Institution: Cardiff University

Unit of Assessment: Biological Sciences (5)

Title of case study: Transforming freshwater ecosystem management in Wales and a key UNESCO site in Africa

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:
Isabelle Durance	Professor	01/08/2005 – present
Steve Ormerod	Professor	01/08/1984 – present
Michael Bruford	Professor	01/04/1999 – present
Andrew Weightman	Professor	01/01/1984 – present
Ian Vaughan	Senior Lecturer	01/08/2004 – present
Sian Griffiths	Senior Lecturer	31/12/2000 – present
Harvard Prosser	Senior Research Associate	01/06/2012 – 30/11/2015

Period when the claimed impact occurred: 2015-2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact (indicative maximum 100 words)

Healthy upland rivers and streams provide a major source of clean drinking water and sustain all wildlife downstream, supporting key human activities including fisheries, agriculture and recreation. Despite this, freshwater ecosystems are amongst the most threatened in the world. Cardiff research found that transfers of energy by river ecosystems connect landscapes, river biodiversity and services such as clean water or the provision of fish. These findings were critical to a new, sustainable freshwater management programme at a UNESCO World Heritage Site in Africa. The research also prompted an overhaul of both the policy and practice of freshwater ecosystem management in Wales by underpinning The Environment (Wales) Act 2016 and a new, catchment-driven approach by Wales's national water utility provider and Natural Resources Wales.

2. Underpinning research (indicative maximum 500 words)

In the UK, upland catchments are mostly managed to deliver goods and services with high market value (such as meat and timber), often with little consideration to the river organisms and processes that keep these freshwaters healthy. The costs of this mismanagement include loss of biodiversity, water pollution with ensuing higher costs of water treatment, and loss of a range of goods and services that healthy freshwater ecosystems can provide such as fish or protection from flooding.

In 2011 the Natural Environment Research Council (NERC) launched a strategic programme on Biodiversity and Ecosystem Service Sustainability (NERC-BESS, 2011-2017). BESS was the first national research programme to focus on understanding the role of biodiversity on ecosystem functioning and service provision at a landscape scale. Based on Cardiff's expertise on freshwater ecosystems **[3.1]**, Durance and her colleagues led DURESS, the £3.2M freshwater component of the BESS programme **[G3.1]**. The project aimed to demonstrate that it is possible to manage catchments to promote healthy freshwater ecosystems, which could in turn deliver a range of benefits for multiple users, now and for future generations.

Before Cardiff's work, investigations linking biodiversity and ecosystem services were scarce and qualitative, and failed to provide decision-makers with necessary evidence. Cardiff's research quantified the missing link between landscape management, river biodiversity and the sustainability of these services for human wellbeing. The Cardiff team measured and modelled variation in river ecosystems using a range of scales from gene to ecosystem, and from experimental mesocosms (artificially constructed model ecosystems) to entire catchments in Wales and England.

The key research findings from DURESS were as follows:

- **Pioneered and evidenced the concept of energy transfer through river systems:** The Cardiff team examined the link between biodiversity and ecosystem services through a fundamentally novel concept rooted in thermodynamics, which proposes that freshwater ecosystem service provision and resilience depends on the capacity of rivers and river organisms to transfer energy unhindered **[3.1]**. Cardiff's work evidenced how catchment management controls the amount of energy (in the form of carbon such as leaves, or in the form of heat from the sun) that enters river ecosystems, and how that energy is transferred through the food chain from microbes to fish or birds **[3.1, 3.2]**. This concept provided first principles on which to guide landscape decisions.
- **First quantitative evidence of the links between catchment use, freshwater biodiversity and ecosystem services:** Through DURESS, the team developed the first tools and quantitative evidence directly linking biodiversity conservation efforts focused on the resilience of freshwater ecosystems to the sustainability of ecosystem services for future generations **[3.1-3.4]**. A key finding was that planting deciduous trees along temperate streams increased the carbon resources available to river organisms as an adaptation to climate change, contributing to increased biodiversity as well as increased resilience of ecosystem services, such as recreational fisheries **[3.2, 3.3]**.
- **A framework to link freshwater ecosystem health to human wellbeing:** Many of the ecosystem services that freshwaters provide, such as birdwatching or recreational fishing, do not always provide a material benefit and thus cannot be monetised or valued. The Cardiff team provided the first conceptual tools to identify and account for these services **[3.5]**. For example, for salmon fishing, the team provided the first quantitative evidence of the links between biodiverse freshwater ecosystems, ecosystem services and human well-being (known as the 'ecosystem service cascade') **[3.4]**. Such findings provided a novel framework through which to link freshwater ecosystem conservation aims to human wellbeing, namely in areas of the world where the local, and often poorest, communities depend most on the 'free' services their local river provides, including fishing and clean drinking water.
- **Development of scenarios to visualise the impact of upland landscape decisions on future ecosystem services:** Uplands provide the majority of the UK's drinking water. To help land managers, policy makers and society understand how land management decisions might affect the provision of clean drinking water and other ecosystem services, the Cardiff team worked with more than 15 stakeholders (including Natural Resources Wales and Welsh Water) to analyse future drivers of change in UK uplands up to 2050. Evidence from DURESS was used to produce a set of scenarios showing how land-use choices were likely to affect the sustainability of services **[3.6]**. These were the first scenarios of change to link upland landscape decisions to ecosystem services.

In summary, via DURESS, Cardiff researchers pioneered the idea that 'energy transfers' drive the sustainability of freshwater ecosystem services and demonstrated that if catchments were managed correctly, the energy transferred would help river biodiversity to thrive, further ensuring clean water and improved human wellbeing. The research identified novel principles to guide effective landscape decisions and enable proper valuation of freshwater ecosystem services.

3. References to the research (indicative maximum of six references)

[3.1] Durance I., **Bruford M.W.**, Chalmers R., Chappell N.A., Christie,M., Cosby J.C., Noble D., **Ormerod S.**, **Prosser H.**, **Weightman A.**, Woodward G. 2016. The challenges of linking ecosystem services to biodiversity: lessons from a large-scale freshwater study. *Advances in Ecological Research*, 53, 87-134, DOI: 10.1016/bs.aecr.2015.10.003

[3.2] Perkins D., **Durance I.**, Edwards F.K., Grey J., Hildrew A.G., Jackson M.I., Jones J.I., Lauridsen R.B., Layer-Dobra K, Thompson M.S.A, and Woodward, G. 2018. Bending the rules: exploitation of allochthonous resources by a top-predator modifies size-abundance scaling in stream food webs. *Ecology Letters* 21 (12), 1771-1780, DOI: 10.1111/ele.13147

[3.3] Thomas S., **Griffiths S.**, **Ormerod S.** 2015. Beyond cool: adapting upland streams for climate change using riparian woodlands. *Global Change Biology*, 22 (1), 310-324, DOI: 10.1111/gcb.13103
[3.4] Worthington T., **Vaughan I.**, **Ormerod S.**, **Durance I.** 2020.Testing the ecosystem service cascade framework for Atlantic salmon. *Ecosystem Services*, 46, 101196, DOI: 10.1016/j.ecoser.2020.101196
[3.5] Small N., Munday M., **Durance I.** 2017. The challenge of valuing ecosystem services that have no material benefits. *Global Environmental Change*, 44, 57-67, DOI: 10.1016/j.gloenvcha.2017.03.005
[3.6] Prosser H., Pagella T., **Durance I.** (eds.) 2013. *Upland scenarios 2050: what will the future look like?* PDF.

Selected grant:

[G3.1] Durance I. (PI), **Ormerod S.**, **Bruford M.W.**, **Prosser H.**, **Vaughan I.** and **Weightman A.**; 'Diversity in upland rivers and ecosystem service sustainability – DURESS', Natural Environment Research Council NE/J014818/1, 01/06/2012-01/12/2015, £3,273,787.

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

Cardiff's research linking biodiversity and freshwater ecosystem services resulted in two key impacts: 1) it was integral to a $250M fund protecting one of the world's last remaining near-pristine river systems in Africa; and 2) it transformed policy and practice of freshwater ecosystem management in Wales via the Environment (Wales) Act 2016 and a new, catchment-driven approach implemented by Wales's national water utility provider and Natural Resources Wales.

4.1 Protecting CORB UNESCO World Heritage Site (Angola, Botswana and Namibia)

Cardiff's research **[3.5]** provided the tools to justify protection of the Cubango-Okavango (CORB) River Basin. This is one of the world's last remaining undisturbed river systems, currently threatened by development, as well as a UNESCO World Heritage Site and Wetlands of International Importance (Ramsar Site). The CORB Fund states it is a $250M fund set up in perpetuity to address "the risk of degradation" to the CORB's source waters from demands including energy development, population expansion and significant planned water extraction. "The Fund sees numerous opportunities to respond creatively to these demands and threats by supporting the sustainable use and conservation of water resources and betterment of livelihoods in the CORB" **[5.1]**.

Cardiff's research defining non-material benefits of ecosystem services on which the poorest depend (e.g. clean drinking water) was used to develop an economic valuation framework central to the CORB Fund Business Case. CORB was set up by the Climate Resilient Infrastructure Development Facility, whose Team Leader stated: *"CORB is unique in its trans-boundary nature with many competing demands and the delivery of significant non-material benefits…The CORB fund project thus implements the concepts set out in the Durance paper* **[3.5]** *to understand the valuing of ecosystem services, particularly those with non-material, non-monetary benefits"* **[5.2]**.

The CORB Fund was established in Dec 2019 and is currently in its initial two-year demonstration phase, with $900K of preparation co-funding raised to date **[5.1]**. The Permanent Okavango River Basin Water Commission (OKACOM) is a joint Angolan, Botswanian and Namibian organisation which advises the Fund. In April 2020, OKACOM held consultations with local communities to discuss the most pressing challenges for communities living in the basin, capture strategies for sustainable livelihoods, and plan interactive mapping to identify livelihood vulnerability hotspots **[5.3]**. Community leaders noted that the collaborative work is important to "*change the future and preserve the livelihoods of people in our society"* **[5.3]**.

4.2 Transformation of freshwater ecosystem management in Wales

Cardiff research also led to a new, holistic approach to the management of freshwater ecosystems in Wales encompassing policy, industry practice and natural resource management. This marked a step change away from focusing on the short-term benefits of

meat and timber production, resulting in pollution and higher water treatment costs, to longer-term landscape management promoting healthy ecosystems. Matthew Quinn, Welsh Government Director of Environment and Sustainable Development stated that the research **[3.1, 3.4, 3.5]** "*has given confidence that a new, more holistic approach will deliver on biodiversity interests rather than being a threat to them*" **[5.4]**.

a. Environment (Wales) Act 2016

The Environment (Wales) Act 2016 is the basis for natural resource management in Wales. Cardiff's research **[3.1, 3.6]** was fundamental to principles outlined in the Act, in particular providing quantified evidence of the importance of biodiversity and healthy functioning ecosystems **[3.2, 3.3]**. Steve Spode, Welsh Government Head of Ecosystem Management and Implementation, stated that DURESS provided evidence to test some of the more novel thinking taken forward in the Act, including *"the connections within and between ecosystems in Wales and need to manage whole systems"* **[5.5]**. Many of Welsh Government's key partners (Natural Resources Wales, Dŵr Cymru Welsh Water, and Welsh NGOs) contributed to DURESS, which *"helped raise further awareness around ecosystem-based management, and made its outputs more relevant to Wales"* **[5.5]**.

The Environment (Wales) Act 2016's guiding principles for the sustainable management of natural resources reflect Cardiff research, in particular specifying that environmental interventions should aim to increase ecosystem resilience and benefits to people, "in particular the following aspects (i) diversity between and within ecosystems; (ii) the connections between and within ecosystems; (iii) the scale of ecosystems; (iv) the condition of ecosystems (including their structure and functioning); and (v) the adaptability of ecosystems" **[5.6**, p2**]**. The research also had further lasting impact on Welsh Government policy. Following Brexit, Welsh Government is using the Cardiff research to "*guide the development of our CAP* [Common Agricultural Policy] *replacement land management scheme*" **[5.5]**. The CAP scheme is a system of agricultural subsidies and programmes covering farming, environmental measures and rural development.

b. Changing practice for Wales' national water utility provider

Dŵr Cymru Welsh Water (DCWW) is the sixth largest of the ten regulated water companies in England and Wales, serving over three million people. As a direct result of DURESS's research on the link between catchment management, river biodiversity and ecosystem services **[3.1-3.6]**, DCWW changed its practice to a catchment-driven approach. DCWW's Director for Environment stated: "*the outputs of the DURESS project have brought to our attention the importance of catchment management to sustain Welsh headwaters and the services they provide – e.g., water free from pollutants for the production of drinking water*" **[5.7]**. This led to a number of changes in DCWW operation, for example:

- A new DCWW catchment team which employs 20 staff, described by DCWW as *"a significant change to our business"* **[5.7]**.
- The launch of the Beacons Mega Catchment Partnership in 2017; this involves DCWW working with upland land managers on a nature-based approach to improving water quality in the Brecon Beacons National Park area, which supplies almost all DCWW's water **[5.7, 5.8]**.
- Significant investment into catchment management through DCWW's 2020-2025 Asset Management Plan. Every five years, water companies develop Asset Management Plans which are agreed and funded by the regulator. DCWW's 2020-25 now contains an agreement to: "*invest more than £20m over 2020-25 on developing our catchment knowledge and scientific understanding"*; and *"we are also to invest a similar amount (circa £20m) in developing alternative nature-based solutions which will reduce the nutrient levels in our rivers"* **[5.7]**.

Further Cardiff work, commissioned by DCWW "*formed one of the key building blocks*" for DCWW's Welsh Water 2050 vision document, which "*sits at the centre of DCWW investment and other thinking…referred to by numerous organisations in Wales and the water utility sector*" **[5.7]**. The work examined what considerations the company should make when

planning improvements to make systems, people and assets more resilient, and came as a direct result of the DURESS resilience and scenario research **[3.1, 3.6]**.

c. New sustainable approach to Wales's natural resources management

Cardiff's research influenced Natural Resources Wales (NRW), the organisation responsible for all Wales' natural resource management. Ceri Davies, NRW's Executive Director for Evidence, Policy and Permitting, explained: "*The DURESS team had extensive exchanges with NRW during the life of the project from 2012 to 2015 which influenced the way NRW prepared for implementation of the Environment (Wales) Act and the Wellbeing of Future Generations Act"* **[5.9]**. In particular, Davies noted that NRW used the DURESS Scenarios Report **[3.6]** to **[5.9]**:

- ensure understanding of the practice of integrating 'environmental futures' (which could identify different emerging threats and opportunities) into strategic planning;
- begin identification and consideration of specific issues from the external environment that could influence how NRW delivers its purpose over the short, medium and long term until 2050.

NRW had not previously used scenarios routinely to frame thinking for the future, and the work underpinned the first *State of Natural Resources* (SoNaR) report in 2016 **[5.9]**. The NRW website describes the SoNaR report as "ground-breaking", as "for the first time – the report links the resilience of Welsh natural resources to the well-being of the people of Wales" **[5.10]**. Quinn (Welsh Government) noted that: "*NRW are specifically charged under the Environment Bill with producing a statutory State of Natural Resources Report…The same themes that you see in DURESS, you'll see those in those documents, around the understanding of the connections, and particular emphasis around identifying key systemic interventions*" **[5.4]**.

Quinn also noted that DURESS research findings, on the connection between freshwater biodiversity, ecosystem services and human wellbeing **[3.3, 3.4]**, were used to shape NRW's Area Statements. These Statements outline the challenges and strategies for the management of natural resources in each of the seven Welsh areas. Quinn noted that **"***the Area Statements (informed by the State of Natural Resources Report) will feed directly into the work of the [local] public service boards"*, and that *"like DURESS, this will enable [WG, NRW] to link action in the natural environment to wider well-being*" **[5.4]**.

In summary, Cardiff's research on freshwater ecosystems and their vital role in energy transfer, human wellbeing, and natural resource management, provided critical evidence to establish protection of the Cubango-Okavango (CORB) River Basin. They also transformed freshwater ecosystem management in Wales, through the Environment (Wales) Act 2016, and DCWW and Natural Resources Wales's critical moves towards more holistic and sustainable approaches to natural resource management.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[5.1] CORB Fund leaflet
[5.2] Testimonial: Charles Reeve, Team Leader, Climate Resilient Infrastructure Development Facility (CRIDF)
[5.3] CRIDF blog, 'OKACOM holds community consultations on the future of the Okavango Delta' (April 2020)
[5.4] Testimonial: Matthew Quinn, Director of Environment and Sustainable Development, Welsh Government (annotated transcript from the DURESS project final conference talk given at the Welsh Assembly in 2015)
[5.5] Testimonial: Steve Spode, Head of Ecosystem Management and Implementation, Welsh Government
[5.6] Environment Act (Wales) 2016 (pg 2)
[5.7] Testimonial: Tony Harrington, Director for Environment, DCWW
[5.8] DCWW, *Welsh Water 2050* and evidence CU report to DCWW
[5.9] Testimonial: Ceri Davies, Natural Resources Wales
[5.10] A summary of the *State of Natural Resources* Report, Natural Resources Wales, 2016