Do we need river diversity?

Few natural resources deliver more critical goods and services than rivers

DURESS Photo exhibition 2015

Diversity in Upland Rivers for Ecosystem Service Sustainability

Exhibition Summary

They've shaped our landscape, and our towns and cities have been designed around them. They are vitally important for our everyday lives and our environment. In fact, few natural resources deliver more critical goods and services than rivers. They provide water, food, and energy. They can regulate flooding, erosion, sedimentation, local climates and water quality, while facilitating the dilution and disposal of pollutants. They support adjacent ecosystems, supplying water but also nutrients. They have large cultural value for recreation, tourism, education, heritage and as inspiration for arts and religion.

Up to recently however, we have managed our lands mostly to provide goods with an established market value like crops, meat and fibre, often overlooking the value of river services that we mostly take for granted. There is growing consensus that inappropriate valuation of the world's ecosystem services has led to widespread errors in management with significant social dis-benefits downstream such as floods, dirty water and fewer fish. DURESS was conceived to provide the evidence needed to manage our rivers and their lands more sustainably. Rivers are key to human well-being and prosperity, and we all have a role to play in making sure our rivers continue to be the lifeblood of our lands.

1. Web of Life

We need to better understand the processes carried out by the multitude of river organisms that together help to sustain the services that rivers provide. These organisms are part of an intricate food web that spans both the water and land. The sun's energy is captured through the chlorophyll rich organisms within and around the river, processed by all the river organisms that munch, scrape and filter the valuable carbon energy. And in turn, through the web of life, these organisms fuel everything from brown trout to kingfishers. But we still know little about how different parts of this food web fit and function together. We also lack quantitative understanding of how these river processes contribute to delivering the key ecosystem services on which we rely: clean water, but also fish and birds that are such an important part of our culture and our enjoyment of freshwater landscapes.

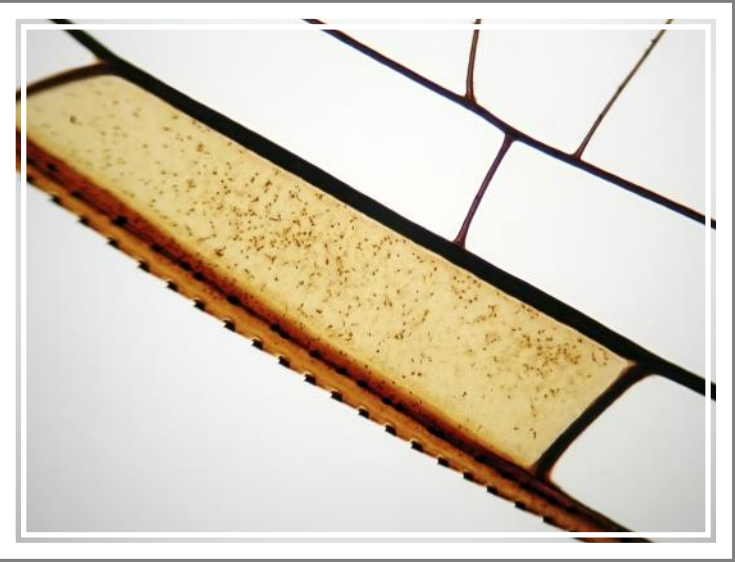
Researching our UK upland sites, we find the position of a particular species in river food webs (e.g. how high up the food chain a species is) can be largely explained by a few simple 'rules', such as how large the species is. Effectively, big organisms eat smaller organisms that in turn prey on even smaller organisms. Indeed, we have found this 'Russian doll' pattern to be repeated across rivers in very different settings. Interestingly, we are finding that some river fish, such as trout, are often more connected to food webs on land rather than in the water, as bugs that fall into the river from the surrounding catchment make up a large part of their diet. Conversely, some land vertebrates, such as kingfishers and dippers, often feed solely on river organisms.

Leaves were painted in an experiment to track their progress downstream

2. Food for thought

At the start of the web of life, trees capture and store energy in the form of carbon. Leaves that fall into streams in the uplands are likely very important in the downstream transfer of energy needed for healthy rivers, and healthy seas.

Rather than simply observing changes in the natural world, DURESS conducts experiments to assess the role of river life in regulating water quality and decomposition. We added tonnes of leaf litter to streams to test whether planting more broadleaf trees alongside streams might help invertebrate and microbe communities to grow and prosper. Our results are starting to show that streams can store, as well as transport, significant amounts of energy, especially where broadleaf trees are present. This stored energy fuels productive food webs all year round, despite large fluctuations in rainfall and river flow patterns which could become increasingly common in the future.

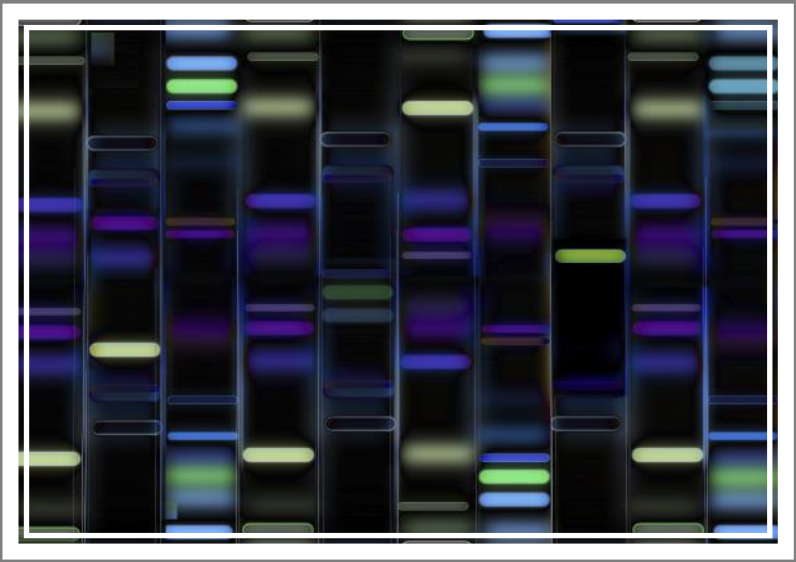


Dragonfly wing

3. The undervalued workforce

Insects and other invertebrates in rivers are crucial in the cycle of energy in rivers, yet their work often goes unrecognised. They shred the leaves and debris that fall into streams, gather and assimilate the production from algae and bacteria, and consolidate it as prey for many fish, birds, bats and other riverside animals.

The DURESS project is highlighting our dependence on these unsung heroes. Invertebrates are sensitive to change. for example many are not able to exist in polluted water. DURESS is investigating how much change can occur before we risk loosing the valuable work that invertebrates do for us.

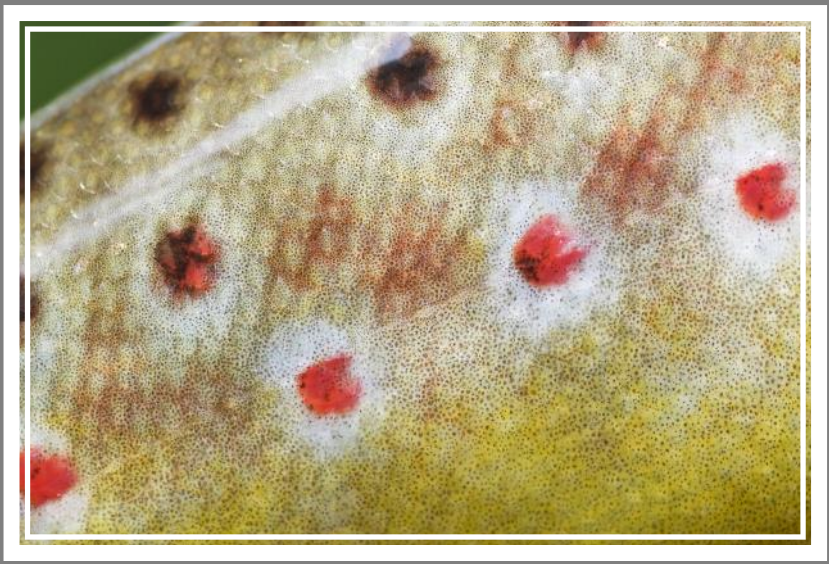


Molecular analyses

4. Pattern of life

Much of the work to assess biodiversity involves counting; counting the number of individual organisms, measuring the size of populations at different sites or measuring the size or weight of individuals. The classical estimation methods are very useful, and in DURESS we have spent an estimated 6000 hours identifying, weighing measuring invertebrate and fish samples over the past two years. But we were also keen to test other measurements of biodiversity, the most elemental of which is genetic diversity, which enables species to adapt to change over time.

We have been using molecular analyses to identify species that we cannot otherwise easily tell apart, such as many microbes. But we have also used the information contained in the DNA of each individual to try and understand what makes some populations more resilient to change than others. DURESS focuses on organisms that play a major role in river ecosystem services; brown trout that contribute to fisheries and recreational fishing, dippers that are valued by nature-lovers and invertebrates involved in decomposition and water quality. Our first results show that Welsh invertebrates are very good at jumping between populations, maintaining high levels of genetic diversity and resilience, but that populations living at the highest altitude tend to be more isolated and may require special conservation attention, an important result given they are generally found in our National Parks.



Trout skin

5. A fishing expedition

Around 6 tons of salmon, trout and eels are produced from Welsh river fisheries each year and angling generates over £105m annually to the Welsh economy. The benefits we derive from ecosystems can be both goods and services: upland rivers contribute to the production of fish and we can benefit from the cultural value of recreational fishing.

While we clearly value our fish, we still know little about how much healthy fish populations depend on river biodiversity. Perhaps more importantly, we cannot really quantify the role of upland streams in sustaining the fish populations that are fished downstream. In DURESS, we have measured the salmon and trout that travel up and down our Welsh streams for two years, to better understand what drives the sustainability of these valuable river organisms. We have also analysed thousands of data gathered over 20 years by the Environment Agency, to identify which combinations of land use, land character and river management have provided the most sustainable fish populations.

6. Muddy waters

Britain's water infrastructure is valued at over £200 billion and worth over £10 billion per year; making the 389,000 kilometres of rivers one of our most important natural assets. With inadvertent (or deliberate) disturbance of the landscape feeding a river, water resources can become coloured, acidic, turbid or carbon-rich making them difficult or expensive to treat for our drinking water. Protecting the catchments surrounding rivers is increasingly seen as a key tool for the UK water sector to reduce treatment costs while improving the quality of our rivers.

DURESS research has demonstrated that day-to-day changes in these key water quality variables are primarily controlled by the natural water cycle and that this can be readily simulated. Successes with our simulation modelling (based on novel river data) offers the potential to reduce water treatment costs and risks by warning of pollution incidents or forecasting changes near water abstractions.

7. What's the use in slime?

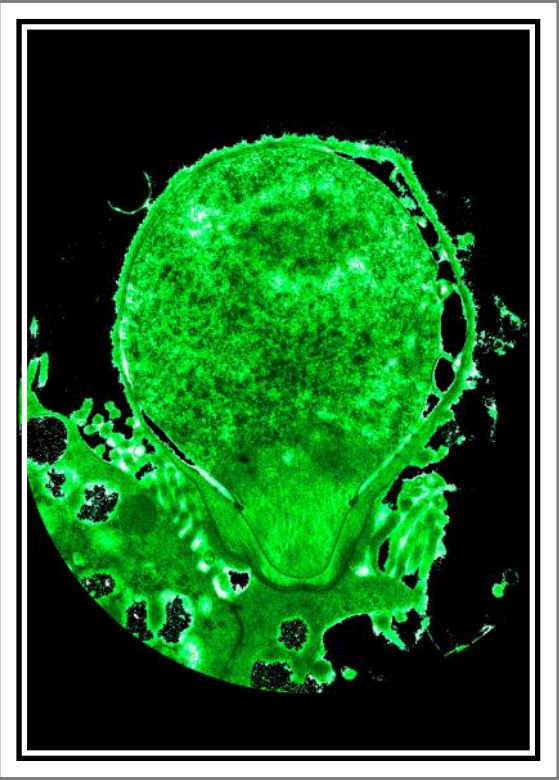
Biofilm is the slime often seen on rocks in rivers. It contains thousands of microbes—tiny living organisms such as bacteria. Microbes play a key role in carbon dioxide consumption, decomposition (the process of rotting dead animal and plant material) and regulating water quality. In fact, microbes probably play the most important role of all organisms in rivers, but we know very little about their diversity (i.e. who they are) or what they do.

Traditionally, to identify microbes, we need to cultivate them (for example in Petri dishes on nutrient agar). This is not possible for all microbes so DURESS uses molecular methods, to identify microbe species, and to identify those that play a role in decomposition and in regulating water quality. In DURESS, we want to quantify how much they help 'clean' our waters. We've been doing experiments in the streams to measure how much biofilm can reduce nitrate pollution, or reduce water colour. We're still finishing our calculations, but it is clear that 'the slime' should be regarded as the "rivers liver" and is really helping to keep our water bills down.

8. A bespoke stream

For almost 35 years, the streams feeding into the Llyn Brianne reservoir, in upland Wales, have provided a living laboratory enabling detailed study of river ecosystems and their functions, and providing an unrivalled longitudinal record of the environmental and biological changes in the rivers of upland Wales. The data researchers have accumulated is so unique, that it is now to be recognised as a Long Term Ecological Research site (www.llyn-brianne.org).

In 2013 we installed these artificial experimental cascades to perform experiments in real life conditions. They are the first cascading channels to be built in an upland landscape. These channels mimic real rivers but allow us to control any variation. For the first time, we can now start to quantify the role that river biodiversity such as biofilms and invertebrates play in controlling water chemistry. And of course we can do much more, experimenting with changing climate or changing stressors.



Cryptosporidium

9. Infective invaders

Not all microbes are beneficial to us: this image is of a pathogen called Cryptosporidium shortly after it invaded a gut cell causing watery diarrhoea, vomiting, stomach pains, and fever, with potentially serious consequences for children and people with weak immune systems. Cryptosporidium multiplies within the host – which could be animal or human - to produce millions of tiny "oocysts" which are shed in faeces. These oocysts become spread throughout the environment and can reach the lakes, rivers and streams we rely upon for drinking water and recreation. Cryptosporidium is of particular concern to water companies as it cannot be controlled in drinking water through traditional water disinfection.

We have found human Cryptosporidium oocysts in fish, indicating that transfer of this pathogen may occur through rivers in ways not investigated previously; aquatic animals may act as transport vectors. This new information will be included with other DURESS data to estimate, using catchment modelling, how risks of Cryptosporidium contamination and infection might change when land use changes. This in turn will be used to help make decisions about reducing public health risks when considering changes to land use.

10. Money down the drain

Economic value drives the industries that manage uplands, for example, forestry, farming, water quality, fish production and even recreation. However, some of the benefits we gain from upland rivers do not have an immediate monetary value which has sometimes resulted in their degradation.

DURESS aims to quantify the value of river ecosystem services, in particular those that are sustained by river biodiversity. We have interviewed 1200 people living and working in upland communities about how they value ecosystem services provided by upland rivers. Initial analysis suggests people most highly value management that improves water quality and that reduces the health risks from contact with river water. The next step in the analysis is to better understand people's motivations for valuing river ecosystem services and also to explore the value of alternative river catchment management scenarios.

11. What does the future hold?

In a world of increasing demand for food and fibre, against the backdrop of continuing degradation of the environment, our uplands face significant challenges. Additionally, whilst society values the cultural and recreational opportunities provided by the uplands, upland communities only rarely reap the associated benefits. Scenarios can be used to aid the discussion and the development of future strategies to respond to these challenges.

By examining drivers of change at both local and global scale, we identified four UK upland scenarios: agricultural intensification, business as usual, managed ecosystems and abandonment (pictured here). We are using these scenarios to draw maps of predicted land use change, a key resource for making management decisions that promote river biodiversity and the benefits that rivers provide.

12. Catchment approach

Water only flows downhill, and this natural process delineates one river from another at 'catchment' boundaries. The lands draining into rivers support their productivity and health, contributing to life support, well-being and prosperity. Changes to headwaters permeate downstream to estuaries and coastal systems.

DURESS results indicate that the benefits from rivers can be enhanced by managing whole river catchments sustainably and with downstream effects in mind. Taking account of how land can be best used for a range of ecosystem services could help maximise natural resource benefits from river catchments, balancing the needs of food and fibre production against the needs for biodiversity, water resources, carbon storage and landscape or heritage.

DURESS team conducting an experiment to measure how leaves make streams productive.

13. Building UK capacity in ecosystem research

A wider aim of the DURESS Project is to foster the development of a UK biodiversity research community with the capacity to deliver internationally excellent and strategic ecosystem science. Enthusiastic researchers from A-level to post-doctoral level have benefitted from on–the-job training as part of the DURESS project.

Our own research has shown that if people know and understand the processes within the natural environment that support human life and provide societal well-being, then they value them more. Placing value on the benefits we gain from ecosystems is the first major step towards management that will ensure the benefits remain for future generations.

14. Resilience

Growing population needs and changing climate will significantly alter catchment land-use and management in future. There may be thresholds of intensive use beyond which biodiversity or ecosystem services collapse, but our knowledge of these points of no return is rudimentary. Nor can we recognise the critical levels of biodiversity necessary to safeguard the services we all need against the tipping points that inevitably lie ahead.

DURESS is using environmental and biological data dating back 35 years from specific catchments (Llyn Brianne) and further afield to help understand the resilience features that may protect us against serious ecosystem damage. We are using these data to project whether species composition, ecosystem functions and even genetic character can be maintained and, if they are damaged, to understand the consequences. This work is vital to ensuring that future generations continue to benefit from the goods and services provided by river ecosystems.

The DURESS project is part of a major Research Council initiative to assess the role of biodiversity in delivering the key ecosystem services on which we rely.

This exhibition highlights some initial research findings. Over the coming months, much more data will be analysed and results published.

For updates visit www.nerc-duress.org

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