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Executive Summary

- We welcome the Committee's consideration of water quality in rivers. With the environmental state of UK surface waters at its poorest level since monitoring began within the current policy framework, it is clear that a robust and evidence-based approach is required to improve the monitoring and management of these critically important ecosystems.
- A narrow focus on water quality indicators risks missing the interactive effects of multiple pressures, such as habitat degradation, global heating and extreme events. To better understand the state of our rivers, and build the knowledge required to improve river health, we need to look at the whole ecosystem and fully embrace new technologies. Thus, we refer to "river quality", rather than water quality, throughout.
- The steps required to improve monitoring, assessment and management of UK rivers include intelligent re-design of monitoring networks, more efficient and comprehensive data collection, more insightful analysis of monitoring data, and a greater focus on diagnostic systems.

Response to relevant inquiry questions

1. What are the best indicators for river water quality that could be used as targets being developed under the Environment Bill?

    1.1. Biological monitoring is central to current practice in river quality assessment worldwide, as exemplified by ecological status classification under the EU Water Framework Directive (WFD). Under this "biomonitoring" paradigm, certain groups of organisms are used as indicators of the pressures on waterbodies. The rationale for this approach is that, throughout their life cycles, resident organisms integrate the effects of pressures which might otherwise be difficult to detect through direct spot sampling of the abiotic environment.

    1.2. Despite the importance of biomonitoring to river quality assessment, numerous direct measurements of the abiotic environment (e.g. pesticides, heavy metals, water discharge) are still collected for a range of purposes. Together, the collection of biological and environmental data should allow us to paint a detailed picture of river quality. Indeed, biological, chemical, geomorphological and hydrological processes are inextricably linked and cannot be fully understood in isolation[1]. However, methods used to assess these different, but

[1] Wilkes, M.A., Gittins, J.R., Mathers, K.L., Mason, R., Casas-Mulet, R., Vanzo, D., Mckenzie, M., Murray-Bligh, J., England, J., Gurnell, A. and Jones, J.I., 2019. Physical and biological controls on fine sediment transport and storage in rivers. *Wiley Interdisciplinary Reviews: Water*, *6*(2), p.e1331.

interdependent, aspects of river environments have developed independently of one another. Monitoring networks for different groups of organisms, and different aspects of the environment, do not overlap in time and space, hampering more complete characterisations of river health. Existing monitoring networks also suffer from extreme spatial bias, neglecting headwater streams which make up the vast majority of freshwater surface area and play a key role as greenhouse gas emitters - contributing over 70% of global riverine CO_2, CH_4, and N_2O emissions[2].

1.3. Rivers are dynamic and hierarchical ecosystems, and their biological communities are highly variable with local responses to pressures set against a backdrop of changes occurring at nested scales throughout the river network. For example, changes in spilling regimes at wastewater treatment plants are superimposed on climate change (global), land-use change (river basin) and flood management impacts (river reach scale). Therefore, management tools that target fixed reference ("near-natural") conditions and assume independence between observations through time and space (e.g. "RIVPACS", the system underlying invertebrate biomonitoring in the UK), do not represent the multitude of drivers re-shaping biological communities. Originally developed to monitor nutrient pollution from agriculture and urbanisation, these tools are now widely used to indicate general river health. They lack the capacity to diagnose 21st Century pressures, such as global heating, extreme events, microplastics, pharmaceuticals and personal care products[3].

1.4. The pressures impacting rivers today are manifold, operating over a range spatial and temporal scales, and frequently interacting to amplify or dampen the effects of other pressures[4]. For example, the problem of fine sediment (particles <2 mm in diameter) has become a major focus for river managers in recent years. Entering rivers from urban and intensive agricultural sources, fine sediment has pervasive impacts on river environments: smothering reproductive habitats of fish populations already impacted by global heating, increasing flood risk in concert with extreme events, and acting as a vector for numerous pollutants, among other negative effects[1]. Independent studies have repeatedly shown that the performance of biomonitoring tools designed to indicate fine sediment pressures is limited compared to those targeting other pressures[5,6]. In Europe, the vast majority (87%[7]) of available biomonitoring methods target nutrient

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[2] Li, M., Peng, C., Zhang, K., Xu, L., Wang, J., Yang, Y., Li, P., Liu, Z. and He, N., 2020. Headwater stream ecosystem: an important source of greenhouse gases to the atmosphere. *Water Research*, *190*, p.116738.

[3] Poikane, S., Herrero, F.S., Kelly, M.G., Borja, A., Birk, S. and van de Bund, W., 2020. European aquatic ecological assessment methods: A critical review of their sensitivity to key pressures. *Science of The Total Environment*, p.140075.

[4] Birk, S., Chapman, D., Carvalho, L., Spears, B.M., Andersen, H.E., Argillier, C., Auer, S., Baattrup-Pedersen, A., Banin, L., Beklioğlu, M. and Bondar-Kunze, E., 2020. Impacts of multiple stressors on freshwater biota across spatial scales and ecosystems. *Nature Ecology & Evolution*, *4*(8), pp.1060-1068.

[5] Wilkes, M.A., Mckenzie, M., Murphy, J.F. and Chadd, R.P., 2017. Assessing the mechanistic basis for fine sediment biomonitoring: Inconsistencies among the literature, traits and indices. *River Research and Applications*, *33*(10), pp.1618-1629.

[6] Mckenzie, M., 2020. Quantifying the response of macroinvertebrates to gradients of fine sediment pollution. PhD Thesis (unpublished), Coventry University.

[7] Poikane, S., Herrero, F.S., Kelly, M.G., Borja, A., Birk, S. and van de Bund, W., 2020. European aquatic ecological assessment methods: A critical review of their sensitivity to key pressures. Science of The Total

pollution. Of the relatively few methods which target other pressures, even fewer are demonstrably adequate indicators of those pressures. For instance, only eight of 90 available methods targeting a wide range of toxic substances (e.g. heavy metals, persistent organic pollutants) in European waters have been demonstrated to actually respond to the presence of the targeted substances[7].

1.5. Ecological status classification, as set out by the WFD, appears to be relatively insensitive to environmental change and unresponsive to management intervention[8,9]. Furthermore, WFD classification focuses solely on the structure of river ecosystems (e.g. the range of species present), yet the first priority for managers should be to ensure functional integrity (e.g. organic matter processing, drinking water provision, fisheries production). Trait-based approaches, which focus on the effects that organisms have on their environment rather than on species' names, have often been proposed as an alternative. However, the link between species' traits and ecosystem functioning is weak and statistical issues obscure quantitative links between trait diversity and environmental change[10].

1.6. Monitoring has traditionally focused on groups of organisms that may be identified and counted in the field or under a microscope, such as fish, invertebrates and diatoms (single-celled algae). However, a stronger mechanistic basis for assessing river quality can be found through targeting microbial communities. The mainstreaming of molecular (e.g. DNA- and RNA-based) technologies now makes this feasible, and more cost-effective than traditional methods when applied at scale. In particular, monitoring the frequency of particular genes activated by bacteria and fungi in response to the occurrence of specific pollutants can provide near instantaneous diagnostic capability and a represents a direct measure of ecosystem functioning[11]. UK authorities are slowly embracing molecular technologies but their focus has been on replacing techniques used to monitor the same target organisms (e.g. diatoms) within the existing monitoring framework, rather than seeking new and improved applications.

1.7. In summary, existing frameworks for monitoring and assessing river quality are firmly based upon 20th century problems, ideas and technologies. The steps required to update these frameworks in light of new environmental issues and emerging technologies all require a greater focus to be placed on data management, statistical literacy and high-performance computing. This includes statistical models that can correct for spatial bias in monitoring networks,

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Environment, 740, p.140075.

[8] Haase, P., Hering, D., Jähnig, S.C., Lorenz, A.W. and Sundermann, A., 2013. The impact of hydromorphological restoration on river ecological status: a comparison of fish, benthic invertebrates, and macrophytes. *Hydrobiologia*, *704*(1), pp.475-488.

[9] England, J. and Wilkes, M.A., 2018. Does river restoration work? Taxonomic and functional trajectories at two restoration schemes. *Science of The Total Environment*, *618*, pp.961-970.

[10] Wilkes, M.A., Edwards, F., Jones, J.I., Murphy, J.F., England, J., Friberg, N., Hering, D., Poff, N.L., Usseglio-Polatera, P., Verberk, W.C. and Webb, J., 2020. Trait-based ecology at large scales: Assessing functional trait correlations, phylogenetic constraints and spatial variability using open data. *Global Change Biology*, *26*(12), pp.7255-7267.

[11] Thompson, M.S., Bankier, C., Bell, T., Dumbrell, A.J., Gray, C., Ledger, M.E., Lehmann, K., McKew, B.A., Sayer, C.D., Shelley, F. and Trimmer, M., 2016. Gene-to-ecosystem impacts of a catastrophic pesticide spill: testing a multilevel bioassessment approach in a river ecosystem. *Freshwater Biology*, *61*(12), pp.2037-2050.

bioinformatics protocols to process the outcomes of DNA- and RNA- based monitoring, artificial intelligence techniques trained to detect early warning signals, and process-based computer models simulating flows of water, pollutants and organisms within river networks.

1.8. A better approach to assessing river quality in the 21st Century lies in:

- Consolidating biological, chemical and hydrological monitoring networks to enable integrated analysis of multiple groups of organisms, from primary producers to top predators, and the environments in which they live
- Redesigning monitoring networks to provide a more representative sample of UK rivers (including neglected headwater streams) and reduce the biases inherent in current approaches
- Fully embracing new molecular technologies to increase the cost-effectiveness of monitoring and maximise the amount of information upon which to base decision-making
- Moving away from phenomenological approaches to classifying river health based on structural indicators and towards diagnostic systems that directly reflect ecosystem functioning
- Harnessing high performance computing technologies to make better use of a wide variety of data on biodiversity and the environment.

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