Institution: Newcastle University

Unit of Assessment: 17b Geography

Title of case study: Establishing ecological and chemical thresholds for sustainable freshwaters

1. Summary of the impact

This work helps the UK and Ireland fulfil their statutory duties to assess and improve the state of freshwater ecosystems. EU legislation requires all water bodies to be managed sustainably to achieve a state close to that of the water body in its natural state. Research in Geography at Newcastle has pioneered the use of diatoms (microscopic algae) in lakes and rivers to describe the ecological characteristics of this natural state and developed models and software that allow deviation from this state to be assessed. The model and database are used by all water agencies in the UK and Republic of Ireland to fulfil their statutory requirements and have led to new environmental standards that indicate that over 40% of the total length of UK rivers is at risk from elevated phosphorus concentrations.

2. Underpinning research

The Water Framework Directive (WFD) created new challenges for regulators around Europe using ecologically-based criteria to ensure the long-term sustainability of Europe's inland and coastal waters. The core principle is that all water bodies should be managed to achieve good ecological status, defined as a state where the biology shows only slight impacts from human activities. This goal creates two major challenges, especially in densely-populated regions. First, how can we know the natural condition of lowland rivers, given the long history of human impacts in these regions? Second, having set these targets, how should catchments be managed in order to achieve them? The required changes affect major economic sectors such as agriculture and utility companies and, via these, all consumers, necessitating a high degree of confidence in assessments before enforcing tighter regulation.

With funding from the Environment Agency and SNIFFER (Scotland and Northern Ireland Forum for Environmental Research) between 2004 and 2008, Drs Steve Juggins (Senior Lecturer) and Martyn Kelly (Visiting Lecturer) developed a conceptual model of the unimpacted state and a set of principles for how 'slight impacts' should be interpreted for diatoms, an extremely diverse and widespread group of algae that are sensitive to changes in water quality and form the base of aquatic food chains in lakes and rivers. These ideas were encapsulated in a numerical model and computer software suitable for use by the UK's statutory environmental regulators **(1)**. The cornerstone of the work is a statistical model that quantifies the relationship between the composition of diatom assemblages and the chemical characteristics of UK rivers. This underpinning research built on a large body of academic work at Newcastle by Juggins on diatom species response modelling to address problems of lake acidification, eutrophication and climate change. The model is supported by an interactive diatom identification guide **(2)** and is used first to predict the biological properties of unimpacted or reference sites, and then to assess current ecological status by quantifying the difference between contemporary diatom samples and the predicted reference state **(1, 3, 4)**. Although similar approaches have been developed elsewhere in Europe, DARLEQ was the first to use a numerical model to give quantitative predictions of diatoms in their natural state. The model was developed initially to assess quality in terms of nutrient impacts on rivers and subsequently validated using historical data **(5)** and expanded to include assessment of acidification effects in rivers **(3)**, nutrient impacts in lakes **(4)**, and quantification of uncertainty **(6)**.

3. References to the research

1. Kelly, M.G., Juggins, S., Guthrie, R., Pritchard, S., Jamieson, B.J., Rippey, B., Hirst, H. & Yallop, M.L. (2008) Assessment of ecological status in UK rivers using diatoms. *Freshwater*

Biology 53: 403-422. REF 2 output: 76262. DOI: 10.1111/**j**.1365-2427.2007.01903.

2. Kelly, M.G., Bennion, H., Cox, E.J., Goldsmith, B., Jamieson, J., Juggins, S., Mann, D.G. and Telford, R.J. (2006) *Common Freshwater Diatoms of Britain and Ireland: An Interactive Identification Key*. Product code LIT 2978; Available as a commercial product from the Environment Agency, Bristol. A partial (non-copyright) version of the identification guide is available online at: http://craticula.ncl.ac.uk/EADiatomKey/html/index.html

3. Juggins, S. & Kelly, M. (2012) *Development of a Water Framework Directive-compatible Metric for Assessing Acidification in UK and Irish Rivers*. Report SC070034/TR2. Environment Agency, Bristol. Available from HEI on request.

4. Bennion, H, Burgess, A, Juggins, S, Kelly, M, Reddihough, G & Yallop, M (2012) *Assessment of Ecological Status in UK Lakes using Diatoms*. Report SC070034/TR3. Environment Agency, Bristol. Available from HEI on request.

5. Yallop, M., Hirst, H., Kelly, M., Juggins, S., Jamieson, J., Guthrie, R. (2009) Validation of ecological status concepts in UK rivers using historic diatom samples. *Aquatic Botany* 90: 289-295. DOI: 10.1016/**j**.aquabot.2008.11.005.

6. Kelly, M.G., Bennion, H., Burgess, A., Elllis, J., Juggins, S., Guthrie, R., Jamieson, B.J., Adriaenssens, V. and Yallop, M.L. (2009) Uncertainty in ecological status assessments of lakes and rivers using diatoms. *Hydrobiologia* 633: 5-15. (International peer-reviewed journal, IF: 1.78; 31 citations) DOI: 10.1007/s10750-009-9872-z.

Research Grants

Principal Investigator	Grant Title	Sponsor	Period of Grant	Value to Newcastle
Steve Juggins	Development of an interactive CD-ROM for diatom identification	Environment Agency	2001-2004	£15,968
Steve Juggins	Diatom Assessment of River Ecological Status (DARES) and Diatom Assessment of Lake Ecological Status (DALES)	Environment Agency	2003-2006	£73,059

4. Details of the impact

1. Informing understanding of water quality

In terms of significance, elevated nutrient concentrations in freshwaters are a major environmental concern and application of the model across the UK has revealed widespread failure to achieve the required good ecological status. Further modelling by Juggins and Kelly, which related the algal assemblages in the DARLEQ database to nutrient concentrations, provided the basis for new phosphorus standards for UK rivers **(IMP1)**. Roger Owen, Head of Ecology for SEPA, said "my view [is that] the impact of the DARLEQ work on the policy environment...has been considerable" **(IMP2)**. The model and database together have led to a greater understanding of what we mean by 'healthy ecosystems' and, in the longer term, contributes to the sustainable management of freshwaters in the UK and Ireland. In the shorter term the research has assessed the ecological condition of UK rivers and improved the design and implementation of new statutory limits for phosphorus in freshwaters **(IMP1)**. As nutrients such as phosphorus were highlighted in a recent White Paper (Water For Life) as one of the biggest challenges facing UK waters, this work is having ongoing impacts on water industry practice and policy, and UK water quality.

2. Impact on practice

In terms of reach, the model and database deriving from the research, disseminated through

journal articles, an interpretative 'evidence' manual **(IMP3)**, computer software **(IMP4)**, and training workshops, has now been formally adopted by the UK and Republic of Ireland administrations. It is used routinely by environmental regulators (including the Environment Agency (EA), Scottish Environment Protection Agency (SEPA), Northern Ireland-EA and Irish Environment Protection Agency, utility companies and environmental consultancies) to comply with the WFD and assess the current ecological state of rivers and lakes in the UK and Ireland. Impact on practice extends from survey planning and field sampling **(IMP3)** through laboratory analysis and data interpretation **(IMP3, IMP4)**. Together, the methodology allows users to estimate the scale and cost of work required to restore waters to a sustainable state. This, in turn, has secondary reach as the outputs from these ecological assessments are used to indicate the types of remediation and restoration appropriate for particular water bodies, and the cost to be borne by consumers via their utility bills **(IMP2)**. Wendy McKinley of the Northern Ireland Environment Agency noted in her testimonial that the "help and support [of the DARLEQ team] enabled NIEA to develop capabilities that are essential as we move into full implementation of the Water Framework Directive" **(IMP5)**.

The pathway for dissemination within the UK agencies was via the UK Technical Advisory Group (UK TAG) for the WFD, a partnership of UK environment and conservation agencies which reports to DEFRA and the devolved administrations. The work was initially appraised by the Rivers and Lakes Task Teams (now combined as the Freshwater Task Team, FTT) and then passed up to UK TAG and the administrations for ministerial sign-off. A formal statement of methods is given on the UK TAG website **(IMP6)**. These fulfil the UK's responsibilities for public dissemination under Article 14 of the WFD.

3. <u>Impact on UK water policy</u>

In terms of significance, the research has enabled the UK and Irish governments to demonstrate that they are meeting their statutory requirements under EU legislation in complying with elements of the WFD **(IMP2, IMP5, IMP7)**. Because the research had established a statistical relationship between the diatom flora and nutrient concentrations in the water, Juggins and Kelly were also contracted to revise UK environmental standards for phosphorus, regarded as the key limiting nutrient in freshwaters. This enabled concentrations appropriate to support 'good status' being established for different types of water body **(IMP1)**. Dissemination included a public consultation stage before the new standards were officially adopted in 2009. These revised nutrient standards, in turn, play a "significant role in determining capital infrastructure spend for the water industry" **(IMP2)**.

The work also has wider significance in Europe where it was evaluated alongside methods developed by other Member States in order to evolve a common view of ecological status. This, in turn, led to adjustment of quality boundaries to ensure a common level of ambition across member states with regard to minimum acceptable water quality. Results of this intercalibration exercise were published in the Official Journal and are now legally binding in the Member States **(IMP8)**.

4. <u>Impact on sustainable water quality</u>

The reach and significance of this work lies in its contribution to improved management of natural freshwater resources in the UK and Ireland. This is a long term process encompassing all aspects of aquatic biology and ecosystem health. Via public consultation exercises it has contributed to scientific debate on the understanding of sustainable freshwater ecosystems. The ecological and chemical standards set as a result of this work have been used to assess compliance and provide an overview of the state of the UK's freshwaters. The situation for the UK indicates that over 40% of the total length of rivers is at risk from elevated phosphorus concentrations **(IMP9)**, allowing strategic planning on remediation measures and some preliminary estimates of costs.

5. Sources to corroborate the impact

(IMP1) Water Framework Directive UK TAG *UK Environmental Standards and Conditions Report*

(Phase 1). Available at: http://www.wfduk.org/resources%20/uk-environmental-standards-and-conditions-report-phase-1. Details the initial proposals for environmental standards (including phosphorus). Pages 28-31 outline the use of diatoms in setting P limits.

(IMP2) Testimonial from Head of Ecology, Scottish Environment Protection Agency.

(IMP3) Juggins, S. and Kelly, M. (2013) *Diatoms as evidence in ecological assessments. A manual for analyzing and using the results of investigations using diatoms*. Environment Agency, Bristol. Available on request.

(IMP4) The DARLEQ Consortium (2012) DARLEQ II, *Diatom Assessment of River and Lake Ecological Quality Version II.* Computer software and User Guide. Software produced for UK statutory environment agencies. Used by all UK administrations plus Environment Protection Agency, Ireland. Available on request.

(IMP5) Testimonial from Principal Scientific Officer: Freshwater Group Manager, Northern Ireland Environment Agency.

(IMP6) Water Framework Directive UK TAG *Biological Methods Statements*. Available at: http://www.wfduk.org/reference/biological-method-statements Two documents in this link give details of formal adoption of DARLEQ methods: http://www.wfduk.org/resources%20/river-phytobenthos (River Phytobenthos.pdf) gives information for rivers whilst http://www.wfduk.org/resources%20/lake-%E2%80%93-phytobenthos (Lake Phytobenthos.pdf) gives information for lakes.

(IMP7) Testimonial from Manager of Rivers and Lakes Monitoring, Environmental Protection Agency, Ireland.

(IMP8) Commission Decision of 30 October 2008 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. *Official Journal of the European Union Series L* 332/20-44. The outcome of the EU's intercalibration exercise – evidence that the Commission had accepted the UK's approach to assessing ecological status in rivers.

(IMP9) DEFRA *Draft partial regulatory impact assessment of environmental quality standards for implementation of the Water Framework Directive in the UK: Annex 3, Proposed standards for phosphorus in rivers*. Available at: http://archive.defra.gov.uk/environment/quality/water/wfd/documents/pdf-ria-draft/ria-wfd-annex3.pdf.