

Institution: Queen Mary University of London (QMUL)
Unit of Assessment: A5 (Biological Sciences)
Title of case study: CS2 – Acidification and recovery of surface waters
<p>1. Summary of the impact (indicative maximum 100 words)</p> <p>Prof Alan Hildrew and his group have carried out research that supports and informs the UK Acid Water Monitoring Network, which was established by Defra to provide information about the effects of changes in emissions policy on freshwater ecosystems in the UK. The hypothesis-driven research on invertebrates and fish explains patterns of ecological recovery in freshwaters following reduced emissions and freshwater acidification. Hildrew's group revealed that biological communities have failed to fully recover following reductions in atmospheric SO₂. These data and insights have: 1) supported organisations tasked with the management of UK freshwaters to meet commitments under the EU Water Framework Directive, 2) informed a range of national and international ecological surveillance programmes, and 3) influenced policy makers, being key to the argument that was made to tighten emissions legislation across the EU in 2012. This work has far-reaching impacts in assessing and amending EU legislation and, ultimately, in reducing air pollution and improving environmental quality.</p>
<p>2. Underpinning research (indicative maximum 500 words)</p> <p>Professor Hildrew has led the research into ecological responses to reductions in acidification (particularly food web processes and productivity) from QMUL for the last 35 years (funded continuously via Defra and others). Additional notable QMUL contributors are Mark Ledger (NERC PhD student, 1993-97: research on grazing in acidified systems), Guy Woodward (NERC PhD student, 1995-99, then Senior Lecturer at QMUL, now (from 2013) Reader at Imperial College; research on foodwebs), Katrin Layer (PhD student, 2001-05; research on acid stream food webs), Gareth Jenkins (NERC PhD student, 2010 to date; research on food web recovery) and John Murphy (QMUL River Communities group, Dorset since 2009).</p> <p>Hildrew's group has used a novel indicator of acidification, initially developed by Murphy, to interpret changes in freshwater macroinvertebrates over 20 years of data ^a. From 1993 to date, QMUL research has been aimed at understanding the recovery process in freshwater ecosystems and particularly in accounting for the sluggish response of the biota to marked improvements in water chemistry. Hildrew and colleagues hypothesised that the loss of species via toxicity has had ramifying consequences through the food web, via indirect interactions producing unexpected non-linearities in ecological recovery and a muted biological response hitherto ^{b, c, d} (i.e. recovery to a non-acidified ecological status has been less than anticipated). They have shown that chemical recovery of the water has unexpectedly resulted in invasions by progressively larger top predators and longer food chains (but not substantial reestablishment of the acid-sensitive fauna lower in the food web), possibly as a result of increases in basal productivity due to more rapid decomposition of organic matter ^e. Further, the assemblage of acid-tolerant generalists, having taken over the 'grazing niche', seems able to resist the recolonisation of acid sensitive specialist grazers and thus inhibits the anticipated return of such species ^d. The group have also studied the terrestrial dispersal of adult aquatic insects to test, and subsequently reject the hypothesis that dispersal limitations have delayed recovery of chemically improving streams ^f. Their sustained research is crucial to understanding the dynamics of ecosystems in the face of environmental change over time periods (decades) of ecological significance and management interest.</p>
<p>3. References to the research (indicative maximum of six references)</p> <p>^a Murphy, J.F., Winterbottom, J.H., Orton, S., Simpson, G.L., Shilland, E.M. & Hildrew, A.G. (2012) Evidence of recovery from acidification in the macroinvertebrate assemblages of UK fresh waters: a 20-year time series. <i>Ecological Indicators</i>, http://dx.doi.org/10.1016/j.ecolind.2012.07.009</p>

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^b Ledger, M.E. & Hildrew, A.G. (2005) The ecology of acidification and recovery: changes in herbivore–algal food web linkages across a pH gradient in streams. *Environmental Pollution*, 137, 103-118.

^c Monteith, D.T., Hildrew, A.G., Flower, R. J., Kreiser, J., Raven, P.J., Shilland, E.M. & Winterbottom, J.H. (2005) Community responses to the recovering chemistry of acidified fresh waters in the U.K. *Environmental Pollution*, 137, 83-101.

^d Layer, K.L., Hildrew, A.G. & Woodward, G. (2012) Grazing and detritivory in 20 stream food webs across a broad pH gradient. *Oecologia*, 171, 459-471.

^e Jenkins, G.B., Woodward, G. & Hildrew, A.G. (2013) Long-term amelioration of acidity accelerates decomposition in headwater streams. *Global Change Biology*, 19, 1100–1106 -e

^f Masters, Z., Petersen, I., Hildrew, A.G. & Ormerod, S.J. (2007) Insect dispersal does not limit the biological recovery of streams from acidification. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 17, 375-383.

4. Details of the impact (indicative maximum 750 words)

Hildrew's research on changes to ecosystem processes and lags in recovery following freshwater acidification ^{a-f} is having an impact on data interpretation, policy making and environmental management at regional ^{1,4}, national ^{2,3,6,7} and EU ^{7,8} level. Impact since 2008 has principally been facilitated in two ways:

(i) Via the UK Acid Waters Monitoring Network (UK AWMN) ². This network was set up by the UK Government when it entered into international commitments to reduce emissions of SO₂ from UK sources. The network, of which Hildrew is a key member, monitors and conducts original research on sites across the UK (22 lakes and streams, primarily in the north and west but including less well known areas of the south-east identified as susceptible by research at QMUL). This network has been used by a range of international ecological surveillance programmes (see below).

(ii) Via Defra, who use evidence provided by the UK AWMN – and in particular the 20 Year Interpretative Report, produced in 2010 (Chapter 6 of which was principally authored by Hildrew) ³ – to influence policy in the UK and EU (see below).

For both (i) and (ii), Hildrew is one of the principal leads on the research into the ecological responses to deacidification ^{a-f} and was responsible for all the data on invertebrates and key data on fish. Hildrew's research has had substantial impact, via these routes, in at least three different ways:

1. Provision of evidence on which the policy and practice of organisations concerned with managing the natural environment is based

The UK AWMN supports a number of organisations responsible for environmental management of UK surface freshwaters in relation to the EU's Water Framework Directive and sub-Directives on priority substances and the Habitats Directive. The organisations charged with responsibility for ensuring water quality under the EU's Water Framework Directive (which became UK law in 2003) include the Environment Agency (formerly England and Wales), the Scottish Environment Protection Agency, the Environment and Heritage Service of Northern Ireland, Natural England, Natural Resources Wales, Scottish Natural Heritage and the Forestry Commission (with respect to 'forest and water guidelines'). The AWMN provides support for these organisations and so assists them in meeting their statutory obligations under this legislation ², which in turn informs management practices.

For example, the data and interpretations provided by Hildrew *et al.* in the 20-year UK AWMN report ³ (Chapter 6) resulted in a recommendation within Natural Resources Wales to reconsider

their sampling regime for monitoring the effects of acidification on invertebrate communities in the Welsh 'model' lakes, as part of the Water Framework Directive Lake Surveillance Network¹.

The UK AWMN is such an important resource (see 2 and 3 below) that it has recently been tasked with widening its scope to include other 'long-range' environmental stressors in the uplands (most evidently climatic changes, but also deposition of metals and nitrogen – as agents of pollution and eutrophication rather than acidity). Thus, from 2013, the decision has been taken to 'rebadge' it as the Upland Waters Monitoring Network (UWMN).²

2. Provision of data to inform and influence environmental policy decisions and debates

Through the UK AWMN, Hildrew contributes vital invertebrate and fish data (and interpretation of these data^{a-f}) to a number of national and international environmental surveillance programmes as evidenced by their website², which states that UK AWMN

- a) *“contributes data from six sites to the UNECE [United Nations Economic Commission for Europe] International Cooperative Programme [ICP] on the Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes (ICP Waters) at the Focal Centre, NIVA, Oslo, as well as the ICP on Integrated Monitoring (two sites)”*. The role of UNECE is described and expanded on in 3., below.
- b) *That “Data from four AWMN sites are contributed to the UK Environmental Change Network, the European Long-Term Ecosystem Research Network (LTER Europe) and the International Long Term Ecological Research (ILTER) programme”*.
- c) *That “Data from the AWMN has also been used to provide information on acidification status of Scottish rivers to NASCO (North Atlantic Salmon Conservation Organisation) to demonstrate improving status and was explicitly mentioned as an important source of data in the recent NASCO implementation plan for Scotland”⁴.*

In addition, Hildrew's research on ecological hysteresis in ecological responses^{b,c,f}, along with additional QMUL data on recovery of fish populations from a stream in East Sussex, has been cited in the 2012 'Review of long-range, transboundary air pollution (RoTAP)' report⁵, which was produced by NERC Centre for Ecology and Hydrology (CEH) for Defra, Scottish Government, Welsh Assembly Government and Department of the Environment in Northern Ireland. The report, which examines the available scientific evidence on the effect of air pollutants in the UK, is directly aimed at influencing policy (as evidenced by the accompanying 'RoTAP Summary for Policy Makers' document)⁵.

Thus Hildrew's research, reported through the UK AWMN and Defra, has substantial reach across the UK and EU by allowing the efficacy of international environmental policies to be tested. Such research is critical in the environmental arena where changes may be slow but substantial.

3. Contributing to the maintenance and modification of emissions policies across the EU.

Evidence gathered through the UK AWMN has acted as a key driver in drafting and modifying international legislation. Hildrew's research has benefited policy and the environment by providing part of the body of evidence to test the effectiveness of emissions reductions with respect to the principal EU and UNECE legislation on acid deposition and surface waters in the UK². To quote Environment Minister Lord Henley and the UK Government press release⁶ on the 2010 Interpretative Report from the UK AWMN:³

“This report shows the impact of 20 years of Defra policies to tackle acid rain and the environmental damage it causes. It also demonstrates the opportunity we have to build on this success through forthcoming international agreements that will allow us to return damaged rivers and lakes to a healthy state where fish such as trout and salmon can flourish.”

“...whilst the waters are recovering, there is still a long way to go before the plant and animal communities are restored to full health....meaning that further emission reductions may be

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necessary.....Defra is playing a key role in a number of international agreements such as the EU National Emission Ceilings Directive and the Gothenburg Protocol”⁶

Emissions targets across the EU were indeed updated in May 2012 through revision of the Gothenburg Protocol (CLRTAP)⁷ and a recent review of the EU National Emission Ceilings Directive by the European Environment Agency (2012) states that a revision of this legislation is expected imminently:

"While acidification has been markedly reduced.....an assessment using present knowledge" (referring to adverse impacts on biodiversity) "indicates that neither the acidification nor eutrophication objectives have been met. The European Commission is currently reviewing the EU's air policy and..... is expected to propose a revised NEC Directive by 2013 at the latest".⁸

Thus, evidence gathered and interpreted by Hildrew for the UK AWMN and conveyed through Defra and UNECE, ultimately helped to justify the modification of EU emissions policy.

5. Sources to corroborate the impact (indicative maximum of 10 references)**1. Senior Environmental Monitoring Officer (Analysis & Reporting)**

- Natural Resources Wales:** This individual is able to verify that Hildrew's research (as part of the UK AWMN) led to recommendations within Natural Resources Wales to reconsider the sampling regime required for monitoring the effects of acid deposition on invertebrate communities in the Welsh 'model' lakes covered by the EU Water Framework Directive.
2. The background, role and details of the UK Acid Water Monitoring Network, including its specific and ongoing role in policy support, and links to QMUL, can be found on the Defra website at: <http://awmn.Defra.gov.uk/index.php>
 3. Reports to Defra have been co-authored by QMUL scientists and reference QMUL research, the most recent being the 20-year interpretive report that can be found at <http://awmn.Defra.gov.uk/resources/interpreports/index.php> (see Chapter 6, with QMUL authors Hildrew and Murphy).
 4. www.nasco.int/implementation_plans.html – North Atlantic Salmon Conservation Organisation implementation plan for Scotland which explicitly mentions the UK AWMN as an important source of information on the acidification status of Scottish rivers
 5. www.rotap.ceh.ac.uk/documents – RoTAP report to which Hildrew contributed evidence as an associate member but was not an author (see www.rotap.ceh.ac.uk/about). The report references QMUL research. Specifically see section 5.34 'Ecological responses to reductions in acidity' and Fig. 5.19 (p 127), which shows QMUL data.
 6. The UK Government press release on the UK AWMN 20-year interpretive report³ is at www.Defra.gov.uk/news/2010/08/19/acid-rain-20-years-on
 7. www.gov.uk/government/publications/emissions-of-air-pollutants
See 'Emissions of air pollutants in the UK, 1970 to 2011 – revised update', which details new commitments for reductions in SO₂ and other air pollutants as a result of the 2012 revisions to the 'Gothenburg Protocol' (CLRTAP).
 8. Evaluation of progress under the EU National Emission Ceilings Directive 2012 and intentions to revise current emissions targets appears on the European Environment Agency's website at www.eea.europa.eu/publications/evaluation-progress-nec-2012