Institution: University of Stirling

Unit of Assessment: C17 Geography, Environmental Studies and Archaeology

Title of case study: Protecting and restoring aquatic systems

1. Summary of the impact

The primary mission of the Centre for River Ecosystem Science (CRESS: http://www.cress.stir.ac.uk/index.html) is to build and translate scientific evidence into advice to end-users and policy makers in river management, both nationally and internationally. Site-based advice, design and monitoring have been provided to 55 projects, including award-winning river engineering schemes. Independently, our research in community ecology, fluvial geomorphology and agricultural pollutants has supported an outstanding contribution to the UKs response to the key EU Environmental Directives - Water Framework, Flooding, Species & Habitats and Bathing Waters. We have developed the official tools that are now used to determine the status of freshwaters and structure catchment management plans, and trained others in their use, have pioneered risk assessments and modelling of nutrient, pathogen or carbon losses, publicised their effects, scoped mitigation options though engaging with end-users, and steered the pan-European comparison of bio-assessment methods that now underpins common water policy.

2. Underpinning research

CRESS was founded at the University of Stirling in 2005 via an Enterprise award. CRESS academic staff (Willby, Oliver (since 2010), Gilvear (Stirling 1990-2013 and now at Plymouth) work collaboratively and in close association with funders and stakeholders in three main areas.

1. Restoration and management: work centres on geomorphic impacts of flow regulation and river engineering on channel morphology and the policy arena surrounding river restoration. Knowledge in river science and ecology acquired over the last 20 years has formed the basis of advice and designs for environmentally-sound river engineering schemes (permitting industrial use of floodplains and their rehabilitation) and multi-benefit restoration projects (e.g. Natural Flood Management). Examples of important principles include effects of flow-bed morphology interactions on salmonids, future-proofing fluvial erosion hazards (1; see section 3 for references), the role of floods in maintaining and renewing riparian habitat (2) and their use in place of costly and ineffective engineering to create natural habitats.

2. Assessment, impact and monitoring: This research builds on an empirical knowledge of species- and trait-environment relationships developed by Willby since the late-1990s (3,4). It focuses on development and testing of biomonitoring approaches for use in assessing the ecological or conservation status of freshwaters at national and European scales, for monitoring the status and effects of protected, invasive or reintroduced species, diagnosing causes of deterioration and developing novel solutions to the challenges of bio-assessment in densely populated international river basins (5). As a direct result the UK has achieved and adopted holistic tools for classification of ecological quality in its lakes and rivers and established improved environmental standards for regulation of nutrients in rivers. In parallel to this we have demonstrated the utility of remote sensing for mapping physical habitat in rivers or harmful algal blooms in lakes (6), and developed and validated geomorphological tools for assessing effects of river engineering on the ecological quality of rivers (Morphological Impact Assessment System) and the passability of artificial barriers to fish (Barrier Porosity Assessment Tool). These tools now form the basis for planning restoration or licensing management of rivers by government agencies.

3. Regulation and delivery: Our research exploits fundamental understanding of behavioural traits of pollutants in the soil-water continuum to refine models and develop tool kits for environmental protection. Underpinning research has included the development of novel participatory approaches (e.g. Citizens' Jury - with multiple stakeholders) and integration of local expert knowledge into decision support systems, field investigations providing the first comprehensive approach for estimating a dynamic *E. coli* reservoir at the headwater catchment scale (7) and thus evidence to

support mitigation measures to safeguard water quality and human health; assessments of quantitative and qualitative data from UK water companies to highlight interacting factors (and inherent uncertainties in data) that can impact on decision-making for management of disease outbreaks (8).

3. References to the research (CRESS staff in **bold)**

Key papers

1. **Gilvear, DJ**; Heal, KV; Stephen, A (2002) Hydrology and the ecological quality of Scottish river ecosystems *Science of the Total Environment* 294: 131-159 Journal Impact Factor: 3.26
2. **Gilvear DJ; Willby N** (2006), Channel dynamics and geomorphic variability as controls on gravel bar vegetation development, River Tummel, Scotland, *River Research and Applications*. 22, 457-474 JIF: 2.43
3. **Willby, NJ**; Abernethy, VJ; Demars, BOL (2000) Attribute-based classification of European hydrophytes and its relationship to habitat utilization. *Freshwater Biology* 43: 43-74 JIF: 3.93
4. **Willby, NJ**; Pulford, ID; Flowers, TH (2001) Tissue nutrient signatures predict herbaceous - wetland community responses to nutrient availability *New Phytologist* 152: 463-481 JIF: 6.74
5. Birk S; Van Kouwen L; **Willby, N. (**2012) Harmonising the bioassessment of large rivers in the absence of near-natural reference conditions - a case study of the Danube River *Freshwater Biology* 57: 1716-1732. JIF: 3.93
6. Hunter PD; Tyler AN; **Gilvear DJ**; **Willby NJ** (2009) Using remote sensing to aid the assessment of human health risks from blooms of potentially toxic cyanobacteria. *Environmental Science & Technology* 43: 2627-2633. JIF: 5.26
7. **Oliver DM**.; Page T; Zhang T; et al. (2012) Determining *E. coli* burden on pasture in a headwater catchment: Combined field and modelling approach. *Environment International* 43: 6-12. JIF: 6.25
8. Austin Z, Alcock RE, Christley RM, Haygarth PM, Heathwaite AL, Latham SM, Mort M, **Oliver DM**, Pickup R, Wastling JM, Wynne B. (2012). Policy, practice and decision making for zoonotic disease management: water and *Cryptosporidium. Environment International*, 40: 70-78. JIF: 6.25

Key grants:

- NERC knowledge exchange, 2009, CLAD: Carbon Landscapes and Drainage £240k
- NERC, 2011-13, Delivering healthy water: building the science policy interface to protect bathing water quality, £125k
- NERC, 1997-2000. A functional approach to modelling river vegetation. Glasgow and Stirling £191K
- NERC, 1999-2002. Longitudinal gradients in river biodiversity. Personal fellowship. N Willby. £150K
- Defra, 2010-11, Catchment modelling strategies for faecal indicator organisms: options review and recommendations, £31k subcontract from CREH ltd.
- Defra, 2010-13, Delivery of phosphorus and faecal indicator organisms from agricultural sources to watercourses (PEDAL2), £39k subcontract from Lancaster University
- SNIFFER, 2006-2009, Development of a Water Framework Directive compliant tool for the ecological classification of canals. £55k.
- Environment Agency/SNIFFER 2002-2009, Developing a WFD tool for classifying the Ecological Status of Rivers and Lakes using macrophytes. £230k.
- SNH/SEPA studentships 2006, 2009 and 2012; Assessing the performance of morphologically based river typing in Scotland using a geomorphological and ecological approach; Prediction of morphological adjustment and societal response to channel instability resulting from increased flood frequency in Scotland; Assessing the impact of changing river flows on the distribution and spread of invasive riparian plants.

4. Details of the impact

CRESS employs two non-academic staff plus regular internships and apprentices to meet its workload in knowledge exchange (KE) activities and to build capacity. Our effectiveness in translating high quality scientific research into policy and practice on an on-going basis is reflected in a list of regular clients that include SNH, SEPA, EA, RSPB, SNIFFER, DEFRA, Scottish Government and industry (e.g. Scottish Power, Scottish Coal). Since 2008 CRESS staff participated directly in 55 UK-based projects that focus on restoration of physical habitat and water quality to improve ecological status, as prescribed under the EU Water Framework Directive (WFD). CRESS activities have proved highly influential in awareness raising, stakeholder engagement, training of professionals and in underpinning policy and guidance. For example Dr Roger Owen, Head of Ecology at the Scottish Environment Protection Agency (SEPA) remarked that '*Willby has very significantly influenced and assisted the practical application of biological assessment methods for implementation of the WFD at UK and EU level. The quality of Dr Willby's work has been outstanding and is well recognised within the European Commission*' (see Factual Statements). CRESS has also been heavily involved with Scotland's Centre of Expertise for Waters (CREW) established to connect research with policy impact. For example, the team jointly led the 'Diffuse Pollution Management' project that prioritised measures for improving water quality under the next phase of Scottish Rural Development Programme (SRDP) funding.

CRESS initiatives have contributed measurably to the protection and enhancement of aquatic systems and the goods and services they deliver. The following projects showcase a variety of traceable impacts (**letters in bold** refer to corroborating sources in section 5):

- The NERC KE project, Carbon Landscapes and Drainage (CLAD), led to the production of Carbon and Water guidelines, a re-evaluation of carbon savings from wind-farms due to peat losses, training in aquatic carbon flux monitoring in England, Scotland, Eire and Malaysia and publicity on the importance of peatland management in climate change policy. This stemmed from our studies of carbon losses from peatlands impacted by windfarm development. **A**
- Intercalibration of Water Framework Directive methods: we designed the approaches adopted by the EU to determine the comparability of national methods of assessment of surface waters. This process is of fundamental importance because it ensures parallel ambition and investment in protection of water resources across the 27 EU member states. **B, C**
- Improved modelling of relationships between primary producers and nutrients in rivers has allowed us to derive site-specific regulatory targets for phosphorus with defined uncertainties, replacing general standards for which the uncertainty was un-quantified. These targets have now been subject to public consultation and subsequently adopted by UK administrations (UK Technical Advisory Group on WFD) and will dictate significant capital spending. **C, D**
- Based on studies of fish behaviour in relation to flow and barriers to upstream migration CRESS designed a tool allowing prioritisation of barrier removal to restore salmonid fisheries (EA, SEPA). Over 3000km of river identified via this tool have been restored and now have improved fish access and 70 experts across the UK have been trained in the use of the tool. **E**
- The 'Scottish Rivers Handbook' was lead-authored by CRESS on behalf of CREW and designed to give an overview of the physical character of Scotland's rivers and to educate people on working with river processes in a sympathetic manner by explaining the forms, functions and benefits of rivers to society. The book was distributed to River and Fishery Trusts and riparian landowners throughout Scotland and at major stakeholder events and was downloaded 500 times within the first six months of publication. **F**
- Our work on trends in catchment scale river restoration practices for SEPA was quoted in the Scottish Parliament in 2009 during the reading of the Flood Risk Management Bill. **G**
- Our pathogen fate and transfer data have been used by the US Department of Agriculture to parameterise the extension of an international model (the Soil & Water Assessment Tool) for predicting microbial pollution in agricultural catchments. **H**
- We have trialled and improved approaches for engaging stakeholders in diffuse pollution control (CREW) and evaluated strategies to assess the effectiveness of diffuse pollution mitigation policy in Scotland. Scottish Government commissioned this work to help inform revisions to the next round of the Scottish Rural Development Programme. **I**
- The NERC KE project led by Stirling "Delivering Healthy Water" established a working group to

provide a mechanism for the exchange of knowledge, experience and evidence between academic, regulatory and public stakeholders with regard to new technologies and 'rapid methods' for assessing bathing water quality. We produced a decision-making framework and associated briefing papers to underpin and guide future decision-making ahead of the review of the Bathing Water Directive. **J, H**

5. Sources to corroborate the impact

A. NERC KE CLAD - Carbon workshops (for regulators and industry); articles *Planet Earth* 2012, 2013; PhD studentships gained Green Energy Awards 2011 and selected for NERC Science Impacts Database www.clad.ac.uk.
B. 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.
C. Factual statements from SEPA and EC commending work of Willby in WFD implementation
D. Water body classifications and environmental standards adopted by UK administrations for regulatory purposes following public consultation http://www.wfduk.org/stakeholders/stakeholder-review
E. Development and training for fish barrier assessment http://therrc.co.uk/RESTORE/September2012_Scotland/Fish_pass_assessment_tool_Colin_Bull.pdf and corroboration by SEPA of its impact via river restoration. http://www.therrc.co.uk/2012%20Conference/Outputs/Gilvear%201%20Final.pdf
F. Lead-authored *River Keepers Handbook* presenting principles and showcasing examples of good and poor practice in river management http://www.crew.ac.uk/sites/www.crew.ac.uk/files/publications/scottish%20rivers%20handbook%20web.pdf
G. Gilvear DJ, Casas R, Spray C (2012), Trends and issues in delivery of catchment scale river restoration: *River Research and Applications* 28: 34-67. quoted in Scottish parliament during reading of 2009 Flood Risk Management Bill http://www.scottish.parliament.uk/parliamentarybusiness/Bills/16275.aspx
H. Factual statements from United States Department of Agriculture, DEFRA and Surfers Against Sewage commending work of Oliver.
I. CREW diffuse pollution management: http://www.crew.ac.uk/projects/diffuse-pollution-management
J. NERC KE Delivering Healthy Water – regulator, policy and industry workshops and development of a decision-making framework for UK Government and WHO http://www.deliveringhealthywater.net