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| **Institution:** University of Stirling | | |
| **Unit of Assessment:** 14. Geography and Environmental Studies | | |
| **Title of case study:** Protecting the best and restoring the rest: successful implementation of water policy and action for Europe's freshwaters | | |
| **Period when the underpinning research was undertaken:** 2012-2019 | | |
| **Details of staff conducting the underpinning research from the submitting unit:** | | |
| **Name(s):** | **Role(s) (e.g. job title):** | **Period(s) employed by submitting HEI:** |
| Nigel Willby | Professor | 2002 - Present |
| Colin Bull | Lecturer | 2006 - Aug 2019 (seconded to Atlantic Salmon Trust until 08/2024) |
| Alan Law | Research Assistant then Lecturer | 12/2015 - Present |
| **Period when the claimed impact occurred:** 2014 onwards | | |
| **Is this case study continued from a case study submitted in 2014?** N | | |

## 1. Summary of the impact

Stirling research has been instrumental in implementing policies designed to protect and restore water resources used by the EU's 0.5 billion inhabitants.

**Impact 1. Cross-national implementation of the Water Framework Directive (WFD)** is reliant on protocols we developed to harmonise the 100s of different methods used by Member States to assess surface waters. Going beyond co-operation, harmonisation of assessment under the WFD is critical to the environmental and economic sustainability of freshwaters, particularly for those that flow across national boundaries such as the Danube, Rhine, and Elbe. Building on this, our work has also defined the much sought-after nutrient targets now used by Member States to improve the health of their lakes and rivers.

**Impact 2. Restoration and management** of the UK's Norfolk and Suffolk Broads and Scotland's rivers is dependent on the use of our tools and advice to statutory agencies. Our work has enabled ambitious restoration projects, such as the GBP4,500,000 plan for Hoveton Great Broad, while measures to reverse wild salmon decline in Scotland, including opening access to over 3,000km of spawning habitat, have been guided by the tool we developed.

## 2. Underpinning research

Protecting and restoring freshwaters is an urgent priority. The ecosystem services they provide are of paramount importance, not least to human health and wellbeing, yet freshwaters globally are in a grave state and losing biodiversity faster than any other ecosystem type. In Europe the Water Framework Directive (WFD) seeks to deliver 'good ecological status' across surface waters using holistic, catchment-based approaches. Major obstacles to this ambition are (i) harmonising 100s of different methods developed by Member States for assessing ecological status and (ii) identifying what management responses will bring the biggest benefits in the shortest time, giving best value for public funds (Fig. 1). The mission of Stirling's Freshwater Sciences research group (led by Willby and Bull since 2005, joined by Law in 2019, and supported by several PDRAs and a team of PhD students) has been to target these obstacles and translate scientific evidence into advice to end-users in water policy and management, both nationally and internationally. We have a history of grant funding from NERC (GBP3,700,000), and research commissioned by the EU and major UK environment (Environment Agency – EA; Scottish Environment Protection Agency – SEPA) and conservation agencies (GBP750,000). Our research falls into two themes:

*Assessment and monitoring*: this builds on knowledge of species- and trait-environment relationships developed over 20 years and supported by NERC and UK environment regulators. Our work emphasises the need for complementary information on taxonomy, biological traits, and ecological preferences to understand why freshwater organisms respond predictably to environmental pressures at different scales. These principles underpin the subsequent

development and testing of biomonitoring approaches for assessing the ecological status of freshwaters (lakes, rivers, and canals) nationally and across Europe (see output **R1**). Our research on the effects of invasive species and impacts from river and lake engineering, supported via five studentships funded by NatureScot (formerly Scottish Natural Heritage) and SEPA, has helped to guide risk assessment. It has highlighted novel solutions for bio-assessment in densely populated transboundary river basins (**R2**) and established a convergent view of healthy freshwater systems in the face of divergent national approaches (**R1, R2**). Our modelling of pressure-response relationships for biological responses to nutrients in lakes and rivers at a European scale illustrates how these relationships can be used to formulate environmental standards with known uncertainties (**R3**) and has provided regulatory targets for major nutrients in freshwaters (Fig. 1).

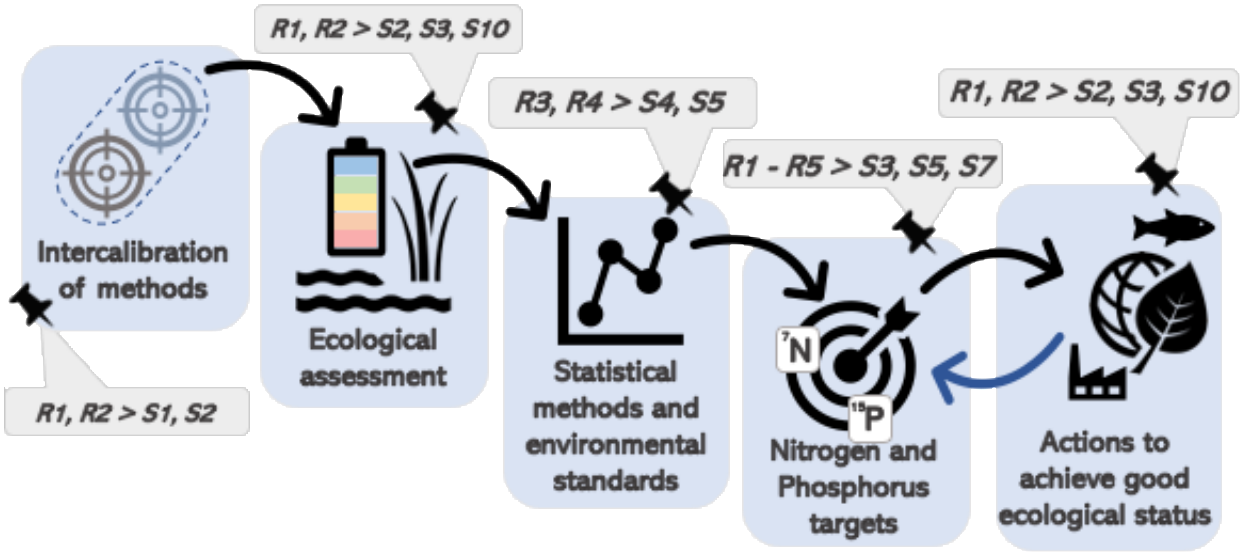


Figure 1: Key stages in assessing and restoring freshwaters through policy implementation and design of actions. Pinned labels reference the research (R) and sources to confirm its impact (S).

*Restoration and management*: scientific road-testing of restoration practices in lakes and rivers means that actions delivered via WFD management plans are evidence-based and have the greatest chance of success. Such actions range from reducing nutrient loads and biomanipulating the fish community in shallow lakes (**R4**), through to changing riverine connectivity by barrier removal (Fig. 1). Our research is supported by ongoing major funding from NERC to explore how interactions between stressors and altered connectivity shape biodiversity and ecosystem function in freshwaters (NERC Hydroscape project: PI Willby), as well as commissioned projects. We have critically evaluated the principles underpinning restoration of shallow lakes (**R5**), working with the Broads Authority who are acknowledged as an international leader in lake restoration. Shallow lakes are consistently amongst the most challenging habitats to restore; we prioritised the value of different approaches and demonstrated how lake history and climate can moderate their effectiveness. In parallel, Bull's work on the ecology of protected migratory lampreys and fish responses to barriers (**R6**), commissioned by NatureScot and SEPA, has also underpinned principles underlying the assessment of barriers to fish passage on rivers and the prioritisation of barriers for removal to increase access upstream.

## 3. References to the research

**R1.** Poikane S, Portielje R, Denys L, Elferts D, Kelly M, Kolada A, Mäemets H, Phillips G, Søndergaard M, Willby N & van den Berg MS (2018) Macrophyte assessment in European lakes: Diverse approaches but convergent views of 'good' ecological status. *Ecological Indicators*, 94: 185-197. DOI: 10.1016/j.ecolind.2018.06.056

**R2.** Birk S, Willby NJ, Kelly MG, Bonne W, Borja A, Poikane S, van de Bund, W (2013) Intercalibrating classifications of ecological status: Europe's quest for common management objectives for aquatic ecosystems. *Science of the Total Environment* 454: 490-499. DOI: 10.1016/j.scitotenv.2013.03.037

**R3.** Poikane, S, Phillips, G, Birk, S, Free, G, Kelly, M & Willby, N (2019) Deriving nutrient criteria to support 'good' ecological status in European lakes: An empirically based approach to linking ecology and management. *Science of the Total Environment*, 650: 2074-2084. DOI: 10.1016/j.scitotenv.2018.09.350

**R4.** Hilt, S and 24 others (2018) Response of Submerged Macrophyte Communities to External and Internal Restoration Measures in North Temperate Shallow Lakes. *Frontiers in Plant Science* 9: 194. DOI: 10.3389/fpls.2018.00194

**R5.** Phillips, G., Bennion, H. Perrow, M.R., Sayer, C.D., Spears, B.M. & Willby, N. (2015) A review of lake restoration practices and their performance in the Broads National Park, 1980-2013. Report for Broads Authority, Norwich and Natural England https://www.broads-authority.gov.uk/__data/assets/pdf_file/0025/205855/Broads-Lake-Review.pdf

**R6.** Bull, C. (2018) Implications of modifying the current WFD1112a passability assessment protocol to adopt an automated version based on the French ICE protocol (Baudoin et al., 2015) [SNIFFER 2 Report Final Submit March 2018]. Scottish Environmental Protection Agency. https://www.stir.ac.uk/research/hub/publication/1683317 (PDF can be provided on request)

***Key funding sources*:**

1. NERC Highlight Topic Consortium grant (2015-2020) NE/N006437/1: Hydroscape: connectivity x stressor interactions in freshwaters (GBP2,900,000), Stirling led (PI: Willby), Stirling share GBP663,165)
2. Broads Authority/Natural England (2013-2015): An evidence-based review of the effectiveness of lake restoration practices in the Norfolk Broads (1982-2012) (GBP45,000)
3. EU Intercalibration Review Panel (2014-2016) Expert contract for Willby (20 days)
4. PhD studentships (x5) (SNH funded: 2012 - 2016, 2014 - 2018; Assessing the impact of changing river flows on spread of invasive riparian plants and impacts of invasive plants on salmonid fisheries; SEPA funded: 2012 – 2016: Monitoring invertebrate responses to hydromorphological change; Ecological responses to water level change in lakes; NERC CASE funded: 2014 – 2019: Lake restoration using geo-engineering approaches)
5. Environment Agency/SNIFFER (2002-2009), Developing a WFD tool for classifying the Ecological Status of Rivers and Lakes using macrophytes (GBP230,000).
6. Environment Agency/SNIFFER (2007-2011) Intercalibration of macrophyte-based classifications of rivers and lakes across European countries. (GBP32,000 via EU).
7. SNIFFER (2006-2009), Development of a Water Framework Directive compliant tool for the ecological classification of canals. (GBP55,000)
8. Institute of Fisheries Management/SNIFFER (2009-2011), Trialling of the methodology for quantifying the impacts of obstacles to fish passage (GBP82,000)

## 4. Details of the impact

### Impact 1. Cross-national implementation of Water Framework Directive assessment

The vision of the Water Framework Directive (WFD) has been widely praised but its implementation has proved hugely challenging. Our activities have been crucial in securing this implementation.

We have underpinned the **intercalibration of WFD methods**: as the EU state, '*The intercalibration process is a critical step in the implementation of the Water Framework Directive*

*(WFD) as it ensures harmonised boundaries of aquatic ecological assessment systems between EU Member States*' (see evidence **S3**). It reduces bias and promotes equality of ambition in protecting or restoring water resources. Without intercalibration countries would simply continue to manage their water resources on an ad hoc and unilateral basis, even in international river basins where problems are shared across countries, thereby defeating the unifying purpose of the WFD (**R2**).

However, intercalibration is complex because national classification methods that were developed independently must be compared across multiple countries in each ecoregion of the EU, for each of the multiple water body types (e.g. large rivers, deep lakes) and biological quality elements (fish, invertebrates, macrophytes, diatoms, and phytoplankton), and in both freshwaters and coastal/transitional waters, giving rise to almost 1000 permutations (S2: Annex I) (**R2**).

Willby co-designed (with Sebastian Birk, University of Duisburg-Essen) the protocols for harmonising all national methods for classifying ecological status, as well as quality controlling newly developed classification methods. The approaches and associated guidance and training we developed and refined for the EU (**S1**) were pivotal in securing approval of the outputs from the 14-year WFD intercalibration programme. The official European Commission Decision 2018/229 (**S2**), explicitly acknowledges the approaches we designed and their role in delivering a successful outcome to the intercalibration process (also testified by **S3**). Because of this process hundreds of previously disparate national classification systems have been harmonised, **allowing accurate water body classification and aiding delivery of WFD objectives**. The importance of these contributions is reflected in a testimonial from the EU (**S3**) which describes the work of Willby as having '*played a crucial part in the implementation of the WFD across Europe*'.

The EU state that a '*major achievement of WFD implementation has been the establishment of a common view of ecological status through the intercalibration (IC) exercise (Birk et al., 2013* [**R2**]*)*' (**S5**, p.10). Our approach to developing environmental standards for nutrients to support good ecological status in Europe's lakes and rivers, co-designed with staff from the EU Joint Research Centre (**R3**, **S4**), was incorporated into **EU policy on best practice in setting national regulatory targets** for major nutrients with defined uncertainties (**S5, S3**). For the first time these targets include nitrogen alongside phosphorus. This is of critical relevance to agricultural practice, farming being a major source of nitrate pollution, and provides the much-needed baseline for management plans to target when restoring nutrient-enriched water bodies and in gauging progress (**R3**).

### Impact 2. Restoration and management

Initiatives led by the Stirling Freshwater Science group have contributed measurably to the **protection and enhancement of aquatic systems in the UK**, and the biodiversity and ecosystem services they deliver.

The evidence-based review of lake restoration practices for the Broads Authority, led by Willby and based on 30 years of monitoring data (**R5**) has **shaped their future strategy for lake restoration** (Lake Restoration Action Plan 2016/17 – 2021/22), **and site-level decision making** (**S6**). The Norfolk and Suffolk Broads are a major freshwater biodiversity hotspot, supporting a quarter of Britain's rarest species. They are also among the highest profile water bodies in Britain, with annual visitor numbers of 7,600,000. This Action Plan is designed to help the Broads meet 'good ecological status' under the WFD, consistent with the definition underpinned by our research (**R1**). Within the Broads the GBP4,500,000 restoration of Hoveton Great Broad is one of the largest and most ambitious freshwater restoration projects undertaken in the UK to date. Our evidence-based review was described by Natural England, who lead this project, as a '*key source of guidance and inspiration in planning the Hoveton Great Broad restoration'* (**S7**).

Bull designed a tool (**R6**) for the Environment Agency and the Scottish Environment Protection Agency allowing rapid assessment of the severity of river barriers to fish migration (**S8**, **S9**). The tool is now an **integral part of the process of selection, prioritisation, and restoration of river continuity in the UK**, enabling barrier removal to restore salmonid fisheries as required under the

WFD. SEPA noted that the contributions of Dr Bull '*have played a significant part in helping …meet these priorities*' (**S9**) and over 3,000km of rivers now have improved upstream access for Atlantic salmon and other migratory fish as a result of the removal of barriers identified via this tool. Following further development of the tool by Bull, in 2015 it was formally adopted by the UK Technical Advisory Group responsible for WFD implementation (**S9**, **S10**) and we trained more than 100 experts in its use. Aside from the environmental benefits of this work, the contribution of wild salmon to Scotland's economy (angling estimated gross added value of GBP29,000,000 per annum: http://stir.ac.uk/4bo) means that mitigation measures such as this are vital for the future of wild salmon and its associated industry in Scotland.

**5. Sources to corroborate the impact**

**S1.** Willby, N., Birk, S, Poikane, S. & Van De Bund, W. (2014) Water Framework Directive Intercalibration Manual: Procedure to fit new or updated classification methods to the results of a completed intercalibration. European Union Joint Research Centre. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/water-framework-directive-intercalibration-manual-procedure-fit-new-or-updated

**S2.** European Commission (2018). Commission Decision of 12 February 2018 establishing, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, the values of the Member State monitoring system classifications as a result of the intercalibration exercise and repealing Commission Decision 2013/480/EU. Official Journal of the European Union, L 47: 1-91 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018D0229&from=EN (L 47/2, paragraph 4 refers to **S1** plus the guidance we published pre-2014).

**S3.** Testimonial letter from WFD Scientific Project Officer, Joint Research Centre, European Union

**S4.** Phillips, G., Birk, S., Bohmer, J., Kelly, M., Willby, N., Poikane, S., (2018) The use of pressure-response relationships between nutrients and biological quality elements as a method for establishing nutrient supporting element boundary values for the Water Framework Directive, EUR 29499 EN, JRC114381. DOI:10.2760/226649

**S5.** Phillips G, Kelly M, Teixeira H, Salas F, Free G, Leujak W, Pitt JA, Lyche Solheim A, Varbiro G, Poikane S, (2018) Best practice for establishing nutrient concentrations to support good ecological status, EUR 29329 EN, JRC112667. DOI:10.2760/84425.

**S6.** Kelly A., Wakelin T., (2016) Lake Restoration Action Plan 2016/17-2021/22: https://www.broads-authority.gov.uk/__data/assets/pdf_file/0020/226820/Lake-Restoration-Action-Plan-2016-17-to-2021-22.pdf [This action plan relies on **R6** for its scientific base]

**S7**. Testimonial statement from Senior Standing Waters Specialist, Natural England.

**S8.** WFD111 Phase 2a Course resolution rapid-assessment methodology to assess obstacles to fish migration: Field manual level A assessment (2010) https://www.sniffer.org.uk/wfd111-phase-2a-fish-obstacles-manual-pdf

**S9**. Testimonial statement from Ecology Partnership & Development Unit Manager, Scottish Environment Protection Agency

**S10.** Water Framework Directive – United Kingdom Technical Advisory Group, (2015) UKTAG River Assessment Method – River Continuity: Barrier to Fish Migration Method (Scotland). ISBN: 978-1-906934-60-6 https://tinyurl.com/y98zmd7u