associated video/image analysis, were recognised as appropriate for species detection. However, some participants suggested that image-based approaches, in a more general sense, can be used to quantify both species abundance and community composition as well. As specific examples, they gave aerial imagery for the detection of species in hard-to-access areas, automated image-analysis for plankton and benthic communities (Albini *et al.*, 2023) and the deployment of (un)baited cameras for amphibian detection and fisheries assessment (capitalising on AI-based approaches for species classification).
- **Organism tracking and movement.** Several workshop participants suggested the application of technologies that, broadly, collect information on the movements of organisms. Animal tracking technology was mentioned as a means of assessing how invertebrates and vertebrates use freshwater habitats (e.g. Jacoby & Piper, 2023). AI-enhanced fish counters were also suggested as a more specific case, as was the use of weather radar to assess insect emergence (Stepanian *et al.*, 2020). These approaches were recognised for their ability to yield information on species abundance and ecosystem processes.
- **Citizen science.** The role of citizen science in gathering biological data was clearly recognised (Collins *et al.*, 2023; Bishop *et al.*, 2025). This was both using Apps for opportunistic species recording, and through the potential to align novel monitoring technologies with citizen science

schemes, to “support data quality”. Voluntary recording opens opportunities for “whole landscape freshwater biomonitoring”; a need highlighted during this workshop exercise.

- **Additional ecosystem process measures.** In addition to the methods already identified, participants noted the usefulness of measuring decomposition rates in freshwater ecosystems using cotton strips (Colas *et al.*, 2019), and the application of stable isotope analysis to make inferences about energy flows within food webs (Maguire & Grey, 2006).

Novel approaches to measuring chemical stressors

During the workshop break-out session, participants identified several approaches to monitoring variations in chemical concentrations, and therefore exposure, in freshwater ecosystems (sample collection and analysis), as well as approaches to analysing the uptake of contaminants by resident organisms.

- **Passive sampling approaches.** Workshop participants suggested that the deployment of passive integrative samplers can provide useful data on chemical exposure within UK fresh waters (e.g. Söderström *et al.*, 2009; Almeida *et al.*, 2016), including dissolved inorganic chemical stressors (e.g. nitrate), wide-ranging organic compounds (e.g. POCIS - Polar Organic Chemical Integrative Samplers), or airborne contaminants (e.g. passive integrative gaseous phase samplers). Such devices are simple to deploy and provide a time-integrated measure of chemical exposure for resident organisms.
- **Microfluidics.** There was also recognition of the potential of microfluidic “lab-on-a-chip” technologies for monitoring chemical exposure. These are based upon the miniaturisation of chemical analyses within microdevices that can process small volumes of water *in situ* (AlMashraa *et al.*, 2024). Water may be injected into such systems by a syringe pump, for subsequent analysis, but some designs rely on passive chemical uptake instead.
- **Optical sensors.** For some chemical stressors/water quality determinants, there exist sensor-based monitoring approaches that can yield high frequency concentration data and would allow monitoring and analysis of short-term and episodic chemical exposure events. Workshop participants identified UV optical sensors for dissolved organic matter and nitrate as specific examples of such approaches (Kim *et al.*, 2025).
- **Bankside analysis.** High-frequency chemical stressor/exposure data can also be collected through the deployment of automated bankside monitoring stations. These infrastructures typically pump water from a freshwater ecosystem and deliver it to a combination of sensors and chemical auto-analysers (Bowes *et al.*, 2012). As for the deployment of sensors alone, such approaches allow the monitoring of episodic chemical exposure events (Outram *et al.*, 2014; Lloyd *et al.*, 2015).
- **Advanced chemical analysis.** Modern approaches to analysing the molecular structure and elemental composition of chemicals in the environment were seen as valuable in augmenting more established chemical monitoring approaches. Insights into molecular structure provide opportunities to infer sources of pollutants, transformation processes in the environment, and pollutant fate (Lloyd *et al.*, 2023). Participants also recognised the potential utility of techniques that can rapidly detect and quantify chemicals of concern in the environment, such as Inductively Coupled Plasma Mass Spectrometry (ICPMS) and X-ray fluorescence (XRF) spectroscopy (Lawlor & Tipping, 2003; Bearcock *et al.*, 2017).
- **Tissue analyses.** In addition to the various approaches identified for monitoring chemical concentrations in the external environment, workshop attendees also suggested the value of measuring chemical concentrations/loads in organism tissues (e.g. animals, aquatic

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macrophytes, mosses). This complements other approaches to chemical monitoring, by specifically revealing the bioavailable fraction of chemicals and giving a more direct measure of organism exposure. The National Fish Tissue Archive, delivered through collaboration between UKCEH and the Environment Agency, exemplifies this approach (Jürgens *et al.*, 2013).

Novel approaches for monitoring the physical environment

Workshop participants primarily highlighted the importance of gathering landscape-scale data on the distribution and extent of freshwater habitats, as well as on hydrological regimes within the ecosystems themselves.

- **Remote sensing.** Workshop participants identified several remote sensing technologies that could be used to map and provide structural information on freshwater habitats (including restoration projects), including satellite earth observation, aerial imagery from drones, and LiDAR (Light Detection And Ranging). It was specifically noted that such approaches enable landscape assessment of the freshwater environment, including the distribution and coverage of small water bodies such as ponds. Remote sensing can also provide valuable information on waterbody conditions via optical properties e.g. chlorophyll and phycocyanin concentrations (Hunter *et al.*, 2008; Liu *et al.*, 2018; Liu *et al.*, 2021), coloured dissolved organic matter (Chen *et al.*, 2017), and aquatic plant coverage (Nelson *et al.*, 2006).
- **Flow monitoring.** Flow gauging and monitoring are vital for quantifying the hydrological regimes to which organisms are exposed and adapted. There was recognition of the need to better integrate modelled and measured flow data and biodiversity data, to enable assessments of the ecological impact of flow variation. This could include the deployment of Acoustic Doppler Current Profilers (ADCPs) or use of satellite digital imagery (Everard *et al.*, 2025). Coupled with this, workshop participants also recognised the importance of monitoring (and perhaps modelling) sediment mobilisation processes in the freshwater environment.
- **Aquatic Eddy Covariance (AEC).** The deployment of AEC systems would allow investigation of oxygen fluxes between sediments and overlying waters, through high resolution measurements of oxygen concentrations and turbulent water movements (Berg *et al.*, 2020). As such, this approach allows the determination of ecosystem metabolism (respiration – primary production balance) through coupled chemical and physical measurement.

Innovative modelling and analytical approaches for data interpretation

The workshop break-out group on modelling and analytical approaches considered pressure-response relationships that spanned the systems diagram provided (Figure 2). Discussions yielded both recommendations of specific analytical methodologies and insights into key considerations for any such modelling approach.

- **Multiple stressors.** There was recognition of the need for modelling approaches that can incorporate the potential effects of multiple stressors on freshwater biodiversity indicators (community composition and function), rather than single stressors (Jackson *et al.*, 2016; Birk *et al.*, 2020). These models should include hydrological conditions, given their role in shaping communities, and consider the network structure of the freshwater environment. Such approaches are needed for empirical and process-based models. Causal inference approaches were suggested to address the likely correlations among environmental stressors. There was, however, clear recognition of the complexity of disentangling such effects.

- **Direct and indirect effects.** Environmental attributes and stressors may impact freshwater species both directly and indirectly, via other ecosystem states and processes. Structural equation modelling was suggested as a means of teasing apart such complexities (Han *et al.*, 2026).
- **Spatial distributions.** There was consideration of the need for spatial analyses of freshwater biodiversity in relation to habitat characteristics and stressors (Domisch *et al.*, 2015; Wagner *et al.*, 2020), with both integrated species distribution models and hierarchical Bayesian occupancy models being specifically mentioned. It was suggested that such approaches could be used to integrate different data types, to produce more robust inferences.
- **Spatio-temporal mismatches and dynamics.** Workshop participants highlighted the value of analytical approaches that can allow us to address the complexities of spatial and temporal associations between environmental stressors and ecological responses in fresh waters. Freshwater communities can respond to environmental stressors with a time lag, or communities at one location may respond to stressors at another (e.g. downstream biological responses to upstream stressors in river networks). Meta-community dynamics are also of great importance. There exist techniques, such as distributed lag models (Le *et al.*, 2020), that allow the incorporation of such spatio-temporal lags in stressor-response relationships. There was also recognition of the “messiness” associated with joining datasets for environmental stressors and ecological responses, that have often been collected at different locations and on different sampling dates. There was, however, a suggestion that several techniques already exist that can help address this issue, including Bayesian hierarchical modelling, functional regression, smoothing approaches, and the inclusion of latent variables.
- **Observation processes.** A key consideration when integrating stressor and ecological data collected from different monitoring schemes is that data sets will have been gathered for different purposes, using varied monitoring technologies or sampling protocols, and will likely differ in their spatial, temporal, and ecological coverage and resolution. However, analytical techniques exist that allow the incorporation of observation models alongside the modelled stressor-response relationship, providing statistical descriptions of how data were collected and allowing for this during the integrated stressor-response modelling process (Isaac *et al.*, 2020; Jarvis *et al.*, 2023).
- **Machine learning.** Participants also recognised the potential to apply machine learning approaches (e.g. random forests) to investigate complex relationships within high-dimensional data sets, such as freshwater stressor-biodiversity data that include many measured variables (Kakouei *et al.*, 2021). Recurrent neural networks were specifically mentioned as approaches that are especially suited to time series data from long-term monitoring schemes.

5.2.2 Developing fit-for-purpose freshwater ecosystem indicators

Freshwater ecosystems respond to multiple stressors that can interact in complex ways, making it hard to understand the specific drivers of changing biodiversity. As such, if we are to manage and protect these ecosystems effectively, we need indicators that tell us how “healthy” freshwater ecosystems are, how they are changing, and whether management interventions are working (Stephenson *et al.*, 2024). In the workshop breakout session on indicators, there was clear recognition that such indicators must be fit-for-purpose. Specifically, that they should be relevant to the specific pressures and goals of monitoring, sensitive enough to detect changes caused by multiple stressors, practical to measure and interpret, scalable across different regions and timeframes, and useful for decision-makers and stakeholders.

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- **Landscape pressures.** Workshop participants recognised the potential of earth observation techniques to produce indicators of landscape scale pressures acting on fresh waters. There was a specific suggestion of creating heat maps of the intensity of stressors across space. However, there was recognition that such techniques will not necessarily provide direct data on the intensity of all impacts of land management. In addition, species distribution models were suggested as valuable, in that they allow inference on spatial variations in stressors based upon patterns in species presence/absence and abundance.
- **Species and communities.** It was recognised that useful ecological indicators can be derived at multiple levels of biological organisation. On one hand, information on sentinel species, selected due to their sensitivity to environmental stressors, can be used to provide early warnings of change. On the other hand, multi-species indicators can provide valuable information on broader scale ecological change, for example the JNCC indicator on birds of the wider countryside and at sea ([UKBI - Birds of the wider countryside and at sea | Advisor to Government on Nature Conservation | JNCC](#)). The range of species contributing to such indicators would need to be habitat dependent, but it was suggested that indicators across the tree of life (e.g. “microbes to birds”) would be especially powerful in detecting multi-stressor effects.
- **Functional indicators.** In addition to taxonomically based indicators (single or multi-species), there was clear recognition of the importance of ecosystem function indicators (Colin *et al.*, 2018; Goździejewska *et al.*, 2024). These could, for instance, include measures of functional richness and provide information on stressor-driven changes to important ecosystem energy flows and structures (e.g. decomposition, food web attributes). It was suggested that modern metagenomic techniques offer promise with respect to monitoring ecosystem functions (e.g. carbon and nitrogen cycling in biofilms), though they are currently in the research phase, and that multi-species indicators may also allow functional inference. Through functional metrics, it may be possible to better understand changes in ecosystem resilience and stability.
- **Stressor-specific indicators.** In addition to stressor-agnostic measures of community change, there was also clear recognition of the need to develop indicators that provide information on freshwater ecosystem responses to specific stressors. It was also observed, however, that established metrics designed to indicate the impacts of specific stressors are often sensitive to multiple stressors, making attribution of change difficult (Jones *et al.* 2023). Recent developments to the Community Temperature Index (Bowler & Böhning-Gaese, 2017), developed to reveal climate warming impacts, have considered this issue of attribution. Participants noted, however, that multiple-stressor effects can arise in many different ways, according to whether or not the individual stressors share overarching drivers, pathways to the ecosystem in question, and modes of action. Coupled with variations in species sensitivity to each stressor, this means that the challenge of attribution is significant.
- **The role of AI and machine learning.** Participants recognised the potential of AI, and more specifically machine learning, to provide new approaches for the integrated analysis of varied data sources. It was suggested that such techniques could reveal emergent ecosystem properties and provide novel measures of nonlinear, stochastic ecosystem change, and closeness to ecological tipping points.
- **Open data platforms.** There was recognition that the development of a central, open access, data platform would be a key enabler for metric development, analysis, and interpretation. This would allow the wider community to integrate freshwater data sets in new ways and pose new questions, collaboratively.

5.2.3 Developing a vision for an integrated monitoring and analysis system

Five breakout groups identified a wide range of enablers and barriers to a more integrated freshwater monitoring, analysis and interpretation system, and these have been thematically grouped in Table 2. It was clear that there is, first and foremost, a need to better understand the *status quo*; the totality of monitoring effort across organisations, the strengths and weaknesses of each scheme, and the key decision points that have led us to where we are now. This knowledge would provide the foundation for building a more integrated approach.

A key point that was raised was the need for both leadership and collaboration in building this new integrated approach. We need an organisation to “own” the challenge and vision of building a more integrated framework, and effective community collaboration around this leadership (including a culture of open science and data, and strategic alignment). This will require overcoming non-trivial challenges associated with long-term funding to support partnerships, the recruitment and retention of technical specialists within the sector, upskilling volunteers for participatory approaches, and navigating the complexities of organisational priorities.

Data discoverability and open access are key to this endeavour, but it is vital that associated metadata (e.g. methods used, precise sampling locations) are also available, and integration would be greatly enabled by effective data quality assurance, common data standards, agreements on data usage, and fair authorship agreements that allow monitoring teams to be properly credited for their efforts. To integrate diverse data streams, we need empirical approaches that allow modelling of large volumes of complex and diverse data, and that can help address biases inherent in individual monitoring schemes using the “strength” of multiple data sources. The implementation of such analyses, and subsequent interpretation, would be facilitated by a shared digital infrastructure that is open for community use and development.

There were some important cautionary notes to this ambition. Firstly, we must not devalue established monitoring methods in the pursuit of developing and integrating more novel approaches. It is still the case that established approaches deliver data and knowledge that cannot be gleaned through other approaches. We should not, therefore, view newer methods as substitutes for established ones; rather, complementary approaches that deliver different kinds of information and metrics. Secondly, there was concern about making fundamental changes to long-running monitoring schemes (e.g. intensive site-based monitoring), in that these could undermine long-term data consistency and our ability to compare current and future ecosystem state with the range of historic variation. A case was made for greater community collaboration around long-term monitoring sites, to deliver a better understanding of change in the freshwater environment.

Finally, and importantly, workshop participants identified a need to strengthen the narrative around long-term environmental monitoring. We collectively need to ensure that the public and policy makers understand that monitoring is more than data collection, rather it is research that allows us to develop understanding of ecosystem processes and change over time, and this evidence and understanding can be used to guide management, conservation and restoration efforts, for the benefit of society.

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Table 2. Key enablers of, and barriers to, the better integration of established and novel freshwater monitoring approaches.

Enablers	Barriers
Understanding our current position	
A clear overview of the current UK freshwater monitoring “landscape”, across organisations.	Lack of awareness of the community’s changing understanding of freshwater biodiversity trends and drivers.
A recorded “history” of monitoring and key decision points that led to the present state, so that we can learn from successes and mistakes.	
A critical review of the positive attributes of current schemes and approaches, and diagnosis of the gaps that need to be filled.	
Leadership and purpose	
A clearly articulated purpose, and research questions that require the integration of monitoring efforts.	The current lack of an organisation or consortium with the leadership and vision to “own” the data integration challenge.
Clear links between research and policy needs.	Long-term vision being undermined by changes in political priorities over time, and a lack of sustained Governmental support.
Collaboration and partnerships	
Fostering a culture of open science, with associated sharing of methods and metrics/indicators.	Difficulties in acquiring long-term funding to support partnerships in the delivery of monitoring, analysis and interpretation.
Working together to widen the scope of monitoring to the whole water environment.	The diverse and specific needs of different monitoring organisations, and inertia to change.
Effective communication and collaboration among monitoring organisations and sectors.	A progressive loss of specialist technical experience and expertise in the UK workforce and associated recruitment and retention issues.
Joined up organisational strategies, and a common vision for monitoring, analysis and interpretation.	A lack of training capacity and coordination for large numbers of citizen scientists.
Data	

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Enhanced data and metadata discoverability and open access, across monitoring organisations.	Biases in the taxonomic, habitat, and stressor coverage of institutional data sets.
Adoption of consistent data standards across institutions.	A lack of standardisation in data collection methods across organisations and schemes.
Better georeferencing of observations, to allow assessment of spatiotemporal overlaps between biodiversity, stressor, and environmental data.	Differences in the “information content” of data types e.g. presence/absence and abundance data.
Agreements on data usage and authorships for both data and resulting publications.	Costs associated with storage of large volumes of data from emerging methods (e.g. eDNA, computer vision, passive acoustics).
The use of monitoring technologies that can deliver data across species groups.	Fragmentation of monitoring data among different repositories; who would ultimately host/manage the data as a whole?
Appropriate calibration of established and emerging methods to rigorously assess their complementarity.	Potentially rich historic data sets that have yet to be digitised and made analysis-ready.
	Organisational variability in the standard of data quality assurance.
Physical and digital infrastructures	
Shared digital infrastructures for data visualisation and analysis, with user-friendly interfaces.	Concerns about changing monitoring infrastructure, and the associated loss of value of existing long-term schemes.
An integrated monitoring network to reduce duplication of effort among organisations and allow efficient resource use.	Concerns about devaluing more established monitoring methods in favour of emerging ones.
Analysis and interpretation	Limited time and resources for analysis and interpretation.
Statistical tools and methods suitable for the integrated modelling of large, complex, diverse data sets.	

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Skilled people were identified as key to realising the vision of an integrated monitoring network. There is a need to build the UK freshwater ecology skills base, but also recognition that the varied members of a wider UK partnership could offer wide-ranging skills towards a collective vision. For example:

- **Academic institutions:** data collection, statistical modelling and GIS approaches to analyse and interpret data, expert advice and training to regulators and other early adopters of new monitoring technologies, expert advice to Government on current ecosystem state, advocacy through professional networks.
- **UK research organisations:** integrated analysis of data streams, use of open data platforms, experience and knowledge of data pipelines, metadata standards, development of robust and standardised (long-term) monitoring protocols, management of large long-term data sets, access to local and national stakeholder networks.
- **NGOs and regulators:** data collection, taxonomic training, field skills training, data science and GIS skills, use of open data platforms, experience of working in partnerships.

Another key principle that emerged from discussions was the need to make efficient use of the limited funding and resources that are available for freshwater monitoring. Participants asked whether there is duplication of data collection among organisations, potentially wasting resources, and suggested that resources should be targeted at shared and policy-relevant priorities. Furthermore, it was suggested that the UK community should seek to learn from experiences in other countries that have explored such integration of monitoring effort.

Existing monitoring data were of course identified as a key resource to furthering our understanding of changes in freshwater ecosystems, and it was recognised that these data could be effectively re-purposed and analysed in novel ways to address emerging questions. There was a recognised role for data science here (digital tools, platforms, pipeline, expertise) in providing the digital infrastructure to enable the integration and analysis of data in new ways.

A wide array of partnering organisations were identified that would play a role in building and delivering a more integrated approach to freshwater biodiversity monitoring, analysis and interpretation (Table 3). The roles of these partners spanned data collection and provision, expert analysis/interpretation/advice, provision of sustainable long-term funding, promoting public engagement and citizen science, advocacy for fresh waters, capacity building, and policy support. At this stage in the workshop, it once again became clear that there is a need for overarching leadership of such a collective.

Table 3. Key partner organisations for integrated UK freshwater biodiversity monitoring, analysis, and interpretation.

Sector	Organisations	Additional comments
Government and regulators	Government and relevant departments (e.g. Defra); regulators (EA, SEPA, NRW).	Government support is essential to sustained funding and assuring the policy-relevance of monitoring. Also, there is a need for clear and consistent messaging on the importance of freshwater biodiversity.
Academia and research	Universities; academic and research organisations (e.g. UKCEH, BTO); UKRI and NERC; professional societies (e.g. BES, BGS).	Collection of data, analysis and provision of expert interpretation and guidance.

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Private sector	Water industry; consultancies; professional bodies (e.g. CIEEM and CIWEM); digital industry (e.g. Amazon, Microsoft, Google); agriculture and farmers unions; forestry; aquaculture; commercial fisheries; vets; instrumentation manufacturers, pharmaceutical and chemical industries.	Making data collected by the private sector openly available. Engagement with the digital industry to build capacity/enable new analyses of high volumes of complex data. A need for more emphasis on the polluter pays principle.
NGOs and community groups*	Community groups (e.g. “Friends of...” groups, Rivers Trusts, CaSTCo); local recording groups (e.g. CEDaR, NBN); angling clubs, charities.	Collection of data and advocacy for freshwater biodiversity/public engagement. There would be great value in NGOs willing to trial new collaborative approaches with academia and research organisations.
The wider public	Landowners, citizen scientists, catchment stakeholders, the “general public”.	Collection of data and advocacy for freshwater biodiversity/public engagement. Granting land access for monitoring.
Financial	Philanthropists; insurance companies; green finance.	Exploring options for financial sustainability for freshwater monitoring and analysis, at UK scale.

*The research elements of NGOs have been included within the “Academia and Research” category.

5.2.4 Evaluation and Equality, Equity, Diversity & Inclusion

The workshop was viewed as highly successful, with most participants rating the organisation as excellent and the content as relevant, accurate, and well structured. Presentations were judged to be engaging and visually clear, and almost all attendees felt that the event met or exceeded their expectations. Participants also felt that registration was straightforward, and accessibility was widely praised. Interaction opportunities, both with speakers and via the online platform, were generally rated as good, with only a few minor issues raised.

The feedback showed that participants were highly satisfied with the quality of the workshop content. Most respondents selected “*Strongly agree*”, in relation to the statement that workshop material was accurate, well organised, and pitched at the right level. A smaller number selected “*Agree*”, and there were no negative responses.

Respondents also reported that the event met or exceeded their expectations. Most felt that the workshop met all expectations, with some stating it exceeded them, and none suggesting it fell short. This demonstrates that the event delivered effectively on what participants anticipated.

For most participants attending the workshop, goals were to learn something new, connect with others in the field, or understand the latest developments. The strong agreement ratings suggest that the workshop successfully met these needs by offering clear, informative, and well-structured content that helped participants gain new insights.

Equality, Equity, Diversity & Inclusion (EEDI) principles were embedded throughout the design and delivery of the session. The online format supported participation across the four UK nations and a range

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of sectors, with good engagement from Early Career Researchers (23% of the attendees). Inclusive facilitation methods, such as small group discussions with designated facilitators and scribes, helped accommodate different communication styles and ensured everyone had the chance to contribute. Most respondents described the event as highly inclusive, indicating that participants largely felt welcomed and able to engage. However, some feedback highlighted the need to further improve speaker diversity, particularly in relation to ethnicity, suggesting an opportunity to strengthen inclusivity in future events.

Accessibility was further supported through online question submission and the Q&A function, allowing participants to engage in ways that suited them best. Feedback consistently described the event as easy to join, welcoming, and well organised.

Demographic data showed strong representation from senior professionals, particularly from research institutions and universities, with most attendees based in England and a smaller number from Scotland, Wales, and Northern Ireland. Gender representation leaned towards men, and ethnic diversity was limited. For workshop participants, the most frequent overarching areas of interest were Biodiversity, followed by Pollution, Data Science, and Hydrological Extremes.

Participants also offered constructive suggestions, including increasing diversity among speakers and attendees, and refining the use of interactive tools (such as alternatives to the Mural board) to strengthen engagement. Overall, the event delivered on its aims, was well received, and highlighted clear opportunities to build upon an already strong foundation.

5.2.5 Survey and workshop murals

Working with Envirovisuals, we created two murals to depict the major themes arising from the survey (Figure 16) and the survey and workshop combined (Figure 17). These murals used river channel imagery to represent the flow of discussions from an assessment of the current situation regarding monitoring of freshwater biodiversity in the UK, through to a desirable, more integrated future. These images will be used in project communications, to disseminate our findings.

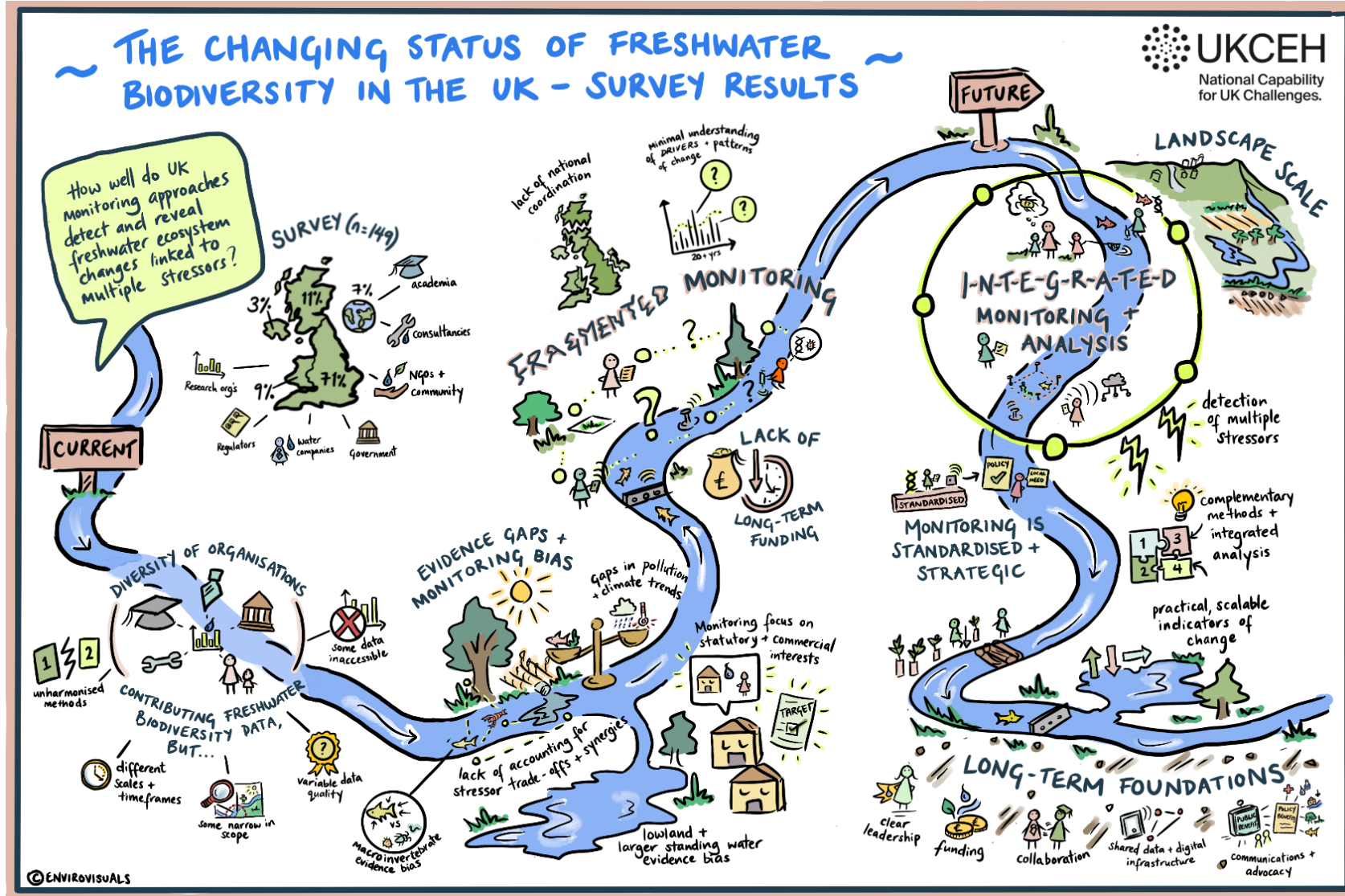


Figure 16. Mural depicting the major themes arising from survey responses (Rebecca Roberts, Envirovisuals).

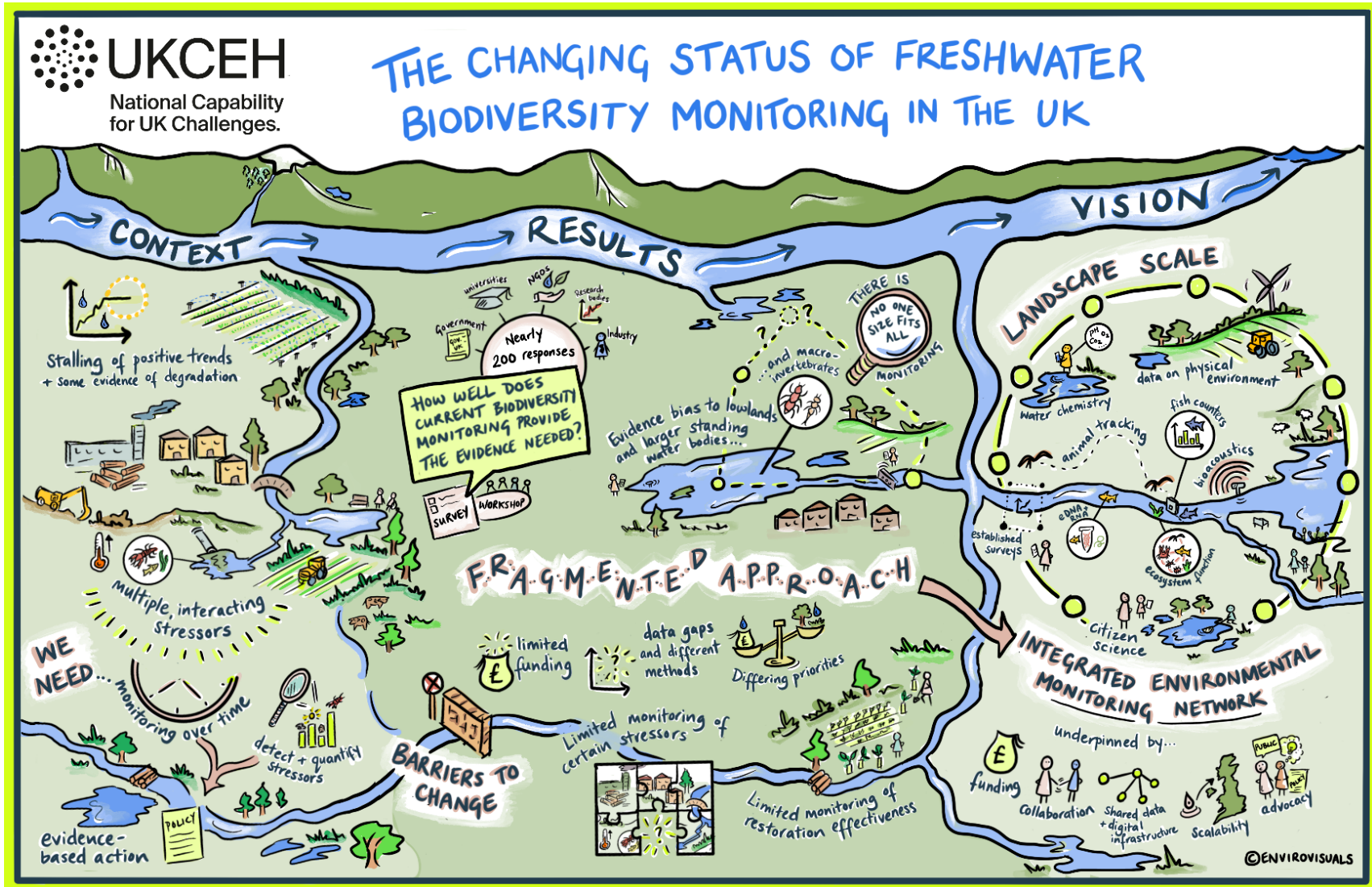


Figure 17. Mural depicting the major themes arising from the survey and workshop combined (Rebecca Roberts, Envirovisuals).

6. Discussion

6.1 Key themes arising from the survey and workshop

Through our process of community engagement, we identified important perceived limitations of the current state of UK freshwater biodiversity monitoring. A key point is that the current monitoring, analysis and interpretation “landscape” is viewed to be fragmented, with numerous organisations working (understandably) towards their own goals, using approaches that are not standardised with those from other organisations within a diverse multi-sectoral community. While we acknowledge that organisations have their own priorities for monitoring and analysis, we need to work towards a collaborative approach and shared vision, so that we are better equipped to detect and understand the major pressures acting on fresh waters at UK scale, to our shared benefit (see also Barnes *et al.*, 2025).

We identified several perceived biases in the current evidence base for UK freshwaters, with respect to the species and environmental stressors being monitored, the coverage of freshwater ecosystem types, and the spatial and temporal scales of monitoring and analysis. As such, we have highly variable levels of fundamental understanding of how specific components of the UK freshwater landscape are changing, and the multiple stressor-response relationships underpinning these changes. This impacts upon the confidence with which we can enable evidence-based management and restoration activities in different ecological contexts.

Given the above observations, we need to critically evaluate the extent to which we can fill important knowledge gaps. A key consideration here is whether more novel approaches to monitoring are mature enough to provide repeatable, reproducible and accurate data. We should not view novel approaches as substitutes for more established ones; each monitoring approach will provide different types of information, varying in spatial and temporal resolution, ecological resolution (e.g. presence/absence, abundance, diversity, community composition at varied taxonomic levels) and measurement currencies (e.g. absolute or relative abundances, concentrations, areal coverage). We need to explicitly recognise this and understand what new types of data can and cannot tell us, in comparison to more established approaches. There is a clear role for our current network of freshwater monitoring sites in providing opportunities to compare established and novel approaches, learn, and understand the capabilities and potential efficiencies of newer technologies. We note, however, that these needs are set against a backdrop of resource and funding cuts that are challenging existing data collection, analysis and interpretation. This latter point was recently raised with respect to the current state of broader biodiversity monitoring in Northern Ireland (Barnes *et al.*, 2025).

In creating a vision for the future of UK freshwater biodiversity monitoring, we must retain clarity of purpose. We need to have a collaborative approach that can still deliver the data and insights required by regulators and conservation organisations to report on ecological status and protected sites and areas, as well as providing the basis for the development of new fundamental understanding of ecological responses to pressure and management actions. Through fundamental research with high quality data, we can learn and provide the best evidential basis for statutory monitoring and compliance with legal targets (e.g. the Environment Act 2021, Stephenson *et al.*, 2024).

Finally, we identified varied perceptions of the extent to which public and political narratives on UK freshwaters are evidence-based. These views belie a great complexity of factors, not least the extent to which complex, multi-issue messaging on the state of freshwaters can be effectively communicated when current discourse can be led by simple narratives on single issues. There is a clear need for effective translation of scientific findings in accessible ways and using novel approaches (e.g. by working with

artists). Throughout this endeavour it will be essential to communicate scientific rigour and engender widespread trust in the research process.

6.2 Next steps

Initial engagement through the survey and workshop identified some priority activities that could be undertaken to enable a more integrated vision of freshwater biodiversity monitoring in the UK:

- To address the need for a clearer overview of current monitoring activities (Table 2), we propose the development of a shared resource library providing key information and metadata on UK freshwater monitoring schemes. This should include initiatives from across the multi-sectoral monitoring landscape identified during this project, as well as information on the purpose of each monitoring scheme, the questions being addressed, the focal taxa, habitats and spatiotemporal scales, and key protocols.
- We identified a clear need for both leadership and collaboration around a shared goal of more integrated, representative, and comprehensive freshwater biodiversity monitoring, analysis, and interpretation. As such, we suggest establishing a special interest group with membership from across the multi-sectoral landscape, as a vehicle to identify shared priorities and work towards a shared vision.
- The findings of the current project should be shared with the UKCEH team working under National Capability to develop the vision for an Integrated Environmental Monitoring Network (IEMN) for the UK, so that the community perceptions and needs identified here can inform the design process.
- Translate the current report into a short recommendations paper suitable for policymakers, including our key findings, and recommendations.

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9. Appendices

Appendix Table A1. Membership of the Project Steering Group

Organisation	Name
British Trust for Ornithology (BTO)	James Pearce-Higgins
Cardiff University	Steve Ormerod
Natural England	Daisy Burris
Natural England	Melaine Fletcher
Queen Mary University of London	Iwan Jones
UK Centre for Ecology & Hydrology	Marcia Spencer
UK Centre for Ecology & Hydrology	Stephen Thackeray
University of Bristol	Penny Johnes (Chair)

9.1 Pre-workshop survey



The Changing Status of Freshwater Biodiversity Monitoring in the UK

Who is this survey for?

This survey is intended for individuals and organisations involved in freshwater biodiversity and water quality research, monitoring, policy, and conservation in the UK. This includes scientists, data managers, environmental NGOs, government agencies, and other stakeholders with knowledge or interest in the state of UK freshwater ecosystems and the pressures they face.

What are we trying to find out with this survey?

This survey has been developed to help us capture community knowledge, needs, and priorities with respect to monitoring of freshwater biodiversity, and the pressures it faces, in the UK. We will use this information to develop the structure and content of a subsequent online workshop, in which a smaller team of invited experts will explore how well-equipped we are to detect and understand the effects of pollutants on the health of UK freshwaters. Your responses will help us understand what topics and outcomes matter most to you.

The survey takes approximately 15-20 minutes to complete.

Respondent Information

1. What type of organisation/institute are you affiliated with?

(Please select all that apply).

- b. Government
- c. Government Agency
- d. Water Company
- e. Non-Governmental Public Body
- f. Research Institution
- g. University
- h. Commercial business
- i. Other (please specify)

2. How would you describe your role?

- a. Environmental/ecological researcher
- b. Data scientist
- c. Campaigner
- d. Citizen scientist
- e. Water/Land/Asset manager
- f. Regulator
- g. Other (please specify)

3. Would you describe yourself as an Early Career Researcher?

The definition of an Early Career Researcher (ECR) can vary slightly depending on the institution, funder, or context, but a commonly accepted definition in the UK is someone who is within eight years of their PhD award (or equivalent professional training), or within six years of their first academic appointment (e.g., lecturer, research fellow), excluding any career breaks.

- a. Yes
- b. No
- c. Don't know

4. If you plan to attend the workshop, what would be your main goal for attending?

(Tick all that apply)

- a. Learn something new
- b. Contribute my perspective
- c. Connect with others in the field
- d. Understand the latest developments
- e. Influence future direction
- f. I do not plan to attend the workshop
- g. Other: (please specify)

5. **In which part of the UK do you work?**

- a. England
- b. Northern Ireland
- c. Scotland
- d. Wales
- e. International

Main Survey

6. **In your view, how comprehensively have the following environments been monitored for biodiversity in the UK?**

Please rank them from 1 (most comprehensively monitored) to 4 (least comprehensively monitored).

- 1. Freshwater
- 2. Marine
- 3. Terrestrial
- 4. Estuarine / transitional waters

7. **Based on your experience and available evidence, which of the following organisations do you believe play a major role in gathering freshwater biodiversity data in the UK?**

(Please select all that apply).

- a. Government Agencies
- b. Water Companies
- c. Non-Governmental Public Bodies
- d. Research Institutions
- e. Universities Commercial businesses
- f. Non - Governmental Organisations
- g. Other (please specify)

8. **Please feel free to explain your answer** (optional)

9. **Based on your experience and available evidence, which of the following freshwater ecosystem types do you believe are most well monitored for their resident biodiversity in the UK?** (Please select all that apply).

- a. Upland streams
- b. Lowland streams and rivers
- c. Ponds
- d. Upland lakes/reservoirs
- e. Lowland lakes/reservoirs
- f. Urban waters (running or standing)
- g. Wetlands

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h. Other (please specify)

10. **Please feel free to explain your answer** (optional)

11. **Based on your experience and available evidence, which of the following freshwater ecosystem types do you believe are least well monitored for their resident biodiversity in the UK?**

(Please select all that apply).

- a. Upland streams
- b. Lowland streams and rivers
- c. Ponds
- d. Upland lakes/reservoirs
- e. Lowland lakes/reservoirs
- f. Urban waters (running or standing)
- g. Wetlands
- h. Other (please specify)

12. **Please feel free to explain your answer** (optional)

13. **Based on your experience or available evidence, which type of freshwater ecosystem in the UK most urgently requires improved monitoring, analysis, interpretation, and fit-for-purpose approaches to support its resident biodiversity?**

(Please select all that apply).

- a. Upland streams
- b. Lowland streams and rivers
- c. Ponds
- d. Upland lakes/reservoirs
- e. Lowland lakes/reservoirs
- f. Urban waters (running or standing)
- g. Wetlands
- h. Other (please specify)

14. **Please feel free to explain your answer** (optional)

15. **Which taxonomic groups do you consider to be currently under-studied, which could be important in future for providing robust information on the changing status of UK fresh waters?** (Please select all that apply).

- a. Aquatic plants
- b. Benthic algae
- c. Planktonic algae
- d. Microbial communities
- e. Zooplankton

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- f. Macroinvertebrates
- g. Invertebrates
- h. Fish
- i. Wetland birds
- j. Other (please specify)

16. **Please feel free to explain your answer** (optional)

17. **Which types of environmental stressors are currently underrepresented or poorly indicated by existing freshwater biodiversity data in the UK?**

(Please select all that apply).

- a. Climate change trends
- b. Extreme weather and flow events
- c. Nutrient pollution
- d. Metal pollution
- e. Agrochemical pollution
- f. Emerging contaminant pollution (e.g. pharmaceuticals, PFAS compounds, plastics)
- g. Habitat modification
- h. Invasive non-native species introduction
- i. Other

18. **Please feel free to explain your answer** (optional)

19. **Given current freshwater biodiversity monitoring efforts, at what spatial scales do you think we are well-equipped to quantify and understand change?**

(Please select all that apply).

- a. UK-scale
- b. Individual UK countries: England, Scotland, Wales, Northern Ireland
- c. Individual catchments
- d. Individual river reaches/water bodies

20. **Please feel free to explain your answer** (optional)

21. **Given current freshwater biodiversity monitoring efforts, at what temporal scales do you think we are well-equipped to quantify and understand change?**

(Please select all that apply).

- a. Decadal
- b. Year to year
- c. Seasonally
- d. Monthly
- e. Shorter than monthly

22. **Please feel free to explain your answer** (optional)

23. **To what extent do you agree with the following statement “In the UK, sufficient effort has been maintained over the long term to monitor freshwater ecosystems.”**

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Scale 1----- Scale 10
Strongly disagree *Strongly agree*

24. Based on your experience or available evidence, what do you believe are the major barriers to understanding the trends and drivers of freshwater biodiversity change in the UK? (Please select all that apply).

- a. Biodiversity data availability/coverage
- b. Stressor data availability/coverage
- c. Data accessibility
- d. Data quality
- e. Tools to visualise and analyse available data
- f. Funding for data collection
- g. Funding for data analysis
- h. Other (please specify)

25. Please feel free to explain your answer (optional)

26. Which monitoring approaches do you think will help us most in filling important gaps in our understanding of freshwater biodiversity change in the UK?

(Please select all that apply).

- a. Established/traditional taxonomic surveys
- b. eDNA/molecular approaches
- c. Passive acoustic methods (e.g. hydrophones)
- d. Active acoustic methods (e.g. echo sounding/sonar)
- e. Image analysis/computer vision
- f. Remote sensing (e.g. drones, satellites)
- g. Citizen science / community monitoring
- h. Other (please specify)

27. Please feel free to explain your answer (optional)

28. To what extent do you agree with the following statement “Public discourse on the state of freshwater ecosystems in the UK is well informed by available scientific evidence”.

Scale 1----- Scale 10
Strongly disagree *Strongly agree*

29. Please feel free to explain your answer (optional)

30. To what extent do you agree with the following statement “In the UK, policymakers’ understanding of the state of freshwater ecosystems is well informed by available evidence”.

Scale 1----- Scale 10
Strongly disagree *Strongly agree*

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31. **Please feel free to explain your answer** (optional)
32. **Do you have any additional thoughts or reflections that haven't yet been captured? Please feel free to comment on the evidence or experiences that have informed your responses above.**

9.2 Workshop agenda



NC-UK National Science Series

The Changing Status of Freshwater Biodiversity in the UK: Current evidence, challenges, and possible futures

Wednesday 12th November 2025, 13.00 – 17.15

Despite evidence of recovery in UK freshwater ecosystems from some of the past effects of sanitary and industrial pollution, especially in urban areas, more recent data suggest that these positive trends have stalled. Some regional assessments even hint at degradation, particularly in more rural regions. Key questions are now focussed on *i)* understanding the changing combination of stressors responsible, including climate and land use change, habitat alteration, species introduction, and impacts by both long-standing and emerging pollutants; *ii)* addressing the impacts through appropriate monitoring, research and effective management. Pollution is particularly prominent in public and political debate, and it is essential that we have robust evidence to enhance scientific understanding, inform debate and guide action.

This online workshop will bring together experts in freshwater biodiversity and water quality to evaluate the effectiveness and representativeness of current UK monitoring approaches, with respect to providing the evidence needed to detect and understand ecosystem change in response to pollution. We will explore the essential elements needed to evaluate ecosystem impacts and identify key challenges and opportunities. We hope to identify and confront significant issues such as gaps in data coverage, hurdles to data integration, and the complexities involved in interpreting the data available. At the same time, we will identify promising opportunities such as novel, cutting-edge monitoring and analytical techniques (for both water chemistry and data).

Aims:

- To understand how well-equipped we are to detect and understand the effects of pollutants on the status of UK freshwaters.
- To guide priority actions for monitoring freshwater biodiversity and freshwater ecosystem quality in the UK.

Chaired by Professor Penny Johnes, University of Bristol

Facilitated by Paul Mahony, Countryside

Time		Presented by
13.00 - 13.05	Arrival and welcome	Paul Mahony
13.05 - 13.20	Where are we now? Understanding freshwater biodiversity trends in the UK	Steve Ormerod <i>Cardiff University</i>
13.20 - 13.30	The current state of UK freshwater biodiversity monitoring: voices from our community	Steve Thackeray <i>UKCEH</i>
13.30 - 13.50	Voices from research, regulation & the wider community <ul style="list-style-type: none"> • Academic community 	Iwan Jones <i>QMUL</i>

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	<ul style="list-style-type: none"> • Regulatory community • Voluntary sector 	<p>Sarah Pick <i>Environment Agency</i></p> <p>Sasha Woods <i>Earthwatch</i></p>
13.50 - 14.00	Q&A	Paul Mahony Penny Johnes
14.00 - 14.10	Screen break	
14.10 - 14.25	<p>New tools, new questions - What can new tools really tell us? Exploring the role of molecular, chemical and novel sensor technologies in freshwater monitoring</p> <ul style="list-style-type: none"> • Regulator • Academic 	<p>Sarah Pick <i>Environment Agency</i></p> <p>Lori Lawson Handley <i>UKCEH</i></p>
14.25 - 15.25	<p>Breakout activity 1 - How could novel monitoring and analytical approaches help us understand UK freshwater biodiversity and the pressures acting upon it?</p> <p><i>Discussion questions:</i></p> <ul style="list-style-type: none"> • <i>What the approach adds to our understanding of freshwater biodiversity change (what gaps it fills).</i> • <i>The ecosystems to which it is most suitable.</i> • <i>Its current readiness level and future potential.</i> • <i>Its limitations and uncertainties.</i> 	
15.25 - 15.30	Plenary	Paul Mahony Penny Johnes
15.30 - 15.40	Screen break	
15.40 - 16.30	<p>Breakout activity 2 - How can we integrate freshwater biodiversity monitoring and analysis in the UK?</p> <p><i>Discussion questions:</i></p> <ul style="list-style-type: none"> • <i>What are the key enablers of a more integrated monitoring network?</i> • <i>What are the main barriers to such integration?</i> • <i>With respect to an integrated network, what can we already achieve and what could your organisation contribute?</i> • <i>Who else needs to be involved to make this work?</i> 	
16.30 - 16.40	An example vision - the National Capability Integrated Environmental Monitoring Network	Pete Henrys <i>UKCEH</i>
16.40 - 17.00	Q&A on the example vision.	Penny Johnes
17.00 - 17.05	Closing Remarks	Penny Johnes
17.05– 17.15	Workshop evaluation	Paul Mahony



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please contact:**

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