LET IT FLOW

VOLUME 1, 2020 | RECONNECTING PEOPLE WITH RIVERS

AMBER

BEST GUIDANCE ON **BARRIER MANAGEMENT** IN RIVERS

BREAKING BARRIERS

Dealing with obsolete structures

BALANCING ACTS

When dam removal is not an option

EUROPE'S FIRST BARRIER ATLAS!

How many barriers are in Europe's rivers?

DOES SIZE MATTER?

Impacts of big and small barriers

Rivers run through our history and folklore, and link us as a people. They nourish and refresh us and provide a home for dazzling varieties of fish and wildlife and trees and plants of every sort.

– Charles Kuralt

View across the Ljubljana Moor with the Ljubljanica River, Slovenia.
© Arne Hodalic / Wild Wonders of Europe

FROM THE EU COMISSIONER:

VIRGINIJUS SINKEVIČIUS

I was born in a country where rivers have always been special, offering excellent opportunities for fly fishing and kayaking. Rivers are an important part of our county side, villages and landscape. Rivers matter for people and nature, not only in my home country but all over Europe. However, when it comes to freshwater, it's no secret we have challenges to overcome. Rivers sustain much of the food we consume but are also important for power, recreation and transport.

We are on a journey to a climate-neutral planet, one that relies on increasing the generation of which may also include hydropower from rivers. But as our climate changes, so do our rivers. Some will have less water, while others will have much more, and the frequency of extreme droughts and floods will increase too. Europe has the highest density of weirs and other stream barriers in the world, as the AMBER project has revealed. Many of these barriers are abandoned or obsolete but continue to block sediment transport and the movement of fish and other aquatic organisms. They represent a flood hazard, fragment our rivers, and prevent rivers from playing their natural roles. Over 60 percent of EU rivers, lakes, and wetlands are in a poor state in part due to habitat fragmentation and loss of connectivity. To improve the health of our rivers, we need to reconnect them.

I believe this challenge can bring new opportunities. We need smart solutions that benefit the environment and lead to a sustainable, healthier, and more prosperous society. Solutions designed for the future, not borrowed from the past. Solutions that maximize benefits to the community and minimize environmental impacts. When it comes to reconnecting our rivers, one size will not fit all. The challenge of improving river connectivity and social prosperity is best served by managing barriers adaptively, as advocated by AMBER. There are already a lot of good examples being implemented throughout Europe of what is possible to achieve.

That is why I welcome initiatives that enable people to reconnect with their local rivers, and share insights and best practices to make our rivers healthy again. This magazine is the first step to get all of us involved and help us create a new future for our rivers and the lives they sustain.

A NOTE FROM THE EDITORS

Photo © Pexels

“Why a magazine on reconnecting people with rivers?” We’ve heard the question many times when we told others about our ambition to produce a magazine about the Adaptive Barrier Management of European Rivers (AMBER) project.

We have met so many people who share an interest in rivers and the ecological diversity they support. Many dedicate their time in and around waterways for work, passion, or interest. We meet these people at conferences, meetings, and field-trips, eager to know what's going on in river management and to learn what's new and inspiring. With this magazine, we hope to involve these people and many others, from local practitioners to European policy makers. Our goal is to work together to maximize benefits for our rivers and minimize anthropogenic negative impacts. A magazine allows us to share the beauty of rivers that we enjoy so much and to provide guidance for how to restore and protect these ecosystems.

The origin of this magazine stems from a project involving scientists, representatives from the hydropower industry, government agencies, and non-governmental organizations who gathered to make an impact on Europe’s water management. This EU Horizon 2020 funded project, called AMBER, aimed to produce the first comprehensive Pan-European Atlas of river barriers and develop a range of tools to help managers prioritize the restoration of stream connectivity.

Throughout this magazine, we share results, thoughts, and ambitions for the future. Inside, we illustrate the issues of river fragmentation and restoration in Europe and abroad and what can be done to tackle these challenges. For those interested in the research related to each article, we have gathered the relevant documents and included the AMBER Field manual and Best Guidance on Barrier Management, on our website amber.international/magazine.

As a reader of this magazine, you probably care a lot about the health of our rivers. Let’s connect! To inspire each other, learn, and join forces on relevant projects and share new insights and tools. This magazine is for and about you. We want to hear your comments, ideas and suggestions. Contact us on amber.international.

Enjoy and let it flow!

Information: how fragmented are our rivers?

Knowledge: why does it matter?

Innovation: looking for solutions

Application: getting it done

Inspiration

A fiery passion to make a difference: the steps it took for AMBER to go from an idea to a project to restore river connectivity in a better way.

"We are very ambitous!"

'When I am in a river I make no distinction between work and leisure.' The man behind the AMBER project smiles, as if he is apologizing for his answer. Born in Spain, but living now in the UK for many years, where he is Professor of Aquatic Biosciences at Swansea University, Carlos Garcia de Leaniz is a man on a mission to make the world a better place for people and fish. "I have two favourite rivers', he says, 'the headwaters of the River Asón in Northern Spain, and the Girnock Burn in Scotland. Both are relatively pristine areas, where one can feel connected to rivers and the lives they sustain." The salmon rivers of Spain turned out to be a game changer for Carlos' life, where he first experienced the satisfaction of restoring habitats for fish. "After breaching a weir, we saw salmon swimming in spawning areas where they hadn't been for a hundred years. That is so special! At the same time it made me sad, as such successes were only a drop in the ocean. There is still so much to do". Hence, the seeds for the AMBER project were planted.

Frustration as trigger

But the trigger to start drafting the project was a matter of frustration. In 2014, three old friends met at Swansea in Wales. Eric Verspoor, Phil McGinnity and Carlos have a long history of researching salmon together. They also share some pretty strong views on the need to protect this iconic fish. "We were frustrated that popular solutions like stocking and fish passes were not working. In general the approach was too much 'one size fits all", says Carlos. The three men locked themselves away for three days to piece together a global project to help alleviate this issue. They were looking for funding calls. But there were none. "It seemed nobody wanted to fund what we wanted to do. But we found a EU funding opportunity about ecosystem restoration that we thought might enable us to focus on the restoration of salmon rivers. Dams and other river barriers are one of the main threats to salmon, so we decided to focus on that problem". Within a few months they drafted a concept note inspired by a 'wordle' compilation of the EU funding call description, and lured some colleagues to help them write an application.

Taking time to plan for impact

The growing group of participants decided to focus on river fragmentation in Europe. They aimed to produce the first comprehensive Pan European Atlas of River Barriers and develop a range of tools to help managers prioritise the restoration of stream connectivity. "We were very ambitious because we wanted to make an impact. That is why dissemination was a core element of the project and why we have a broad range of stakeholders on board. Everyone used their networks. For example, it was thanks to Patrick Martin in France and Paul Kemp in the UK that we managed to have four industrial partners on board, while Niels Jepsen in Denmark invited the Joint Research Centre of the EC to join us. "Knowing some core partners before you start a project is important because it cuts down on the time needed to achieve the necessary group cohesion".

Having a good idea is essential, but Carlos explains, that was the easy bit. "The journey from idea to application follows a very tortuous road, one fraught with challenges and false leads. Applications for EU Research and Innovation funds are very competitive and typically have a very low success rate, in our case it was just 4 percent" Carlos is glad they did not know this at the time, because it would have been very difficult to convince people to put all the effort into the application!

From Information to Innovation, and into Application

"Before one can restore river connectivity one needs to know the facts. Facts set the scene", explains Carlos. Therefore, the first question that AMBER had to address was about the extent of fragmentation in Europe's rivers: How many barriers are there? where are they located? How big are they? What impacts do they cause? "We did not really know the answers to any of these questions. The location of all the big dams was, of acourse, well known, but we soon realized these were just a tiny fraction of all the barriers in rivers". Based on small scale studies the AMBER team predicted that there might be hundreds of thousands of weirs and other small barriers that were not mapped. Crucially, they suspected that many of these barriers would be abandoned, and could therefore be removed. "But information alone would never restore rivers, simply bridging knowledge gaps would never be enough", says Carlos. "We had to develop tools to quantify stream fragmentation, to prioritize barriers for removal and mitigation, and to provide estimates of costs and benefits. But, ultimately, what river managers need the most are practical solutions to restore river connectivity, or to manage dams in more sustainable ways. Hence, we had to turn data into knowledge, and knowledge into solutions". For this reason, AMBER was structured around five core

"It is so satisfying to pick something challenging but useful, making the world a better place."

work packages that used an adaptive approach to turn information (the barrier Atlas) and innovation (the AMBER tools) into application (a series of case studies). Legacy and impact would be achieved via a dedicated dissemination and knowledge exchange programme.

Proud

After almost four years of running the AMBER project Carlos is proud. He sits up and counts on his fingers while he talks. First, the Barrier Atlas is a real achievement. No other barrier database comes even close to it. Second, the suite of AMBER tools is a great legacy that will be used extensively in years to come. But third, the aspect Carlos says he is most proud of, is the paradigm shift that the project has brought about. Until recently, in many European countries, the problem of stream fragmentation and loss of connectivity was mostly about upstream fish passage, and frequently only considered salmon or a few other migratory fish. "We had to remind people that rivers are more than fish, that fish are more than salmon, that barriers are more than dams, and that water abstraction is more than just hydropower. That is our mantra. It may seem obvious now, but stream restoration had been coloured by the needs of fish for far too long." This holistic view of restoring river connectivity advocated by AMBER is already informing EU policy and has featured in high impact media outlets, like The Guardian, El Pais, and Nature.

Lessons learned

Has it all been a howling success with the AMBER project? Carlos nods his head. "Of course not. There have been many challenges and difficulties to overcome, and four years had not been enough to do all we wanted. The management of such a large, international network needs the right balance of charm, tact, resilience and drive to build relationships and trust. On the one hand you need to deliver on time following exact EU regulations, and on the other hand you need to bear with very busy people and different stakeholders with contrasting views". He states that during the project there had been quite a few staff changes, including three different project managers, three different EU project officers and also other key people switching jobs. This can be stressful and draining, as it forces one to develop working relationships all over again. It requires a flexible approach to problem solving. Carlos admits: "The administration and finances of the project can be daunting. Thankfully, we have been supported by amazing, understanding people and this has made all the difference."

Blue Rivers

"I am really excited about our next dream project, BLUE RIVERS". Building and expanding on the concept of 'good ecological status' embedded in the Water Framework Directive, BLUE RIVERS proposes to award BLUE Flags to Rivers as a way of recognizing the natural value of the best EU rivers. Similar as currently done with beaches, it seeks to reward those rivers that constitute the best exemplars of river integrity and that need to be preserved in each country. This will help to develop a network of National River Parks in each Member State, expanding on the concept of 'Water Museums' promoted by UNESCO. "We also want to identify and promote the best examples of river restoration. In this way, we hope to create a new pan-European river culture, one that focuses on the benefits of having healthy rivers, not on fines and failure to meet environmental standards". We want European citizens to take ownership of their national rivers and feel proud about them again."

Move away from pessimism

"You know, I told you about my love for the River Asón, in Cantabria (Northern Spain). In the nearby Mirón Cave archaeologists discovered ancient fish bones, which radiocarbon dating showed were 40,000 years old! Sonia Consuegra (also in AMBER) was able to sequence their DNA and determine they were from Atlantic salmon, a species which is now threatened with extinction in many places. To think that we could lose salmon from these rivers in just a few decades, that our ancestors had enjoyed for tens of thousands of years, is just shocking. But our work there and elsewhere has shown that restoring connectivity and river habitats is possible, and that results can be fast. It is very satisfying to pick something challenging that makes a difference. That's why I tell my students to do something useful with their lives and help make the world a better place, for people and fish. We need to move away from pessimism. In fact, we have no choice."

Career Notes:

Carlos received the Prize 'Living Streams 2014' in Spain for his sustained efforts on the restoration of Atlantic salmon: *http://riosconvida.es/wordpress/premios-rios-con-vida-2/*

He is also credited for having pioneered dam removal in Spain, and was named "River Restoration hero 2008" in World's River Review by International Rivers: *https://www.internationalrivers.org/resources/interview-with-pedro-brufao-rios-con-vida-spain-35711*

River Garry © Shobhit Pipil

ADAPTIVE MANAGEMENT EXPLAINED

Dalmatian pelican, Danube delta rewilding area, Romania
© Staffan Widstrand / Wild Wonders of Europe

If you google the word 'adaptive,' you will see that it is one of the buzzwords of today's society. But what does it mean to adaptively manage river barriers, and why is it so important?

Everyday life is about being adaptive, and managing a river is no exception. Water managers are increasingly being asked to manage rivers through an adaptive management approach. This concept, however, is not novel.

Adaptive management for rivers is a way to structure and implement decision-making processes for the management of both species and their natural habitats. It stems from the idea that ecosystem management and conservation is a dynamic and unpredictable process, and thus it must be modified as we gain knowledge and learn from experience. It is also a process that requires the involvement of all relevant stakeholders. Therefore, adaptive management of barriers in rivers aims to have hydropower companies or other barrier owners, river managers, anglers, and all other related groups come together to make decisions about management that will maximize benefits and minimize ecological impacts.

Adaptive management can have significant benefits in the context of barriers. People living in areas where adaptive barrier management has been applied report having more fish, more beautiful rivers, more tourist opportunities, and more sustainable generation of hydropower. They are usually proud of their achievements and believe adaptive management should be the aim. However, before one starts with adaptive management, there are a few issues to consider.

To adapt or not to adapt

So what do we recommend? Within the AMBER project, we have gathered knowledge on the subject through literature as well as through our case studies. Here are a few things we've learned along the way.

First, adaptive management requires economic investment. Involving stakeholders, looking for common objectives, and regular reviews can be very time-consuming and expensive. The advantages afterwards, through a partnership approach are to have joint goals, up to date information, and engaged stakeholders, but it comes at a cost. Lack of consideration for this aspect is one of the most common and most detrimental mistakes one can make in an adaptive management process. It can lead to a complete halt in the process, causing further detriment to the river system in play. This will typically lead to even more costs down the line, as the process will often have to be restarted from scratch when more funds are available.

Second, proper assessments to determine the current state of rivers at relevant temporal and spatial scales are essential to address the issues at hand adequately.

Third, finding the right partners, and not just subgroups, can be a real challenge. There should be equal representation among stakeholders and single stakeholders should not stall the process from moving forward. Identifying and mobilizing the right mix of partners is an essential task, though easier said than done.

Last but not least, is the bureaucratic process. Bureaucracy can significantly hinder progress because it takes time – often too much time, to apply adaptive management and some of the procedures need to be followed. So, one needs to be familiar with the different aspects of bureaucracy involved in the management of rivers. A partnership, or at the very least a dialogue with some of the organizations concerned, will greatly help move the process along. This is important to avoid unnecessary frustrations and delay and to ensure that benefits are achieved in practice.

It's essential to understand and accept that adaptive management may not be the best solution; it won't solve every problem and it isn't the best approach in all cases. When few stakeholders are involved, or the barriers are rather small, it's often too costly and time-consuming to use an adaptive management approach, so alternative strategies should be sought.

That said, when we take these considerations into account and recognise that adaptive management is, in fact, the best approach, the results can be great.

Further reading

Adaptive management in the context of barriers in European freshwater ecosystems

Report of Case Studies

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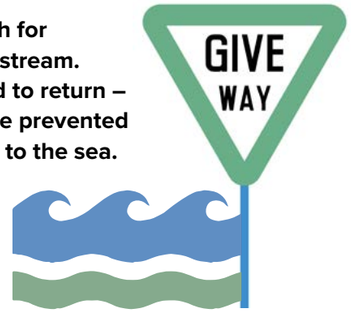
BARRIERS IN **FACTS AND FIGURES**

What do you know about barriers? Here are some interesting findings research has uncovered over the past four years.

1 million

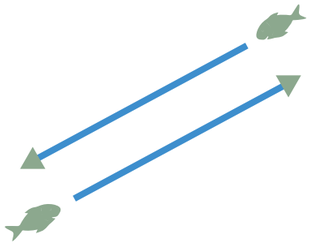
We have counted 680,000 barriers but estimate there may be in excess of 1 million.
(reference: Belletti et al. in prep)

It is not enough for fish to pass upstream. They also need to return – many fishes are prevented from returning to the sea.



300

different barrier types across the EU were identified by European researchers.
(reference: Belletti et al. in prep)



Many technical fishways are often ineffective for 'weaker' swimming species such as the European river lamprey.
(reference: Tummers et al., 2018. Ecological Engineering. 125: 87-95)

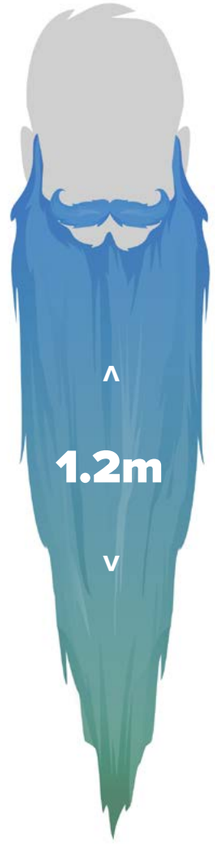
Barriers in rivers affect much more than fish passage. Habitat up- and downstream is modified and frequently destroyed.

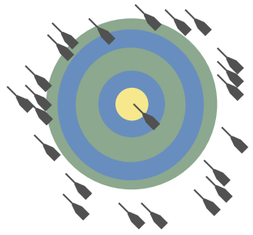
7808

Researchers in the AMBER project caught, measured and released more than 7808 fish in UK and DK including brown trout, Atlantic salmon, minnow, stone loach, eels, bullhead and lamprey during sampling.
(reference: project report AMBER)

During the AMBER project, researchers freed 311 kilometres of rivers from barriers in Denmark
(reference: Removal of small in-river barriers, Denmark and Northern England)

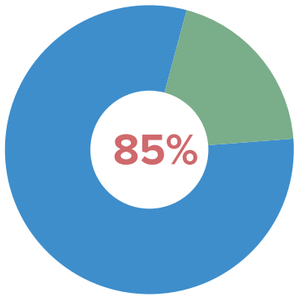
The removal of the Clondulane Weir has been stuck at the High Court in Ireland for more than 10 years. That's the time it takes to grow a beard of more than 1.2m.





River lamprey averaged 43 separate attempts each whilst trying to pass a riverine barrier. Imagine trying to pass dozens of these barriers on their migration!
(reference: Tummers et al., 2018. Ecological Engineering. 125: 87-95)

On average, there is almost one barrier for every two river kilometres in European rivers.
(reference: Belletti et al. in prep)



More than 85% of all barriers in our rivers are small (lower than 1-2 meters).
(reference: Belletti et al. in prep)

People's voices matters. In part due to AMBER involvement, a reservoir planned to be built in the River Nalon catchment was cancelled.

1%

Only 1% of rivers in Britain are unfragmented.
(reference: Jones et al., 2019. Science of the Total Environment. 673: 756–762)

Further reading

Classification map of running waters considering fish community structure and barrier impacts

Role of barriers in managing AIS

BETTER THAN THE GOOD OLD DAYS

The removal of barriers from Danish rivers made fish populations healthier than ever.

Refsgårdslund © Kim Birnie-Gauvin.

Road to recovery

When it comes to rivers and fish, Denmark is a somewhat idiosyncratic place. With the highest point of just 171 metres, its waterways are not only small but lack gradient. And because gradient is so limited, rheophilic habitat (gravel substrate and fast flowing, highly oxygenated water that salmon and trout love so much) is in scarce supply.

"Habitat for spawning and rearing of young fish is something Denmark didn't have much of to start with," explains Kim Birnie-Gauvin of the National Institute of Aquatic Resources at the Technical University of Denmark. "Unfortunately, artificial barriers have taken away most of what little there was."

The biodiversity associated with Danish waterways has declined dramatically over the last century. Intensive agriculture has channelized more than 90% of streams and rivers for drainage, with regular dredging and heavy-handed maintenance further deteriorating physical conditions. Connectivity has been negatively impacted by dams and other barriers, as well as by multiple weirs associated with Denmark's freshwater aquaculture industry (which mostly involves farming rainbow trout).

Yet the story isn't all doom and gloom. Since 1982, Danish legislation on streams and drainage has included clauses which make it possible to implement river restoration. Today, more than 2000 recovery projects have been conducted across the country, with the majority aimed at re-establishing connectivity in river systems and spawning areas. Restoration efforts have varied from active re-meandering with heavy machinery, right through to passive projects involving the simple cessation of river maintenance.

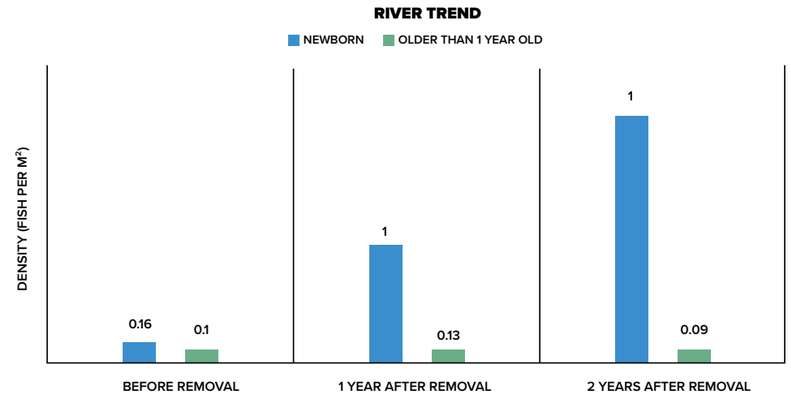
Setting a trend

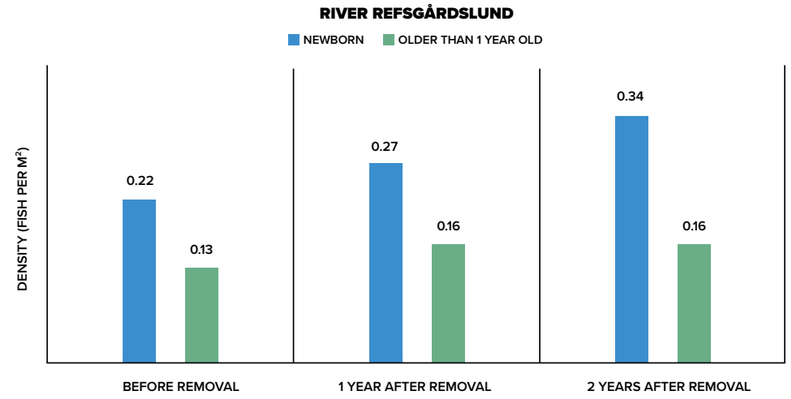
The majority of traditional Danish freshwater fish farms - mostly located in the country's Jutland region - channel water from a river into a series of ponds, usually with the help of a weir. However, stricter environmental legislation and an increase in national funding for changing fish farms mean an increasing number of farms are now switching to recirculating water technology. This technology does away with the weir and reduces water intake, the use of fish treatment medicine, and nutrient discharge. This recirculating system also offers other benefits to the aquaculture itself, such as improved and more controlled growth of the farmed fish.

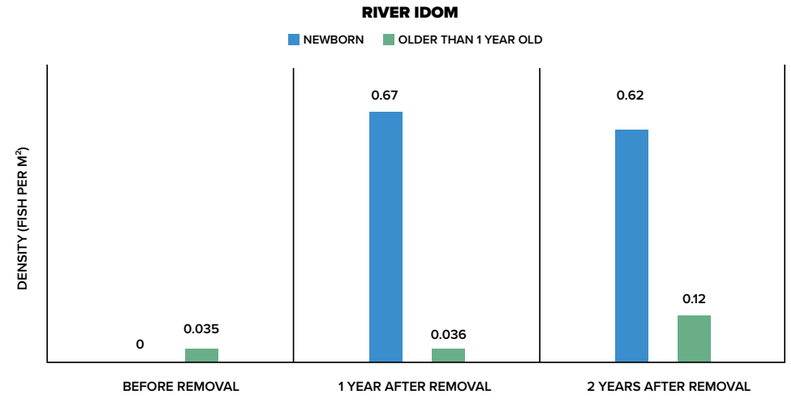
Located on the 70-kilometer River Trend, the Trend Fish Farm is located around 11 kilometres from the Limfjord, which is connected to both the North Sea and the Kattegat

"Habitat for spawning and rearing of young fish is something Denmark didn't have much of to start with."

Photo above shows the portion of the River Idom before barrier removal and the photo below shows the stream after removal allowing for access to an extra 15 km of salmon spawning grounds.
© Kim Birnie Gauvin







Density of newborn (less than a year old) and older fish in numbers per meter squared in the ponded zones of each river before barrier removal, 1 year after removal, and 2 years after removal.

© Kim Birnie Gauvin

Sea. The 1.4 meter-high weir here had a natural bypass associated with it, but this was poorly maintained and inefficient.

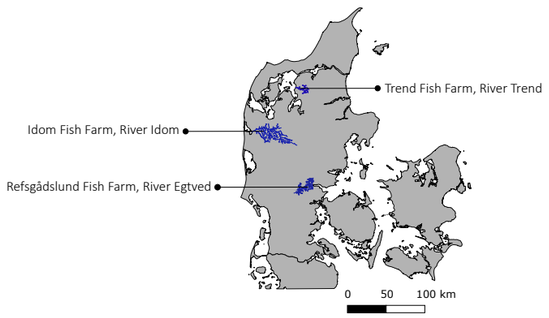
"Despite its relatively small size, the weir affected upstream habitat for more than several kilometres," explains Kim Birnie-Gauvin. "The Trend is mainly a brown trout river, but the density of fish above the weir was very low."

In August 2017, when the owner of the fish farm was given the choice of closing down operations entirely or switching to a recirculating system, he opted for the latter.
As the weir was the only barrier on the Trend, its removal resulted in a gain of almost 60 kilometres of totally accessible, free-flowing river.

"The results were amazing," says Kim Birnie-Gauvin. "A year after they removed the weir, the density of young-of-the-year (YOY, trout born that year) brown trout just above the farm had already soared. The fish farm owner was delighted to see that fish had returned to the upstream habitat of River Trend in such numbers."

Transformative impact
The River Egtved in eastern Jutland is also a brown trout river. Following a decision by a local fish farmer to close down his operations (rather than change to recirculating technology), the 1.5 meter-high weir here was also removed in 2017. With nature allowed to take its course, the removal opened up nearly 50 kilometres of the river upstream. However, another barrier downstream still impeded free access from the sea.

"The density of young trout didn't boom immediately," says Kim Birnie-Gauvin. "This is probably because the



"A year after the weir was removed, the density of young-of-the-year brown trout just above the farm had already soared."

removal was carried out during the spawning season and because of the other barrier lower down in the system. But by 2019, we saw an increase in density by a factor of 1.5."

Brown trout are not the only fish species to benefit from Danish weir removal. Located in western Jutland, the 16 kilometre-long River Idom is a tributary of the larger River Storaa, the second-largest Atlantic salmon river in Denmark. In 2016, the removal of a 1.1 meter-high weir at the Idom Fish Farm - located just 1 kilometre from the confluence of the Idom and Storaa - gave adult salmon free access to an extra 15 kilometres of spawning grounds. The transformation was both fantastic and rapid.

"We went from having no salmon (YOY) upstream of the barrier before its removal to 100 newborn fish in the 50 meters upstream of the barrier just one year after its removal," says Kim Birnie-Gauvin. "These results are really important because the Storaa is home to the only self-sustaining Atlantic salmon population in Denmark. And the reason this population is self-sustaining is that dams similar to this one have been removed throughout the entire lower watershed."

The comeback of fish in the rivers Trend, Egtved, and Idom confirms that the ultimate tool for reconnecting rivers and bringing back suitable rheophilic habitat is barrier removal.

"Dam removal is now the go-to tool for restoring river connectivity and habitat in Denmark," says Birnie-Gauvin. "Migratory fish, like brown trout and Atlantic salmon, have responded so well to this approach that populations today are larger than any historical records - it's better than the good old days."

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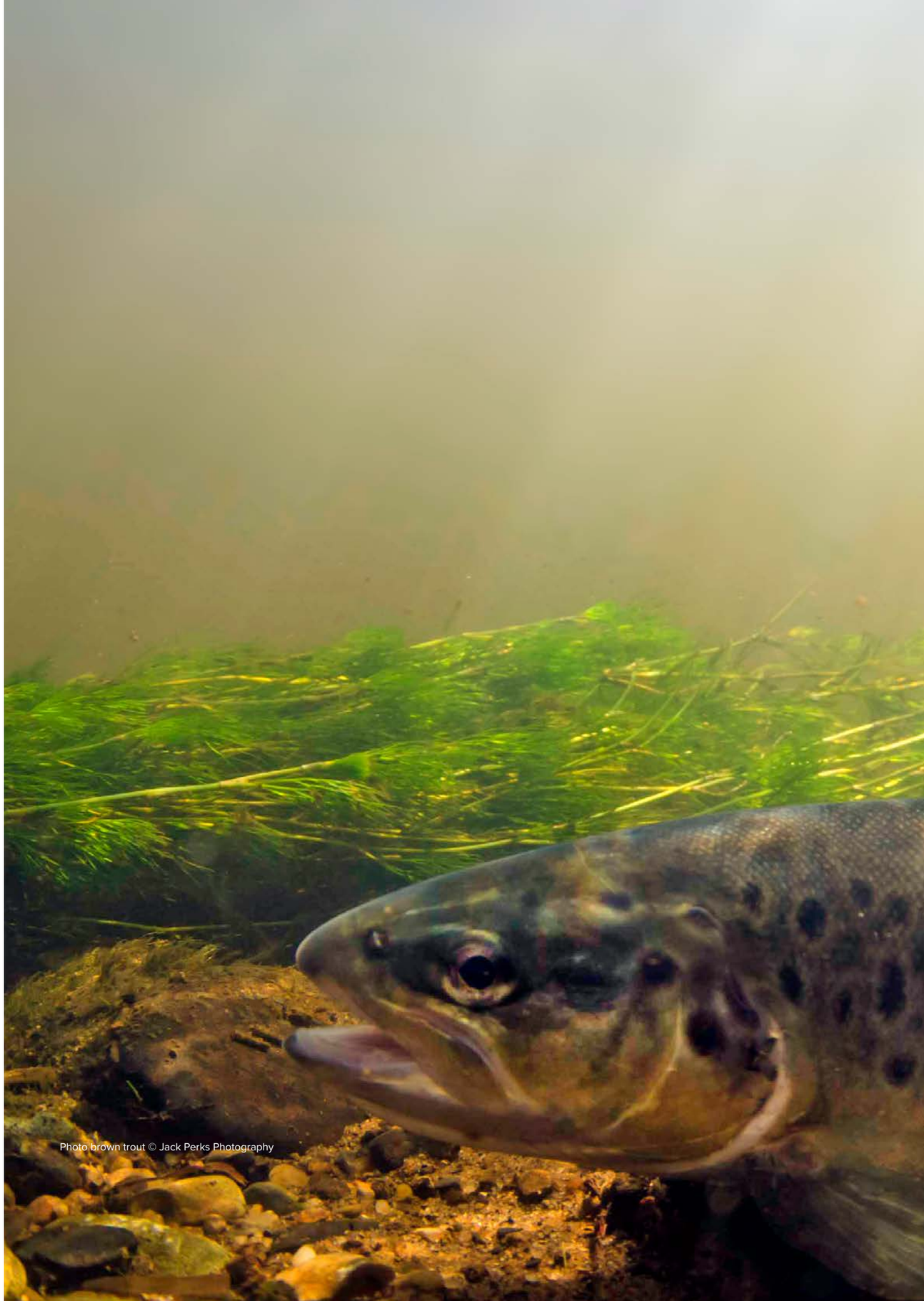
Photo brown trout © Jack Perks Photography

WHAT TO DO WITH ALL THAT DAM(N) SEDIMENT!

Many people may not think about a river's ability to move sediment. However, sometimes rivers are responsible for shaping entire coastlines. In the USA, people are opting to remove dams to save their beaches.

When nature enthusiasts talk about free-flowing rivers, they often speak about fish passage, both upstream and downstream, and removing obstacles. However, Laura Wildman, one of America's premier river restoration specialists and scientific advisor to AMBER, points out the importance of restoring sediment passage as well.

"You don't always see it, but rivers move sediment as well as water. Rivers transport sand, gravel, cobbles, and even boulders along the riverbed, and finer material is transported in the water column. This is how the rivers have shaped the lands and coastlines over time. The amount of sediments transported by rivers is quite impressive." Wildman knows the importance of these sediment flows. For the last 30 years, she has been reconnecting and re-establishing the natural functions of American rivers.

Laura Wildman is a woman who doesn't go unnoticed. She is passionate about rivers and is not afraid to make herself heard. In combination with her impressive list of hundreds of dam removal and river restoration projects in her career, she is a popular speaker on the subject all over the globe.

"I love rivers," says Wildman, "as a child, I spent most of my spare time exploring rivers, fishing, and camping. However, it gets harder and harder to find spare time these days because so many rivers need our help. There are many plans to reconnect rivers and remove obsolete dams in the USA at the moment. Many of the first proactive dam removal projects focused on restoring historic migratory fish runs; however, now we are removing dams for a wide variety of reasons. These reasons include reducing dam safety risk and restoring natural sediment transport processes."

When dams are built, they disrupt this natural sediment transport process. Sediment builds up behind the barriers, leaving the downstream rivers, and eventually, our coastlines, sediment starved. People are now looking toward dam removal as an opportunity to rebuild our depleted beaches and coastal deltas, which play a critical role in coastal resilience.

For example, experts identify beach nourishment as a potentially significant benefit of the removal of the almost 200 foot high Matilija Dam. This obsolete dam stores millions of cubic meters of sediment, on the Ventura River in California. The Surfrider Foundation kicked off the Matilija removal campaign in the early 1990s with a bumper sticker that read "Give a Dam. Free the Sand. Grow the Beach." A study from 2007 finds California's rivers and streams provide about 75% of the beach sand.

With the reality of global sea-level rise, we can expect a growing recognition for the role of sediments in coastal areas. Scientists are working on modelling, and forecasting sediment flows. Wildman thinks this is the logical path forward. "If the dam has been there for a long time, it could have gathered a significant amount of sediment within its reservoir. You have to carefully balance both the potential benefits and impacts of releasing sediment downstream when you are removing a dam." Too much sediment coming down a river in a short timeframe can have a variety of impacts. A recent study on the Asian Mekong river also shows that better planning of barriers can make a huge difference for sediment flows and delta areas. According to the scientists strategic planning 68% of the hydropower potential of the river basin could have been developed while trapping only 21% of the basin's sand load. The current dam portfolio resulting from project-by-project planning uses only 54% of the hydropower potential while trapping 91% of the sand load!

Furthermore, sometimes, the sediment contains contaminants accumulated in previous years when regulations regarding pollutants were less strict. Therefore, experts view proper sediment management as an essential part of river management. Wildman states, "As an engineer and river enthusiast, I'm happy that people are starting to better understand the critical role that rivers play in forming and sustaining our dynamic landscapes. Let it flow!"

Author information
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Laura in her natural habitat! © Laura Wildman

Laura Wildman is the Director at the New England Regional office of Princenton Hydro and external advisor to the AMBER project

The Poutès Dam in France is currently being modified to aid fish migration. By applying adaptive management strategies such as technological innovation and multi-stakeholder dialogue, this pioneering project should deliver a win-win outcome.

Migration, interrupted

Freshwater fish rank amongst the most endangered group of vertebrates on the planet, with populations plummeting by more than three-quarters over the past four decades. Damaged fish communities and declining fisheries characterise global freshwater environments, including those in Europe.

Habitat fragmentation is one of the principal reasons for this decline. While many freshwater fish need to migrate to complete their life cycles, water resource developments disrupt river connectivity, threatening biological diversity and fisheries. Along European waterways, hundreds of thousands of dams, weirs and smaller barriers block migratory pathways.

One such barrier is the Poutès Dam. Lying across the River Allier in central France (a tributary of the Loire), it has devastated the Loire-Allier wild Atlantic salmon population since it was constructed in 1941.

Conflict resolution

There were once 100,000 salmon in the Loire-Allier basin, making it one of the most fertile breeding areas in the whole of Europe. Today there are only a few adults left, despite the removal of and construction of fish passes on other dams in the catchment. With the Poutès Dam preventing salmon from reaching their most productive breeding sites, environmental NGOs and anglers have been campaigning for its removal since the early 1990s.

In 2004, the largely state-owned French electric utility company Électricité de France (EDF) applied to renew their concession on the dam, triggering more intense discussion. Finally, in 2011, following an extended period of consultation involving EDF, scientists, the French government, NGOs and elected officials the New Poutès project was unveiled.

Innovative engineering

Scheduled for completion in 2021, the New Poutès Dam will be a fraction of the height of its predecessor (4 metres, as opposed to 17 metres). The length of the reservoir behind it will also be reduced from 3.5 kilometres to around 350 metres, while fish migration and sediment transport will also be aided by the installation of two fully openable central sluice gates, as well as a fishway and a fish elevator. Despite changes to the dam's configuration and management regime, its overall annual electricity generating capacity will only be 15% less than pre-modification levels.

"The new dam puts technical innovation at the service of biodiversity," says Sylvain Lecuna of EDF, who heads up the New Poutès project. "This is a first in the world of hydropower. The goal of the project was to take into account all environmental and societal expectations, and I think we have reached the best possible solution."

Underpinned by stakeholder engagement, adaptive management is a dynamic, iterative process in which practitioners test hypotheses and monitor results, adjusting behaviour, decisions and actions accordingly. Such a process is exemplified not only in the way that disagreement over the Poutès Dam was resolved, but also in the way the dam is currently being reconfigured, based on research carried out pre-modification.

"The new dam puts technical innovation at the service of biodiversity."

Rapid transit
While well-designed and properly installed fishways can help fish negotiate barriers in rivers, the alteration of natural flow conditions by dams also has a negative impact on fish migration. River impoundment by reservoirs can dramatically change both downstream and upstream flow conditions, confusing fish species which have a natural tendency to orient themselves using water currents (a process known as rheotaxis).

In this respect, reducing the length of the reservoir created by the Poutès Dam should benefit localised fish migration significantly. This was confirmed by studies carried out by EDF and partners prior to the modification of the dam itself, when the reservoir had already been reduced in length from 3.5 kilometres to 1 kilometre.

Over the course of 2017 and 2018, smolts (two-year-old salmon ready to migrate to the sea) were captured upstream of the reduced reservoir, equipped with acoustic transmitters, and released into the Allier. This allowed the impact of the reservoir reduction to be accurately assessed.

"Our results show that reducing the length of the reservoir to 1 kilometre reduced the transit time for smolts from 20 days (median time) to just 3 hours, and that fish were able to find the outlet of the dam easily," says Sylvain Lecuna. "In its final phase, the reservoir behind the New Poutès Dam will only be 350 metres long, so smolt transit times should be even lower."

While transit times were improved, the studies also revealed the negative impact of the dam's turbine intake, which was located close to the outlet. The decision was taken to screen off the intake with a fine grid to prevent smolts from entering it.

"Each year, when smolts are detected at the top of the Poutès reservoir, the water level will be lowered to its optimum level (for migration) and the turbines screened off, to mimic conditions created during the study trials," explains Lecuna.

Enhanced connectivity
A reduced reservoir is not the only way New Poutès will benefit the migration of Allier salmon. The gates of the dam will also be opened three months a year to enhance riverine connectivity and facilitate unimpeded migration. This means more than 90% of the salmon in this stretch of the Allier will be able to negotiate the dam without obstacle.

"This complete permeability, with no flow restriction behind gates or dams, is particularly innovative," says Sylvain Lecuna.

In line with the adaptive management process, monitoring work will be conducted after the reconfiguration is complete to evaluate the number of fish crossing the dam when the gates are open. The fish elevator will also be monitored by cameras. The results generated will allow the impact of the modification to be assessed and fine adjustments to be made.

Progressive solutions
The removal or modification of a dam is never going to be a black-and-white issue, and it will always be a challenge to find mutually acceptable solutions to problems when multiple stakeholders are involved.

"The innovative reconfiguration of dams can reduce their negative environmental impact, while simultaneously safeguarding the socio-economic benefits that such barriers deliver."

Yet the case of the Poutès Dam demonstrates how the potent combination of new technology and adaptive management can deliver change that satisfies and benefits all. It proves that the innovative reconfiguration of dams can reduce their negative environmental impact, while simultaneously safeguarding the socio-economic benefits that such barriers deliver (such as electricity). It also shows how changing the operation of a dam at critical times, based on robust science, can greatly facilitate salmon passage.

"The real takeaway here is that adaptive management has resulted in a dam that causes less environmental damage and which still provides useful services to society," says Professor Carlos Garcia de Leaniz of Swansea University, Principal Investigator and Coordinator of AMBER.

The way forward
Many European dams (such as the Poutès Dam) were constructed in the middle of the twentieth century, at a time when there was far less awareness of and concern for environmental issues. Yet in many cases, the complete removal of these barriers - while it may be environmentally desirable - is simply unfeasible, especially given the EU's increasing commitment to renewable energy.

Only time will tell how successful the reconfiguration of the Poutès Dam has been in terms of meeting project objectives, while even complete success may not lead to a self-sustaining salmon population in the Allier River (which is influenced by a whole host of other factors). It is also important to bear in mind that the reduction in dam height and reservoir length implemented in this case is not an approach that would be viable at many dams. Nevertheless, progress made on the project to date suggests adaptive management tools and techniques may be invaluable when it comes to mitigating the detrimental impact of riverine barriers.

"In my opinion, the combination of technical innovation and multi-party dialogue is a fruitful strategy that should be replicated elsewhere in France and across Europe," says Sylvain Lecuna.

Claus Till Schneider of German energy company innogy agrees.

"Both the hydropower industry and authorities can learn from New Poutès," says Schneider. "Balancing ecological benefits, renewable energy production and investment in mitigation measures, the project is a beacon of collaborative effort and adaptive management."

"Reconfigure or Remove? Since many barriers were built in the first half of the previous century, there will be many choices to be made when these are at the end of their 'lifecycle' or concession. Technical solutions, such as those on the New Poutès Dam, are required when barriers cannot be removed (after years of negotiations between stakeholders it was decided not to remove the Poutès barrier). The debate whether old barriers should be reconfigured or removed can be found all over Europe. "Dam removal will always be the most effective measure for restoring fish migration," says Bösiger from WWF Switzerland. Kim Birnie-Gauvin, PhD at the Technical University of Denmark: "The real problem lies in the accumulated impact of many dams in the same basin. That is why we need river basin-scale management strategies. These should always prioritize removal, and then integrate other approaches, such as ecologically grounded fishway construction, improved barrier management, environmental flow provision, and the strategic prioritization of mitigation efforts."

Further reading
Moving beyond fitting fish into equations: Progressing the fish passage debate in the Anthropocene

Impediments to barrier planning and stakeholder conflict resolution

River Infrastructure Planning Decision Support Tool

Author information
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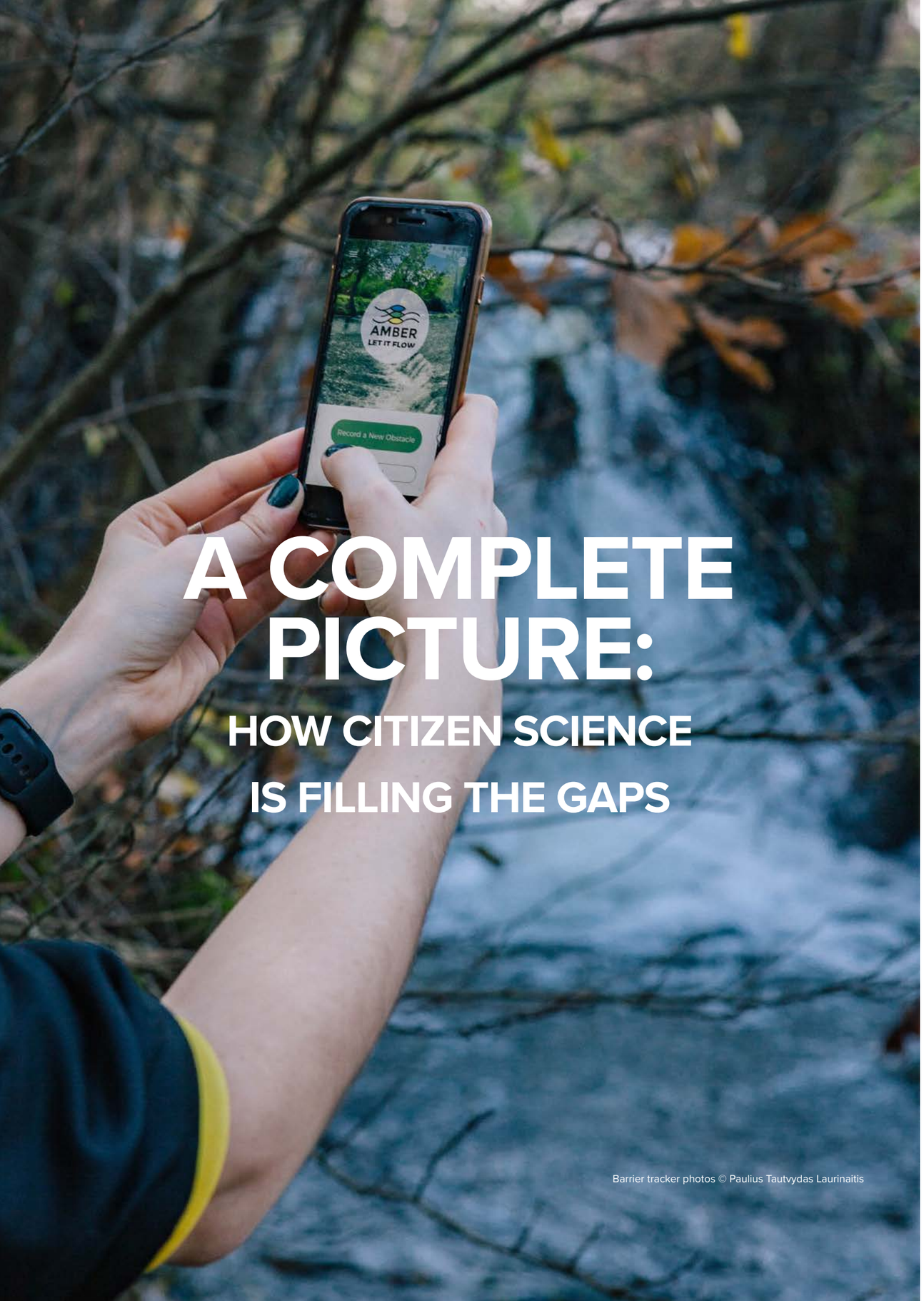

A COMPLETE PICTURE:

HOW CITIZEN SCIENCE IS FILLING THE GAPS

Barrier tracker photos © Paulius Tautvydas Laurinaitis

With hundreds of thousands of barriers in Europe, many of them abandoned, it is nearly impossible to keep track of all of them. One way to alleviate this challenge is to engage citizens to locate barriers and record those that are obsolete. With their help, we can get a better picture of river fragmentation across Europe and prioritize efforts for restoration.

Elevated greenhouse gases, natural disasters, droughts, floods, extinction, overfishing, microplastics, disease… the world today has deviated from its balanced state and seems to be on the brink of environmental upheaval. In fact, rivers rank among some of the most threatened ecosystems in the world. "River conservation and adaptive management are needed all over the world. There are many initiatives from local associations to bring rivers back to life. We need to work together to show politicians and hydroelectric companies that we all need better rivers," explains Sara Garrido-Espinosa, a barrier field validation expert from AEMS Rios con Vida in Spain.

What can you do if you love rivers, but protecting them is not your daily job? Bas Deelman from the World Fish Migration Foundation explains how he and his colleagues from the project team developed and use the AMBER Barrier Tracker phone application. "We wanted to get citizens involved in tracking barriers to support our database of barriers in all European rivers. Our colleagues in the project found existing barrier databases in Great Britain underestimate stream fragmentation by at least 68%. We know this is also true for many other European countries. That is what makes the citizens' gathered data an important component to understanding river fragmentation in Europe and rectifying it."

In 2016, the project team developed the Barrier Tracker application together with Natural Apptitude, available to download on cell phones to record barriers in Europe's rivers. By using the app, participants helped researchers by providing greater spatial coverage than would have been possible using conventional surveys. It also helped to create a better picture of barrier numbers in countries with an outdated database. And the app was not only useful for the project, as the tracked barriers are accessible to all users.

Karolina Gurjazkait, project manager for the Lithuanian Fund for Nature, states, "Lithuania is a small country with a poor barrier database. While our current database does include some dams, it does not include all dams and much less other forms of barriers such as weirs or sluices. The Barrier Tracker app can help fill in these gaps and instigate change."

Another user, Polona Pengal, PhD from REVIVO, Institute for ichthyological and ecological research in Slovenia, explains, "Barrier data is practically impossible to get, and these data are often outdated and incomplete. There is a huge number of barriers in Slovenian rivers that were used in the past but have no function anymore and should be decommissioned." For her, the barrier tracker is a vital instrument to perform the first comprehensive tracking of barriers in Slovenia and to support the local ministry where they lack capacity.

"River conservation and adaptive management are needed all over the world. There are many initiatives from local associations to bring rivers back to life."

Barrier tracker photos © Paulius Tautvydas Laurinaitis

Using this app, users recorded information on over 5,000 barriers in over 30 countries. Many of these barriers were not included in the official databases! One of the fascinating lessons derived from the input is the high percentage of barriers that users think to be 'out of use.' Field studies come to similar conclusions. Researchers are still analyzing the data, but at the time of writing this article, pilot results indicate that perhaps as many as 20% of weirs in Europe's rivers are out of use.

When talking about the importance of the barrier tracker and collaboration Garrido-Espinosa says, "The most important work we can engage in is combining our efforts and fighting for rivers together. This is why I think we need more projects that unify different countries and stakeholders, including hydropower companies, to join forces for the same cause."

The smartphone app is still open for those interested in contributing to the map!

For more information please visit:
portal.amber.international

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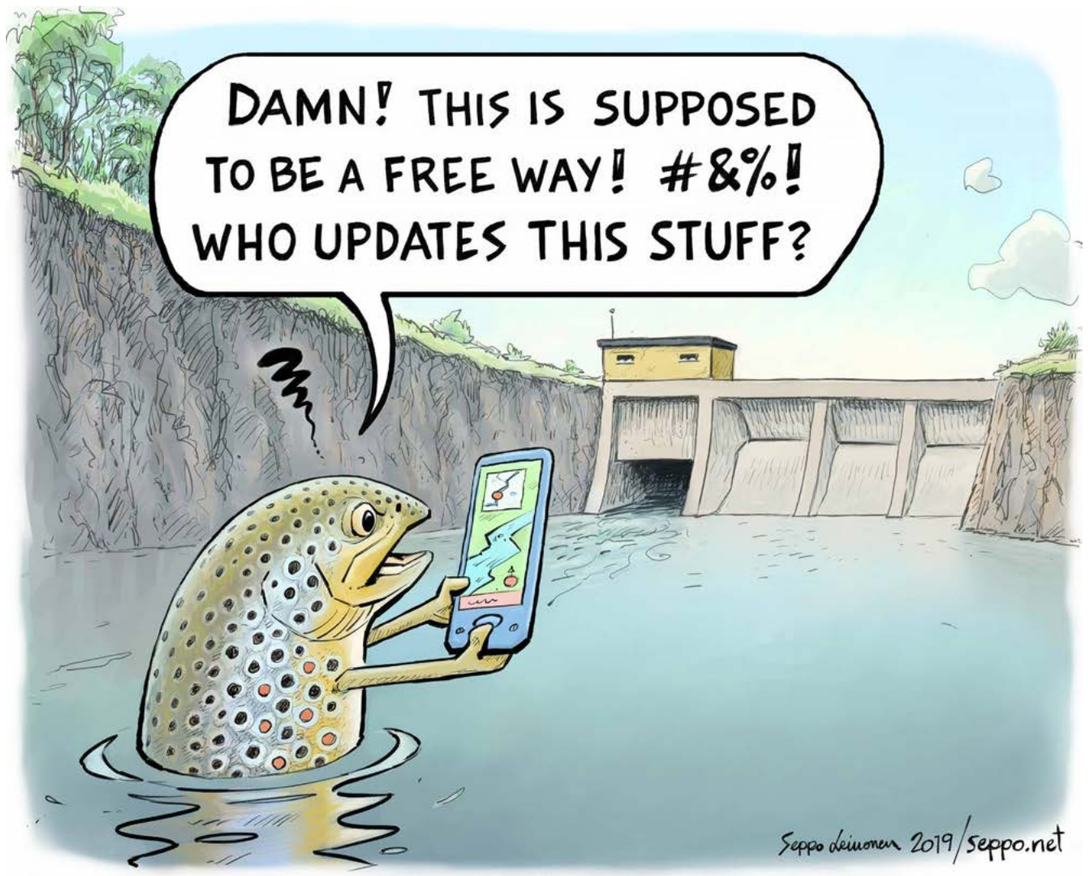


DOES SIZE MATTER?

Europe’s waterways are fragmented by all types of barriers. To mitigate their impacts, we need to think big and manage adaptively.

River Beris, regional park Brazuole Lithuania
© Karolina Gurjazkaité

The nature-like fishway constructed on the Howland Dam on the Penobscot River
© Joshua Royte, TNC Maine

Selective approach

Humans have interacted with and depended on rivers for millennia. Today, thanks to man's desire to govern and harness nature, less than 20% of European rivers and floodplains remain physically unaltered. The remainder are fragmented and disconnected by hundreds of thousands of artificial barriers.

The growing role of adaptive management is a key trend in the way freshwater barriers are operated. The goal of the AMBER project is to facilitate the application of such management techniques - an iterative process of decision making, monitoring, and adjustment - to barrier operation in European waterways. This has the potential to not only enhance riverine connectivity and biodiversity but improve energy security, protect jobs, and boost competitiveness.

Yet adaptive management is not a panacea. The average European waterway is filled with various types of barriers - some have a range of functions, some a single function, and many no function at all. Adaptive management may allow for some of these barriers to be removed, downsized, mitigated, or operated in a less damaging way. But this may not be appropriate in every situation.

Big versus small

Before considering the application of adaptive management, it's essential to examine the environmental impact of relevant barriers more closely.

The German economist E.F. Schumacher popularised the phrase "small is beautiful" to describe technology that minimized social and environmental impacts. When it comes to dams, Schumacher's time-honoured adage is often interpreted literally and taken as read.

It's not hard to see why: the term "small hydropower" generally brings to mind a quaint dam beside a German watermill. This image is in stark contrast to the towering large - hydro facilities such as the Alqueva Dam in Portugal or Hoover Dam in the United States - that radically transform entire landscapes.

But does small hydropower warrant its reputation as being environmentally benign?

"A small barrier can still break connectivity and be incredibly harmful in a biodiversity hotspot," says Ruedi Bösiger, Head of Freshwater at WWF Switzerland. "However, a big barrier in the upstream part of a river catchment can be less detrimental than a dam lower down a basin on an important tributary."

In fact, when it comes to hydropower, small frequently isn't beautiful at all. Small dams are often more numerous and can have severe impacts on habitats and biodiversity while generating comparatively little energy on a per-site basis.

The pictured Quoich Dam on the River Garry is the site of one of the AMBER case studies.
© Shobhit Pipil, Durham University

"In terms of big versus small, the question is how to maximize the use of hydropower potential in a region while minimizing barrier-related impacts," says Claus Till Schneider of German energy company innogy. "Just as the environmental impact of multiple small barriers can be cumulative, we have to take into account the total energy output of such barriers too."

Ruedi Bösiger goes further. "If the objective is to restore connectivity, then barrier removal will always be the optimal solution," he says. "But if it has to be a case of big or small, then we need to improve the effectiveness of big dams in terms of energy production, fish migration and sediment transport, rather than having hundreds of small dams producing roughly the same amount of energy."

Holistic hydropower development and barrier management

Until recently, the hydropower sector was largely focused on the construction and operation of individual power-generating facilities. While there are compelling reasons for working in such a way, this can severely constrain the sustainable development of waterways from a source-to-sea perspective.

Today hydropower development and barrier management are gradually shifting towards a more integrated, landscape-scale approach. Basin-scale planning takes account of engineering, economic, social, and environmental factors across multiple projects and entire river systems, maximizing benefits and minimizing costs.

"This strategy is essential, not only from a hydropower viewpoint but also from an environmental viewpoint," says Johan Tielman, the environmental manager for Swedish hydropower within Uniper, a German energy company Uniper. "What happens upstream clearly affects downstream values and vice versa. The entire river basin needs to be considered as a single social-ecological system. Actions in the upper part will affect the hydrology downstream. The general approach should be to work from the lower parts of the system and upstream, at least if you deal with anadromous species. This will have consequences both for what can be achieved to benefit the ecology and ecosystem-services but also the energy generation and regulatory capacity in hydropower."

Adaptive management is well-suited to handle the level of complexity involved in basin-scale planning. Moving away from the top-down decision making, expert-dominated approaches of the past, it can help to bring stakeholders together, both to evaluate opportunities and risks, and to form a consensus for sustainable and equitable development.

A case in point

A key element of adaptive management and the transition to more adaptive management regimes is the participation of all stakeholders (as opposed to only policymakers) in decision-making processes. Showcasing the benefits of adopting a basin-scale, multi-stakeholder approach to managing hydropower, the Penobscot River Restoration Project in the northeastern United States is the perfect example of what can be achieved when a broad consensus leads to barrier removal and mitigation.

Atlantic salmon, shad, alewives, blueback herring, and other migratory fish were once plentiful along the 175-kilometre Penobscot River. Then, around a century ago, a series of hydropower dams were built across the river. With migration routes blocked, fish populations collapsed.

Starting in 2004, a process of multi-stakeholder engagement eventually led to the removal of two dams in 2012 and 2013, while a fishway was built around a third in 2016. The results have been dramatic.

Before the dams were removed, the number of blueback herring travelling up the river to spawn each year was anything between a few hundred and a few thousand. In 2018, following removal, nearly 3 million were counted in the Penobscot watershed.

Yet perhaps the most telling aspect of the Penobscot project is that the restoration of fish migration routes has not come at the expense of hydropower. By increasing power generation on other dams, the forecasted energy generation from the entire basin will remain the same, and may even increase.

"This illustrates a basic principle," says Ruedi Bösiger. "Within a river basin, there may be multiple ways to achieve a given energy target, and these alternatives can have dramatically different environmental impacts."

Further reading

Passage performance and behaviour of wild and stocked cyprinid fish at a sloping weir with a Low Cost Baffle fishway

Role of barriers in managing aquatic invasive species

Report of Case Studies Demonstrating the Effects of Barrier Removal, Mitigation and Installation

Alqueva Dam © Luis Goncalves

"The entire river basin needs to be considered as one social-ecological system."

Mimicking nature
A river's flow is its heartbeat. Of all the environmental changes caused by riverine barriers, the disturbance of natural water flows is typically the most damaging. The interruption of sediment transport and nutrient cycling, alteration of upstream habitat, disconnection of river channels from their floodplains, and changes to the timing and regularity of downstream flows - all of these factors can have a hugely negative impact on ecosystems and their processes.

Adaptive management can lead to the regulation of flows downstream of dams to mimic natural flows, with high-flow events integrated into management plans in a scientifically grounded way. Managed well, this variance in flow can enhance fisheries, agriculture, and biodiversity.

This highlights the need for dams to be built (or modified) and operated with the capacity to provide the full range of flows required for adaptive management. The reconfiguration of the Poutès Dam on the Allier River in France, for example, will partially restore both sediment transport and fish migration by incorporating fully openable sluice gates.

Alien invasion
Revitalizing river and riverine biodiversity by removing barriers is sadly not as straightforward as it might seem. While barrier removal restores connectivity, it may also facilitate the dispersion of aquatic invasive species (AIS). Increasingly common in European waterways, AIS can pose a severe threat to endangered populations of endemic fish and other aquatic organisms.

The particular vulnerability of freshwater ecosystems to AIS is hardly surprising, given the frequent episodes of introduction and translocation of species from other river basins in ballast water, or for fisheries and aquaculture. An example is the signal crayfish (*Pacifastacus leniusculus*), which is now established in the waterways of many European countries. Originally a North American species, it modifies aquatic ecosystems, competing with native species, spreading disease, and burrowing into riverbanks, which in some cases exacerbates erosion.

"The potential impact of AIS is an increasingly important consideration when it comes to adaptive management," says Dr. Martyn Lucas, Associate Professor in Aquatic Animal Ecology at the University of Durham in northeast England. "It should form part of the decision-making process when it comes to removing or constructing barriers, as well as the installation of barrier mitigation measures such as fishways."

"Within a river basin, there may be multiple ways to achieve a given energy target, and these alternatives can have dramatically different environmental impacts."

Future focus
Today the combination of climate change, population growth, economic development, expansion of irrigated areas, and the pervasiveness of invasive species means it is becoming increasingly difficult to manage European rivers - and their barriers - without a flexible, dynamic, and collaborative approach.

Adaptive management can sometimes be an expensive and time-consuming process, and its effectiveness may be constrained by the irreconcilability of stakeholders. But there is a significant potential benefit in applying its central elements in European barrier management.

"In my opinion, when it comes to smaller scales, for example, a few smaller barriers or even a single larger barrier with few stakeholders, adaptive management is not feasible," says Birnie-Gauvin. "But when you're talking about international river basins with multiple stakeholders, multiple barriers, and multiple socio-economic and environmental variables, this is where such an approach can generate win-win solutions."

Further reading
Effect of artifcial barriers on the distribution of the invasive signal crayfsh and Chinese mitten crab.

Public knowledge of alien species: a case study on aquatic biodiversity in North Iberian rivers

Author information
Daniel Allen
Award winning journalist and photographer, he appeared in more than 60 publications, including the Guardian, The Independent and National Geographic Traveller.

The signal crayfish, *Pacifastacus leniusculus*, is originally a North American species but is now an invasive species in several European rivers.

EUROPE'S FIRST MAP OF RIVER BARRIERS

Lots of barriers!

Over the last three years, AMBER researchers gathered data to complete the first Atlas of River Barriers in Europe. Earlier barrier maps had only considered a few thousand large dams, but the true extent of river fragmentation in Europe was unknown. The new map reveals a more accurate picture of river fragmentation and shows that there are hundreds of thousands of artificial barriers all over Europe.

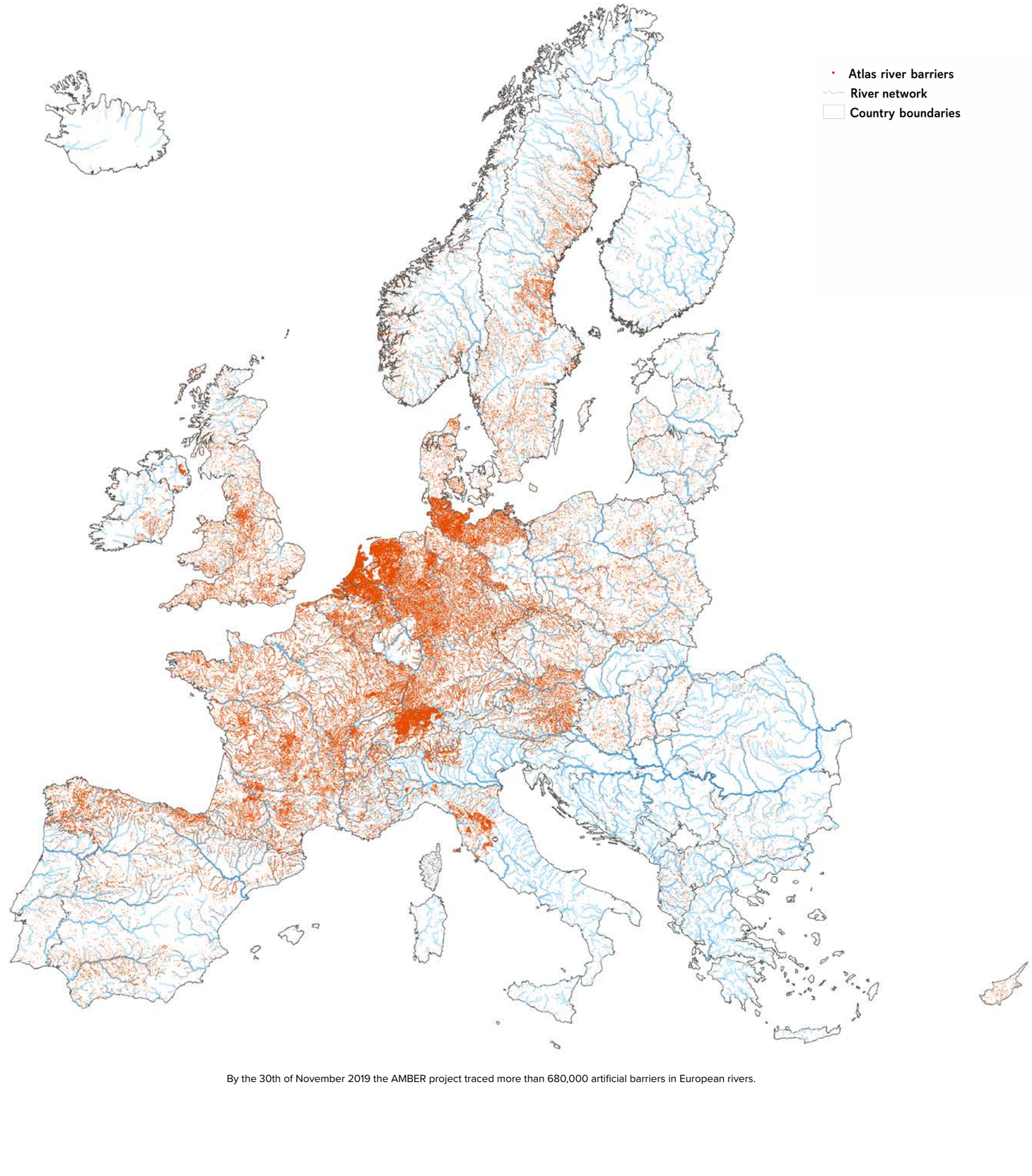
Many kinds of barriers

While compiling the data, there were over 300 different types of barriers identified. The most common types of barriers listed are **dams** (blocks or constrains the flow of water and raises the water level with permanent ponding), **weirs** (aimed at regulating flow conditions and water levels), **sluices** (movable and aimed at controlling water levels and flow rates), **culverts** (aimed at carrying a stream or river under an obstruction), **fords** (creates a shallow place for crossing the river or stream by wading or in a vehicle) and **ramps** (a ramp or a bed sill aimed at stabilizing the channel bed and reducing erosion; recognizable by its stairway-like shape).

Not the full picture yet

To date, this map is the most comprehensive overview of available information on barriers in Europe. There are over half a million recorded barriers fragmenting our rivers. However, through field validations, **we estimate that there may be well over 1 million barriers in Europe's rivers**. For example, Sardinia is white on the map, but that does not mean that there are no barriers.

By compiling this data and creating this inventory, AMBER researchers defined a common standard for displaying and validating the data. Relevant stakeholders can use this standard for future barrier reporting throughout Europe as, currently, data is not consistently available in many European countries.



By the 30th of November 2019 the AMBER project traced more than 680,000 artificial barriers in European rivers.

Are there still free-flowing rivers in Europe?

The inventory of river barriers from European Member States has helped to build the first picture of the scale of river fragmentation in Europe. Unfortunately, the image is alarming—it seems there are hardly any unfragmented, free-flowing rivers at all! In Europe, hundreds of thousands of artificial structures such as weirs, ramps, culverts, and fords, 85% of which are small structures, fragment rivers.

Even areas considered relatively pristine, such as the Balkans, have river barriers. In the Balkans, the situation is better than in the rest of Europe but still worse than we expected. Over 200 barriers are ground-truthed along 570 kilometres of rivers, only 20% are recorded in available in Balkan databases.

The AMBER researchers believe this is the best estimation of barrier density across Europe possible, based on current data and understanding. With this map, one can better visualize and realize the severity and magnitude of the poor connectivity of European rivers. The good news is it can also be used to improve the situation! The data can be used to build models of river fragmentation at various spatial scales that can help water resource managers make better informed decisions that seek to maximize benefits and minimize barrier impacts on European waters.

Further reading

Barrier Atlas website

A comprehensive assessment of stream fragmentation in Great Britain

Author information

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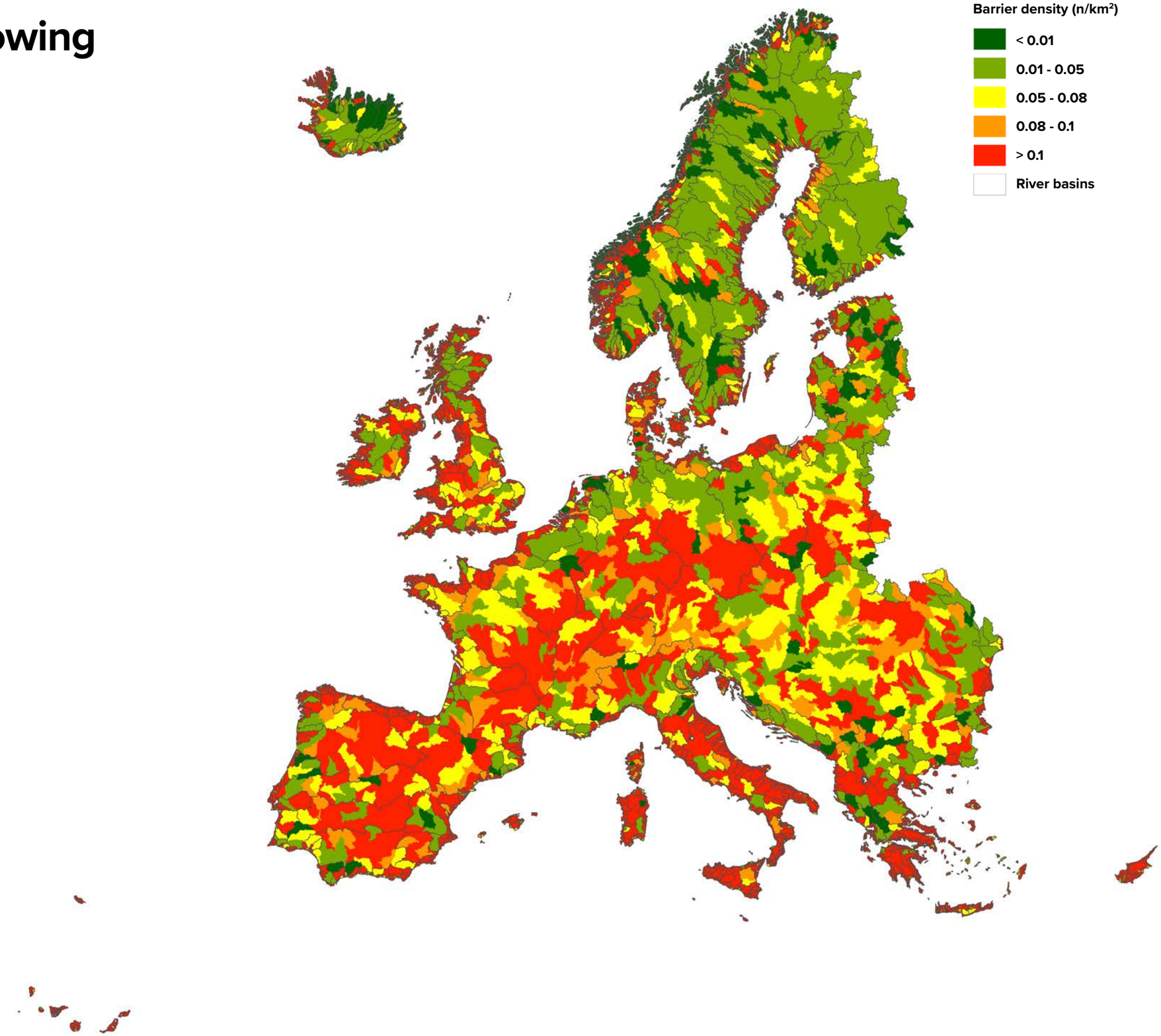
Swansea University, UK.



SOME RIVERS ARE MORE SENSITIVE THAN OTHERS

Europe has many different types of rivers and species of fish. Here we classified rivers into 15 types according to the habitat they offer to fish. We conclude therefore that there are 15 different fish communities in Europe's rivers.

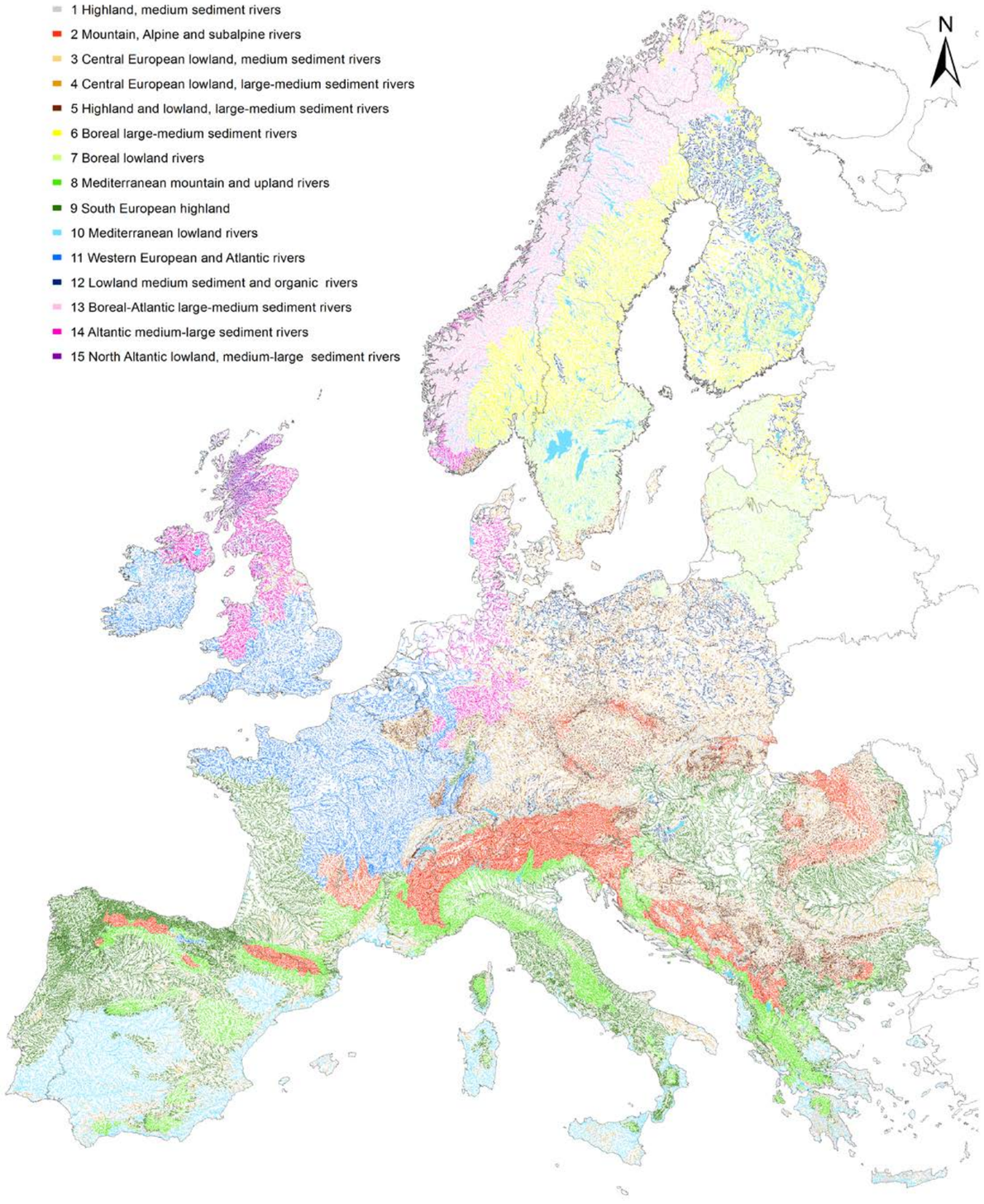
There are also different types of barriers within these rivers. They affect fish communities differently in different habitat types. Generally, the more barriers the bigger the impact. This map shows the locations of river habitat types. The table below demonstrates how each river can be impacted directly upstream of certain rivers if technical conditions or operational modes are not to sustainability standard and reduce ecological potential.

- severe habitat loss (>90%)
- moderate habitat loss (>11-50%)
- major habitat loss (>76-90%)
- low habitat loss (<10%)
- significant habitat loss (>51-75%)

River Type	Dam	Weir	Sluice	Culvert	Ford	Ramp
Highland, medium sediment	major	major	major	significant	significant	significant
Mountain, Alpine and subalpine	severe	severe	major	major	significant	significant
Central European lowland, medium sediment	major	major	major	significant	significant	significant
Central European lowland, large-medium sediment	major	major	major	significant	significant	significant
Highland and lowland, large-medium sediment	major	major	major	significant	significant	significant
Boreal large-medium sediment	severe	major	major	significant	significant	significant
Boreal lowland	severe	major	major	significant	significant	significant
Mediterranean mountain and upland	severe	severe	major	major	significant	significant
South European highland	major	major	major	significant	significant	significant
Mediterranean lowland	significant	major	significant	significant	significant	significant
Western European and Atlantic	major	major	major	significant	significant	significant
Lowland medium sediment and organic	major	major	major	significant	significant	significant
Boreal-Atlantic large-medium sediment	severe	severe	major	major	significant	significant
Atlantic medium-large sediment	major	major	major	significant	significant	significant
North Atlantic lowland, medium-large sediment	major	major	major	significant	significant	significant

Further reading

Conceptual model of ecological impacts of barriers in EU considering fish habitat selection criteria for running waters



BREAKING BARRIERS

Removal of the Sindi Dam in the Pärnu River in Estonia. This is part of a river restoration project that will open up 3300 km of the Pärnu River basin.
© Ministry of Environment Estonia

Removing dams is one of the key options for river restoration favoured by many NGOs. We ask a leader in the field, Rewilding Europe, about their experiences and efforts.

Removal role model
There were many times in the last few years when Külli Tammur, a project leader working for Estonia's Environment Agency, felt like giving up. Working to have the Sindi Dam removed from Estonia's Pärnu River, the array of obstacles blocking her efforts were seemingly as immovable as the dam itself.

"It took a massive amount of planning and paperwork, many difficult conversations, a bit of luck, and an intrepid minister, but we finally achieved our goal," says Tammur. "Now the dam has gone, we are all hugely proud."

Tammur and her team are right to be pleased with their efforts. A record-breaking example of river restoration for the whole of Europe to follow, the demolition of the 150-meter wide, 4.5-meter high Sindi Dam, together with a series of smaller dams upriver (in 2019), will soon mean more than 3000 kilometres of the waterway can again flow freely. By enabling fish to resume their natural migration routes once again, there will be wide-ranging benefits to both nature and numerous Estonian communities.

Across its basin, the Pärnu River drains an estimated one-fifth of Estonia, which means restoration efforts should have a hugely beneficial impact on the country's salmon population.

"Together with its 270 tributaries, the Pärnu was traditionally the biggest salmon river in Estonia," explains Tammur. "We estimated that the annual 'cost' of the dam in terms of its impact on nature was about 4 million euros. Fish will soon be able to swim upriver for about 100 kilometres, rejuvenating nature and benefiting people through new angling and other nature-based tourism opportunities."

Sindi Dam removal © Ministry of Environment Estonia

"A future where the majority of Europe's waterways flow freely should be our goal."

Pan-European restoration
Hundreds of thousands of dams and other barriers, most small and many obsolete, fragment Europe's rivers. These structures, some of them hundreds of years old, have provided irrigation, energy, and other benefits. But their presence has a seriously detrimental impact on fish and other wildlife.

"With undisturbed nature along European rivers in long-term decline, the removal of dams has already proven to be the most environmentally efficient and cost-effective measure for river restoration," says Rewilding Europe Managing Director Frans Schepers.

Founded in 2011, Rewilding Europe is a non-profit initiative working to make Europe a wilder place. Across all of Rewilding Europe's operational areas - which stretch from Lapland to the Danube Delta - local teams are working to create space for self-governing natural processes to shape ecosystems. In addition to letting processes such as forest regeneration, flooding and natural grazing impact landscapes, this also involves restoring rivers to their free-flowing state, or as close to this state as possible.

"There are so many European waterways which would flourish ecologically if they were given the chance," says Schepers. "Healthy, unimpeded rivers make good sense from both an economic and environmental viewpoint."

Practical measures
In 2018, Rewilding Europe conducted river restoration in two of its operational areas: Swedish Lapland and the Oder Delta. This work included the removal of log dams that are a legacy of the forestry industry (in Swedish Lapland), as well as the creation of spawning grounds (in both

All fish are not equal

Artificial barriers are ubiquitous in the vast majority of European waterways. Even smaller ones, such as the weirs removed from the Rivers Trend, Egtved and Idom, can have a severe impact on the populations of both migratory and non-migratory fish. Yet the way that fish respond to the hydrological conditions created at barriers (and by any barrier mitigation measures that might be in place) varies greatly with species.

A study carried out as part of the AMBER project examined the extent to which the physiology, morphology, and behaviour of fish affect their ability to successfully negotiate weir-pool fishways. A range of European freshwater fish species (brown trout, minnow, gudgeon, stoneloach, and bullhead) were involved in the study, which used an experimental cascade to replicate the fishway.

Of the five fish species, only the fastest - the brown trout - was able to swim up the cascade from bottom to top, while the two species with the slowest average swim speed - the minnow and gudgeon - tended to be more sedentary. Larger trout moved up and downstream in the setup more than smaller trout.

"The most pervasive pattern in our results is that passage rates were positively associated with body size, both at the inter- and intraspecific level," explains Professor Carlos Garcia de Leaniz of Swansea University, Principal Investigator and Coordinator of AMBER and co-author of the study. "Many small-bodied fish species need to move up and downstream to complete their lifecycles, which means restrictive barriers can change entire fish communities. These results prove that barrier removal is the best option for restoring healthy, naturally diverse freshwater fish populations."

At those sites where removal is not an option, the results of the study also suggest that a “one size fits all” approach to fishway design - which has typically been adopted in the past - is unworkable. It highlights the need for heterogeneous flow conditions, with a wide range of flow velocities, to avoid barrier mitigation measures having a selective effect on fish populations.

Author information:
Dr. Peter Jones, Swansea University, UK

areas). Rewilding Europe is also involved in the upcoming removal of dams on the Kagach and Kagilnyk Rivers in the Ukrainian Danube Delta.

"Removing dams is one of the most satisfying forms of nature restoration," says Rewilding Ukraine team leader Mykhailo Nesterenko. "Rivers are very dynamic and resilient systems. There are stories where old barriers have been removed, and fish returned within just one day."

Scaling up

In Europe, the EU adopted the Water Framework Directive (WFD) in 2000, which requires member states to restore "Good Ecological Status" to rivers and lakes. The WFD might accelerate a dam removal movement. While some European countries - most notably those on the Balkan Peninsula - are currently on a dam-building spree, dam removal is now ramping up in many others. The past two decades have seen at least 5,000 small dams, weirs, and culverts removed from rivers in France, Sweden, Finland, Spain, and the United Kingdom. In most cases, this has transformed riverine ecosystems enormously. The removal of the Kentchurch Weir on the River Monnow in Wales, for example, has enabled the return of the salmon and eel, while removal of the Maisons-Rouges Dam on France's Vienne River has seen the return of the salmon and sea lamprey.

Despite these achievements, there is still a pressing need to scale up Europe's dam removal process. Removing old and obsolete barriers is an easier way to facilitate this, as functioning structures may require the implementation of adaptive management.

“There are certainly opportunities for win-win situations across Europe," says Devid Krull of German energy company innogy SE. However, dam removal will always entail trade-offs and potential conflicts, especially when you take into account the range of services that functioning dams provide. This level of complexity is why AMBER is so valuable in terms of finding optimum solutions. "Hydropower companies may only switch to fewer and more efficient plants if a series of plants are operated by the same company and no other uses and functions are impacted," he continues.

A freer future

Rewilding Europe joined Dam Removal Europe (DRE) - a body established to encourage the removal of obsolete dams - in 2018. Partnering with organizations like WWF, The Rivers Trust, and European Rivers Network France, the networks continues to promote and accelerate dam removal across the continent.

"There are so many European waterways which would flourish ecologically if they were given the chance."

In addition to its river restoration efforts in the field, Rewilding Europe is also exploring scalable business models that can make dam removal - which is often cheaper than renovation - attractive for European dam owners.

Such models are typically based on the financial valuation of 'goods' that are blocked by the dams, such as migratory fish, water quality, and sediment that is needed downstream. In addition, energy companies are often amenable to agreements that open up catchment areas while they switch to fewer but more efficient hydropower dams.

"Dams block fish migration, stop the flow of sediment and nutrients, and undermine the value of rivers to people and nature," says Frans Schepers. "A future where the majority of Europe's waterways flow freely should be our goal. Practical, profitable business models can help us realize that goal."

Further reading

Passage performance and behaviour of wild and stocked cyprinid fish at a sloping weir with a Low Cost Baffle fishway

Rewildingeurope.com

Author information

Daniel Allen

Award winning journalist and photographer, he appeared in more than 60 publications, including the Guardian, The Independent and National Geographic Traveller.

Kitkajoki River in Oulanka National Park, Finland
© Staffan Widstrand / Rewilding Europe

NEW TOOLS FOR MENDING RIVERS

Rapid barrier passability and hydropower assessment tool

To effectively manage our rivers, we need to know which barriers cause the most problems and which provide an opportunity for development. However, evaluating whether fish can effectively pass over or through a barrier is difficult. Passability is dependent on several factors (e.g., barrier height, water depth, barrier type, presence of vertical drops) and varies depending on the swimming, jumping, and climbing capabilities of each fish species.

After evaluation and field testing of the three most well-developed and widely available protocols already in existence in Europe (SNIFFER, ICE, and ICF), the French ICE protocol has been selected as the protocol of choice for assessing barrier passability for fish. To facilitate the ready use of this protocol, researchers at the University of Southampton developed software to automate the process to enable users to rapidly-produce passability scores for each species at the click of a button.

The software also estimates the hydropower potential at each site through a simple assessment of discharge and head drop. As such, the software produces data that can be used to populate barrier mitigation prioritization tools and efficiently help with catchment level management decisions.

Author Information: Dr. Jim Kerr, University of Southampton, UK

Model of ecological effects of barriers

Fragmented rivers are frequently considered heavily modified water bodies as river barriers affect the natural state and flow of the river. The ecological effects of barriers model demonstrates how barriers may affect natural aquatic habitats, and consequently alter the species and communities that live there (see map of river barriers). This model shows the expected impact of a single barrier on local habitat conditions at a regional scale with all possible mitigation measures applied. It also allows for an estimate of how this impact is increased by multiple barriers along the river.

This tool will be useful for adaptive management of barriers towards fulfilling the requirements of the European WFD and accelerating the achievement of Good Ecological Potential of heavily modified water bodies.

Author Information: Professor Piotr Parasiewicz, The Stanisław Sakowicz Inland Fisheries Institute, Poland

Rapid habitat assessment with remote sensing

Like most animals, fish are impacted by their immediate environment and available habitat. But how exactly do river barriers affect fish habitat, and how is that further affected when you adjust for climate change? Under what circumstances can animals still thrive, and what modifications to barriers can be made that could help restore the up- and downstream environments?

The Rapid Habitat Assessment with Remote Sensing model allows river managers to make these assessments with only a small input of data (e.g., river type, geographic type, climate circumstances) to produce estimated numbers that guide restoration planning and adaptive planning. The model also calculates how river habitats would respond if a dam were taken away or how the dam could be modified to reduce impacts. Moreover, this model produces different scenario outputs to choose from by providing the percentage of river benefit. By understanding how water flow impacts the habitat suitability, this model shows the expected impact of river barriers and climate change.

Author Information: Professor Piotr Parasiewicz, The Stanisław Sakowicz Inland Fisheries Institute, Poland

Integrated agent-based dispersal model

Researchers at the University of Southampton, UK, have developed an Agent-Based Dispersal Model (ABM) to predict the movement of aquatic species as they migrate upstream and approach a riverine barrier. The current model has been parametrized to predict the upstream movement of European river lamprey (*Lampetra fluviatilis*) using data collected from a high-resolution 2D acoustic telemetry study that tracked their movement as they approached a weir in the UK. By understanding how fish movement is affected by the complex flow conditions created at riverine infrastructures, water managers can adapt barriers to create suitable conditions, so the distribution of fish is minimally affected.

When the model is parameterized against the fish present, it can predict how a fish might react if two turbines were turned on instead of three or under high discharge events, which are likely to occur more frequently due to climate change. Would the fish be able to navigate the flow conditions created and find a safe route of passage? Use the tool to find out!

Author Information: Dr. Jim Kerr, University of Southampton, UK

Environmental DNA (eDNA) molecular toolkit

While most studies gauge the level of passability of fish to understand the extent of river fragmentation and measure the success of restoration efforts, metrics of connectivity should also consider the distribution of the whole community and not only fish. AMBER researchers are pioneering the use of eDNA methods to rapidly and cheaply assess stream connectivity. eDNA is different from other DNA techniques in that, instead of purifying DNA from the tissue of an organism, it detects trace amounts of DNA that organisms shed into their environment. It is a forensic approach that is used in AMBER for detecting plants and animals from water samples and therefore infers where barrier discontinuities might exist. eDNA can help water managers estimate how barriers alter the dispersal of animals or the propagules of plants.

The AMBER eDNA toolkit is lightweight, inexpensive, and easy to carry. It can also be used on-site with minimal training. It consists of a series of protocols that use eDNA to analyze the presence of target organisms and the composition of full communities both upstream and downstream of barriers. For example, researchers at Swansea University have used eDNA to estimate the impact of the Poutes Dam in the fish community of the River Allier (France), a task that would have been difficult and costly with other techniques. It helps to map the geographical distribution of aquatic animals in relation to the distribution of barriers and show how barriers might impact species distribution and community structuring.

First, the water is collected into sterile, DNA-free bags or bottles (typically used for sampling swimming pools), and are then either taken back to the laboratory or filtered on-site using readily available sterile syringes. There are two different approaches that are commonly used with eDNA: quantitative PCR (qPCR) and metabarcoding. With metabarcoding, it is possible to detect numerous species at once in a sample, which can show how biodiversity changes in response to dams and other barriers, but the analysis can be complex. In contrast, the qPCR approach targets individual species (for example, migratory fish), and is faster.

Recent technological advances have made the eDNA approach much more affordable. eDNA is helping to resolve barrier impacts and monitor the restoration of connectivity in ways that were not possible to imagine only a decade ago. This toolkit serves as an essential management tool to assess the status and trends of freshwater biodiversity.

Author Information: Professor Sonia Consuegra and Dr. Richard O'Rorke, Swansea University, UK

How far can I swim before hitting a barrier?

Unlike terrestrial habitats, measuring fragmentation in river networks is not straightforward. Rivers are essentially uni-directional systems, where barriers can be viewed as nodes. However, most current methods of measuring fragmentation tend to consider barriers only in relation to fish movements. Researchers at Swansea University have developed a taxa-free metric for AMBER to estimate the extent of fragmentation caused by dams and other barriers, applicable to any species. This novel metric estimates the length of free-flowing, uninterrupted river reaches between two consecutive barriers in the catchment. It works under the premise that all barriers have an impact, regardless of type or height, making it thus applicable to multiple organisms, as well as to sediment transport.

This new measure of river fragmentation can be used by water managers to estimate the potential free-flowing habitat available. In combination with additional contextual information on habitat quality and distribution, this metric can also be used to make stream restoration more effective. For instance, one could determine which barriers cause the most significant loss of connectivity and prioritize others for mitigation, taking not just the needs of fish into account, but other taxa and fluvial processes as well.

Author Information: Dr. Josh Jones, Swansea University, UK

Field work in the UK © Dr Josh Jones

Field work at the River Kingie © Shobhit Pipil

The fish gym

Many fish passes do not work as they are intended, or work only for some species, or under some conditions. The reasons for this are largely unknown but may relate to variation in swimming performance and energetics, both among and within species. Scientists at Swansea University used an artificial cascade and a swimming respirometer (a sort of treadmill for fish) to measure fish passage success and energy expenditure of both strong swimmers like brown trout and weak swimmers like bullhead.

They found that fish that overcome artificial barriers tend to be those that have higher metabolic rates and higher aerobic capacity. The same is valid at the intraspecific level, indicating fish passes may be selecting against weak swimmers. Swim tunnel respirometers provide a useful tool to evaluate the causes of fish passage failures and optimize mitigation solutions around dams, not just for strong swimmers, but for weak swimmers as well.

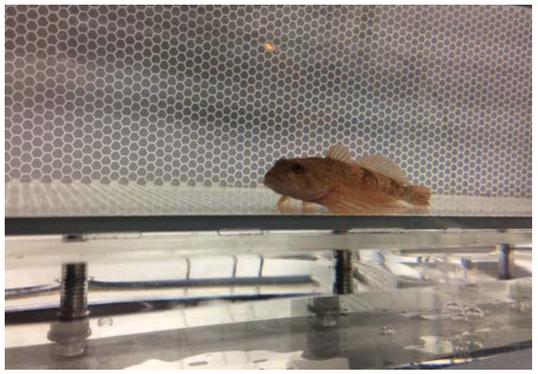
Author Information: Dr. Peter Jones, Swansea University, UK

Barrier planning prioritization model

The barrier planning prioritization tool helps environmental planners and river managers balance environmental and socio-economic trade-offs associated with river infrastructure by selecting the best combination of barrier placement, removal, and mitigation actions. Applicability of the tool was demonstrated using a case study of the Neckar River catchment in Germany. Key evaluation criteria considered in the Neckar River case-study were river connectivity, hydropower generation potential, and various upfront and ongoing costs, including project implementation costs, hydropower retrofitting or installation costs, and annual waterborne shipping costs. Analyses focused specifically on hydropower and river transport as these are the two main human uses of rivers in the Neckar catchment.

However, the model can be readily generalized to consider other environmental and socio-economic factors, which may be important in other planning areas, such as irrigation, drinking, and industrial water supply, fishing, recreation, and water purification. To perform model runs, researchers acquired, processed, and inputted detailed data about barrier positions, river geometry and flow, barrier passability, waterborne shipping, and installed hydropower into the tool. After this, the current situation plus 9 other possible future scenarios were developed and analyzed for the Neckar catchment. Future scenarios included maximizing river connectivity, maximizing hydropower, minimizing costs, and combinations thereof. The main findings are that the current connectivity in the Neckar is deficient. The most well-connected river sections are along the main Neckar, which has a fair number of fish passes and semi-passable locks. For future scenarios, there is a wide range of trade-offs among river connectivity, hydropower, and cost, with gains in one or more objectives invariably coming at the expense of others.

Author Information: Professor Jesse O'Hanley, University of Kent, UK



Brown trout, a strong swimmer (left) and a bullhead, a weak swimmer (right) in the swimming respirometer © Dr. Peter Jones

MORE TOOLS TO COME

FIThydro

Good news for hydropower specialists and practitioners! The Horizon2020 project, FIThydro, is developing three new tools. The project investigates new and innovative solutions, methods, tools and devices for hydropower production in Europe that will improve fish and fisheries impact mitigation strategies.

FIThydro is developing cost-efficient environmental solutions, strategies and mitigation measures to avoid fish damage and to support the development of healthy fish populations. Technologies, methods, tools and devices are evaluated, enhanced and applied at 17 test sites across Europe covering the following topics:

- Downstream Migration
- Upstream Migration
- Habitat and Flow
- Sediments

Results from the FIThydro research are incorporated in three decision support tools:

Decision Support System

FIThydro developes a decision support system (DSS) to help practitioners plan, evaluate and find solutions for hydropower plants. The DSS can be used to determine the risk to fish and help users select appropriate mitigation measures based on characteristics of their hydropower plant and of the river system. The DSS aims at supporting existing agency regulations and decision-support tools but, at the same time, harmonising the approaches, by providing a step-by-step procedure for the initial appraisal and screening of hydropower schemes as well as for defining criteria for best practice in mitigation.

Wiki

A FIThydro wiki is being developed with a catalogue of the mitigation measures as well as methods, tools and devices for planning, implementing and monitoring of such solutions. The mitigation measures presented in the FIThydro wiki cover various challenges related to hydropower and fish, namely environmental flows, habitat, sediment management, downstream fish migration and upstream fish migration. The FIThydro wiki can support decision-making by helping users implement the appropriate mitigation measures for environmental problems caused by hydropower production.

Cumulative Impact Assessment

The project is developing a Cumulative Impact Assessment tool to investigate the impacts of consecutive hydropower plants on fish populations. The tool can be used to assess the impact of multiple plants and dams in a single river basin as well as to determine the population responses to different mitigation measures applied. The model is based on fish life history strategies and provides a GIS-based tool that can model potential basin-scale impacts.

The tools and other FIThydro results are available via the FIThydro website www.fithydro.eu

The results can be found and downloaded at: www.fithydro.eu/dissemination-results/.

Man jumping into river © Pexels

To the lost man, to the pioneer penetrating a new country, to the naturalist who wishes to see the wild land at its wildest, the advice is always the same — follow a river. The river is the original forest highway. It is nature's own Wilderness Road.

Edwin Way Teale

This project has received funding from the European Union's Horizon 2020 research and Innovation programme under grant agreement No 727830.

Photo: © Tallinn University of Technology, Centre for Biorobotics
Map: Countries with FIThydro Test Cases
26 partners from research and industry in 10 European countries
Project duration: 01.11.2016 – 31.10.2020
Further information at www.fithydro.eu

STAKING AN INTEREST

COMMUNICATION AND INCLUSIVITY ARE KEYS TO SUCCESS

The number of Atlantic salmon in Scotland's River Garry has crashed since two dams were installed in the 1950s. Today multiple stakeholders have an interest in the river, its barriers, and its iconic population of fish.

A long way back

Located in the Highlands region of Scotland, the River Garry was developed for hydropower in the 1950s, with two major dams installed. The Quoich Dam, on the upper Garry, is the largest rockfill dam in Scotland and is currently impassable for migratory fish. The Garry Dam, in the lower catchment, has a Borland lift for fish passage. Scottish and Southern Energy (SSE) currently operates the hydroelectric facilities.

Adult salmon numbers ascending to the Upper Garry have declined by well over 90 percent since the dams were constructed. To mitigate this, the Upper Garry Salmon Restoration Project (UGSRP) - a partnership between SSE, Ness District Salmon Fishery Board (NDSFB), Ness & Beauly Fisheries Trust, Mowi, the Scottish Environment Protection Agency and the Rivers and Lochs Institute - has run a supportive breeding and supplemental stocking program since 2014.

The UGSRP was recently integrated into AMBER's comprehensive biological-socio-economic barrier assessment and ecosystem restoration framework to gain further understanding of biodiversity impacts, mitigation needs, and optimal management solutions.

Freshwater barriers and imperilled fish populations tend to generate strong views, and the dams on the Garry are no different. We caught up with four stakeholders to find out their opinions on hydropower, Atlantic salmon, and ongoing efforts to restore this iconic species.

Further reading
Quantification of economic costs and benefits of river infrastructures (evaluation of natural capital)

River Garry © Daniel Allen

Tom Cooper © Daniel Allen

Development Officer
Glengarry Community Woodlands

Tom Cooper

"Adjoining the River Garry, the Glengarry Community Woodland was established in 2016 when the community purchased a 32-hectare woodland in Invergarry. Since then, we have been working to bring the woodland into active management, using it for community activities and creating jobs. From a socio-economic perspective, hydropower is a pillar industry here, with many of Invergarry's 360-strong population involved with dams across the area. The Glengarry Trust, which distributes funds from local renewable energy schemes (to which hydro contributes), paid for 10% of this woodland."

The barrier balance sheet

As increasing human populations place ever more pressure on the Earth's natural resources, so the demands placed on river infrastructure also continue to evolve. While some existing barriers become redundant, others need to be constructed - for example, to generate hydropower or provide water for irrigation, especially in areas negatively impacted by climate change.

The environmental impacts of large dams on European rivers have already been fairly well researched and documented. By contrast, their economic impacts have been far less intensively studied.

Intervention measures, especially physical modifications in rivers and wider catchment areas, are often implemented without adequate investigation of the economic effect on end-users. A full appraisal of the public costs and benefits of dams would inform the decision-making process and highlight any unintended consequences of the intervention.

When it comes to dam removal (or potential removal), a rigorous cost-benefit analysis is rarely carried out either, with the impact of the removal restricted simply to the investor.

The value of restoring fragmented and channelized waterways into free-flowing rivers is similar to that of delivering stormwater from urban surfaces and drains into living streams. At the moment, we need a paradigm shift to appreciate the full socio-economic benefits of adaptive barrier management, which are not limited to the river itself but extend to the entire watershed.

Our research team attached to the AMBER project examined the economic benefits and costs associated with dam removal, collating data from many dam removal projects across the world.

Unsurprisingly, the engineering costs of river barrier removal and mitigation measures are highly variable. This reflects the broad typology of engineering solutions involved in barrier construction, as well as the massive variation in contexts. In addition to the engineering costs, the costs of alternative means of providing the foregone functions of the barrier also have to be evaluated and considered as costs of removal.

Artificial barriers often impact ecosystem services, some negatively, some positively. We concluded that a case-by-case, watershed-by-watershed analysis is the only way to address the net effect. Finally, we need to consider synergistic effects of pressures amplified by climate change, and upstream-downstream dependencies going far beyond physical connectivity. For example changes in precipitation and its timing drives water needs along rivers, and makes the revision of current uses, water permits and ecological flow calculations inevitable. In many cases it creates or strengthens the water-food-energy nexus, which can be dealt with only through extensive communication with stakeholders, and understanding and acceptance of trade-offs.

Kinga Krauze, European Regional Centre for Ecohydrology, Poland;

Sergio Vallesi, Durham University Business School's Centre for Environmental and Energy Economics, UK.

Seasoned River Garry Angler

Richard Allen

"I've been fishing the River Garry for 28 years now. Before the 1950s, this was one of the best rivers in Scotland for salmon fishing, but the dams destroyed that. The salmon population seems to be just about holding its own right now, but it's far from being healthy. That's concerning. Salmon are part of this area's cultural and natural heritage, so it would be a disaster if they disappeared completely.

For me, there's nothing in this world like fly-fishing. From a fishing perspective, it would be wonderful if the dams weren't there."

Richard Allen © Daniel Allen

Richard Allen © Daniel Allen

Alistair Stephen © Daniel Allen

Senior Environmental Adviser, SSE Renewables

Alastair Stephen

"The salmon population in the Garry has undeniably crashed, but the presence of the dams is just one factor. There are a lot of things happening to salmon in the marine environment, which we have no control over. This means far fewer fish are returning to the river to spawn these days.

Dam removal is simply a non-starter. Started five years ago and funded by SSE, the UGSRP is a future-oriented plan backed up by cutting edge genetics and the best available information. The only way forward now is for all project partners to work together and focus our efforts on population rehabilitation. The fish counter at the Garry Dam recorded 27 Atlantic salmon in 2018, compared to 900 in the 1960s. If we're recording a couple of hundred fish a decade from now, I'd consider that a success."

Social perception about dams and reservoirs

There are intangible values associated with dams and reservoirs that must be taken into account when designing river restoration strategies. People have opinions and often also feelings about these infrastructures, so the barriers cannot be changed overnight.

Researchers as part of the AMBER project expected that the social perception towards dams and reservoirs would depend on the characteristics of the region. For example, they expected people in arid areas to be more positive towards reservoirs than in areas where water shortage is not an issue. However, there are many variables to consider in such an analysis, both general (language, culture, historical background, political framework or socio-economic context) and population-specific (sex, age, level and type of studies, the geographical context in which the population lives and works).

Another variable is the direct or indirect relationship that people have with dams and reservoirs (proximity, recreational use, was the dam a reason for the relocation of homes in the past, etc.). Through surveys conducted in 2017 and 2018, the researchers collected data from people living close as well as far away from fragmented rivers. It appears there are differences in perception.

A case study at the Nalón River in Spain showed local knowledge of the effects of fragmentation also influences the perception of dams and reservoirs. The Nalón valley contains the most well-known mining zone of the region, in the middle part of the river. This part of the catchment was and still is degraded, although the upper part retains high natural values - UNESCO recognises it as a Biosphere Reserve. Migrating fish rarely reach this area because of existing dams, and a new dam was proposed for water and energy supply. AMBER researchers contacted the local stakeholders and collaborated with city councils inside the area. The research activities made people in the region more aware of the value of the river and the full breadth of effects a new dam may introduce. This information was also shared and used in newspapers and blogs. In 2018, the regional parliament decided to cancel the building plans.

The role of scientists is not to say what is right or wrong, but to share knowledge. In this case, it was useful to help citizens, especially those in the region itself, to know and understand the effect of new infrastructures in rivers.

Dr Eduardo Dopico Rodriguez,
University of Oviedo, Spain;
Professor Eva Garcia Vazquez,
University of Oviedo, Spain

River Garry © Daniel Allen

River Director, Ness District Salmon Fishery Board

Chris Conroy

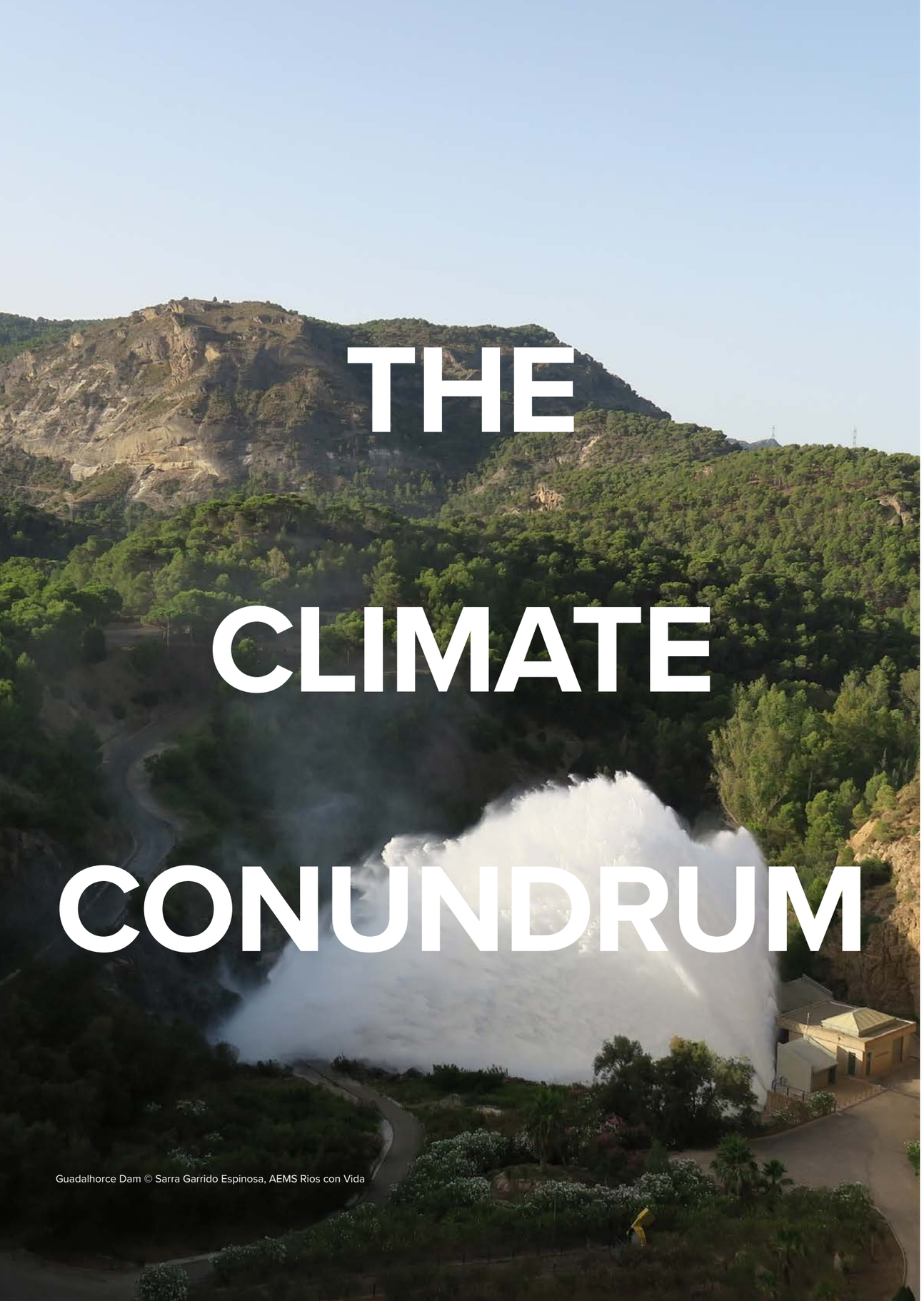
"The real success of the UGSRP to date has been the trust built up between partners. These partnerships and the real-time genetic profiling being used make this is a groundbreaking project.

The presence of dams is undoubtedly one of many complex and interconnected issues impacting salmon populations in the upper Garry system. But the barriers are there, and hydropower brings some essential socio-economic benefits which you can't ignore. Our job is to minimize their impact and enhance salmon populations as much as possible, with a focus on maximizing the number of healthy smolts (young salmon) leaving the river system. With the UGSRP, we're moving in the right direction. I firmly believe our efforts will bear fruit."

Author information
Daniel Allen,
award-winning journalist and photographer.

Further reading
Impediments to barrier planning and stakeholder conflict resolution.

Chris Conroy © Daniel Allen



THE CLIMATE CONUNDRUM

Guadalhorce Dam © Sarra Garrido Espinosa, AEMS Rios con Vida

Climate change will impact European rivers in very different ways. In the face of such impacts, adaptive barrier management can help to enhance ecosystems and safeguard the services they provide.

Balancing act

Human infrastructure currently captures more than half of all available freshwater runoff, with global water withdrawal increasing by around 65 percent between 1979 and 2010. While dams, and the reservoirs they create, can have a devastating impact on wild nature, habitat, and natural processes, they can also provide multiple benefits to humans, through water supply, flood control, irrigation, navigation, recreation, and the generation of hydropower.

Accurately assessing and acting on the perceived benefits and drawbacks of dams and other barriers in freshwater systems is a complex proposition. And today, this task is further complicated by the process of climate change, which is increasingly affecting global weather patterns and the availability and use of natural resources.

Climate is a critical variable in a diverse range of ecosystem processes. This is especially the case in freshwater ecosystems, where it is strongly linked to hydrological and thermal regimes. With higher temperatures generally intensifying the global hydrological cycle, those managing riverine barriers must factor the impacts of climate change into both their short and long-term planning.

"European freshwater ecosystems and the people who depend on them are already and will increasingly be affected in different ways by climate change," says Ruedi Bösiger, Head of Freshwater at WWF Switzerland. "With barriers so ubiquitous in these rivers, barrier management must integrate environmental flow modelling - the flow needed to sustain a healthy freshwater ecosystem. Only by guaranteeing both the quantity and quality of water discharge can we ensure the long-term health and resilience of systems."

Service provision

Dams have a considerable impact on landscapes for two reasons. By altering water flows, they lead to changes in land use, as well as habitats both up and downstream. Additionally, changes to both flows and land use determine the scale of other impacts, such as water pollution, erosion, and biodiversity decline. The construction or removal of barriers, therefore, affects entire river basins and is not merely confined to rivers and their immediate surroundings.

The diverse ecosystem services derived from the presence of barriers means a wide variety of stakeholders and societal sectors are affected by barrier management. The provision of these services will also be significantly impacted by global warming.

"Going forward, our changing climate will amplify the complexity of human-water service interaction," says Kinga Krauze of the European Regional Centre for Ecohydrology of the Polish Academy of Sciences at Lodz. "With dam construction, management, and removal lying at the core of Europe's land-water-energy nexus, climate change must be taken very seriously."

"... river basins impacted by dams require a greater level of proactive management than those that are free-flowing, to mitigate the impacts of climate change."

Geographical variation
Modelling the impact of climate change on hydrological flows means factoring in best and worst-case climate scenarios. Not only this, but those managing European barriers also need to factor in regional variations. Annual precipitation trends indicate that northern Europe has become up to 40% wetter over the last century, whereas southern Europe has become steadily drier. As a result, river discharge has increased in some regions and dropped in others. Moreover, there are more extreme events such as droughts and floods. Hence, higher average flows will not necessarily translate into more water in rivers.

Climate change may also have a marked impact on seasonal variation in European river flows, with higher temperatures pushing the snow limit upwards in northern Europe and mountainous areas. This, in addition to less precipitation falling as snow, will result in a higher winter runoff in northern European and mountain-fed rivers, such as the Rhine, Rhône, Po, and Danube. Less snow and diminishing glaciers will mean there is less water to compensate for low flow rates in summer.

"Europe's melting glaciers may provide slightly more energy production over the next 20 to 30 years, but this will end as these glaciers disappear," says Ruedi Bösiger. "At this point, residual environmental flows will become even more important for habitat connectivity and the mitigation of rising temperatures."

North-south divide
Changes in the average availability of water in the majority of European river basins are estimated to be relatively small over the next three decades. Over the longer term, however, most climate change scenarios predict an increase in annual average river flow and water availability in northern and eastern Europe. In contrast, average runoff in southern European rivers is projected to decrease. Some river basins in the Mediterranean region, which are already facing high levels of water stress, may see severe decreases in water availability.

This variation in flow will, in turn, affect river-related ecosystem services.

"The provision of such services is projected to decline across the board in the Mediterranean and Europe's mountainous areas, while a mixed bag of gains and losses is projected for other European regions," says Kinga Krauze. River regulation, more common in wetter parts of Europe, may alter the availability of water, and existing dams could potentially play a role in mitigating these effects.

"Going forward, our changing climate will amplify the complexity of human-water service interaction."

Localized impacts
A recent study carried out as part of the AMBER project examined how climate change may affect the demand for and delivery of ecosystem services related to three European rivers and associated barriers - the Guadalhorce River (Guadalhorce Dam) in southern Spain, the Vistula River (Włocławek Dam) and River Mienia in central Poland, and the Neckar River in southwestern Germany, which are affected by multiple barriers used for navigation and hydropower (with more hydropower proposed on existing barriers).

"All three rivers and their barriers play an important role in ecosystem service provision," says Krauze, who co-authored the report. "Our modeling shows that climate change will affect these services in different and localized ways, which is partly due to the varying impact on precipitation and temperature, and partly due to the mix of services being provided and how this will change over time.

"From this perspective, barrier management, ecosystem service-based adaptation to climate change and the ongoing delivery of key services require an extensive understanding of the sensitivity of local systems."

On the Guadalhorce River, for example, the Guadalhorce Dam has disrupted habitat connectivity, impacted local animal species populations, and created an irregular flow regime, characterized by flash floods that have caused extensive damage in recent years. On the other hand, the dam and its reservoir generate hydropower and provide water for agriculture.

"As a result of climate change, leading to increasing temperatures and decreasing precipitation, demand for water supply for local agriculture could significantly increase over the coming decades," says Krauze. "The way the Guadalhorce Dam is managed may need to take this into account." For example in the River Mienia, in the Polish lowlands, the impact of the dam appears to exceed the impact resulting from changes in flow regime.

Modeling and management
Nobody knows for sure what the Earth's climate will be like 100, 50, or even ten years from now. Yet it is already clear that river basins impacted by dams require a greater level of proactive management than those that are free-flowing to mitigate the impacts of climate change on both people and wild nature. As the recent AMBER study shows, it is also clear that such management needs to take place at an appropriate temporal and spatial scale.

Prioritization processes have already been developed to evaluate dams and other barriers for mitigation (and possible removal). Historically, most of these used score and rank techniques, where barriers within a given area were either scored on their ecological, physical, and financial impacts or ranked for mitigation under given budgetary constraints. More recently, optimization-based models have taken better account of the cumulative effect of multiple barriers across entire river systems.

Both score and rank systems and optimization approaches are intrinsically designed to incorporate additional variables, such as the altered hydrological flows resulting from climate change. Some scientists have already included future climatic conditions when modeling economic losses (reduced water supply and hydropower) and environmental gains (increased habitat for fish) for optimizing dam removal.

In Europe, striking the right balance between competing socio-economic interests and ecological impacts has already proved challenging for those managing riverine barriers. The need to include climate change as a critical consideration in barrier management will add another layer of complexity, particularly in situations where climate change is judged to be increasing both the environmental impact and economic value of stored surface water.

By taking into account the needs of various stakeholders and continually evaluating multiple variables over time, adaptive management can not only help to minimize conflict but also identify optimum solutions in terms of enhancing ecosystems and safeguarding the services they provide.

"Even if we manage to reduce greenhouse gas emissions in the years ahead, climate change, to varying degrees, is still locked in," says Kinga Krauze. "For many barriers on European waterways, this means that adaptive management will become an increasingly necessary and beneficial tool."

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Further reading
Overview of river ESS demand and delivery in selected case studies under different scenarios


Wroclawek Dam © SSFI Poland

A GREAT LEAP FORWARD

Atlantic salmon © Jack Perks

The AMBER project has enabled the creation of an EU "Salmon Atlas". This invaluable tool not only provides a better understanding of the health and distribution of Atlantic salmon in European waterways, but also highlights which barriers are impeding population recovery.

Population pressure

A legendary traveller and dramatic high-jumper, the Atlantic salmon, is arguably Europe's most iconic fish species. For countless millennia it has roamed the northern Atlantic, spawning in the myriad rivers and streams that empty into this vast watery expanse. Yet today, this incredible animal - labelled the "king of fish" by anglers and conservationists - faces a challenging future.

Habitat fragmentation, climate change, pollution, overfishing, and marine salmon farming have all negatively impacted European stocks of Atlantic salmon. The stocks have decreased from around eight million in the early 1970s to approximately three million today but have been declining for much of the past century. The species has become extinct in many European countries, and further populations have been lost from individual rivers.

Wild Atlantic salmon are under pressure for many reasons. When it comes to reaching their traditional spawning grounds, they need as much help as they can get. And it's equally important that nothing stops their offspring from returning to the sea.

Essential connectivity

As an anadromous fish (one that migrates up rivers from the sea to spawn), the Atlantic salmon is heavily reliant on habitat connectivity for its survival. Although adult salmon have been known to leap vertical obstacles more than 3 meters tall, human-made barriers are considered one of the most pressing threats to existing populations.

Further complicating the picture is the fact that Atlantic salmon are divided into local, reproductively discrete populations associated with individual river systems or tributaries within systems. Each of these populations is a highly valuable component of the salmon's portfolio of genetic diversity, and ultimately the raw material enabling the fish to respond and adapt to climate change.

Groundbreaking assessment

Measuring the impact of riverine barriers on European populations of Atlantic salmon is one of the deliverables of the AMBER project, which includes the creation of an EU "Salmon Atlas." As the first quantitative, river-by-river Atlantic salmon conservation assessment of freshwater habitat conducted in Europe, this will provide a far more in-depth and geographically explicit pan-European understanding of the health and distribution of the species.

Looking at salmon rod catch figures - a reasonable proxy for the productivity and strength of individual river populations dating back over several generations - allowed our team who produced the atlas to identify demographic trends across Europe. This gives us an indication of where fisheries exist, their sustainability, and any surplus that might be exploited.

Going forward, the atlas will also help to identify those barriers whose removal or mitigation would have the greatest benefit in terms of restoring Atlantic salmon populations and generating an economic and social return.

By combining salmon population data with a statistical assessment of the quality and quantity of river habitat and the inventory of barriers in European waterways, we can highlight which barriers are a priority for removal or mitigation.

Restoration potential

A resilient species, the Atlantic salmon, has already demonstrated the potential to recolonize European waterways following the complete removal or mitigation of barriers. Juvenile salmon were recently discovered on the River Ecclesbourne in England (for the first time since the Industrial Revolution), following the installation of fish passes. They have also returned to the Rivers Clyde and Esk in Scotland following barrier removal and easement.

Atlantic salmon are also likely to stage a return in the Sélune River in Normandy, France. With contractors currently removing two obsolete dams - the Vezins and La Roche Qui Boit - 90 kilometres of the waterway will soon be opened up, allowing salmon to migrate once again to their ancient spawning grounds. With barrier removal increasing juvenile salmon habitat threefold, it is hoped that the number of adult salmon returning to the river will increase by more than 1400.

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MY TIP TO YOU

Wisdom is the result of experience and should be shared. So what advice would those with experience of water and river management give to the younger generations?

“Reconnect the headwaters. That is where most of the diversity can be found and where interaction between land and water happens most. Make people aware this is needed to ensure the health of downstream waters.”
Josh Royte, Senior Conservation Scientist of The Nature Conservancy

“Be curious and imaginative. We have seen so many times how a narrow focus makes us miss solutions. Don't look at fish only; look at other fields as well. And last but not least, be persistent as changing paradigms takes a lot of time."
Luca Börger, Professor of Biosciences at Swansea University and former free-lance musician

“Celebrate victories, even if they are small.”
Phil McGinnity, Research Professor in the Environmental Research Institute (ERI) in University College Cork

"Get involved in politics! The politicians must be involved in the issue of rivers, fish, and nature and to be held accountable. Make sure the votes are for the right people.”
Guillermo Giannico, Associate Professor and Extension Fisheries Specialist at Oregon State University

"Ignoring barrier impacts is not an option – work toward solutions.”
Professor Eric Verspoor, Rivers and Lochs Institute, University of the Highlands and Islands, Scotland

“Get engaged in developing and promoting knowledge on river ecosystems, be it in the academia or in environmental agencies. Be aware and acknowledged on the relevant current legislation on river ecosystem protection if you want to enhance it.”
Martina Bussettini, heading the freshwater area at Institute for Environmental Protection and Research (ISPRA)

“Be a hero. We have a mission. We, people integrating biology and engineers, are right. What we do is good for ourselves and the world. We are the progress. It takes time. Don't be discouraged. We will get there."
Piotr Parasiewicz, Professor and Director of Rushing Rivers Institute

“Get a career in a governmental institution. There is so little knowledge in these institutions on fish. If you want to achieve something, work there, and your impact will be much greater than all of us together. Start the change in the system!"
Niels Jepsen, Senior Researcher Denmark Technical University AQUA National Institute of Aquatic Resources

“Listen to very old, professional fishermen. In Latin America and at the Loire, in different places all over the world, I’ve discovered they know so much about fish habitats and migration patterns. We need their knowledge for better river management.”
Karl M. Wantzen, UNESCO Chair, and Professor in Applied Aquatic Ecology at the University of Tours, France

"Spread the news about all the unnecessary barriers that are still in our rivers. We need to remind people that relict weirs, dams and sluices in our rivers make no sense when our rivers are under so much stress. We must get more communities interested in the opportunity to remove these barriers and restore connectivity."
Peter Gough, member of the Institute of Fisheries Management and Chartered Environmentalist in the UK

“Passion will lead you to the right place. Follow your heart.”
Carlos Rodriguez, Filmmaker, and Director of Durienses

UNLEASH THE RIVER TRAVELLER IN YOU

Flight shots over the Arda river canyon, Madzharovo, Eastern Rhodope mountains, Bulgaria © Staffan Widstrand / Rewilding Europe

People with a passion for rivers often enjoy discovering new places. We asked a few researchers to share some of their favorite case study spots. Here are a few travel destinations to add to your bucket list!

Guadalhorce © Sara Garrido Espinosa

Where: Guadalhorce River, Málaga, Spain

When: All year but preferably in spring or autumn

What to do: Visit El Caminito del Rey and Ardales Cave, bird watch at the Guadalhorce River mouth, participate in aquatic sports in the reservoirs, or enjoy the cuisine of the area. Málaga has a unique character, with white villages built on the top of very steep hills (it looks even steeper when driving through by car). Enjoy the Andalucian style of the locals and their taste for sharing conversation for hours around lunch or dinner.

El Caminito del Rey is part of a spectacular natural beauty spot. The boardwalk and a hanging footbridge that stands at 105 meters height, as well as steep walls, make many visitors feel inevitably dizzy. The path is hazardous because of the heights and its very narrow parts; however, it has been refurbished so it could be used for active tourism in natural surroundings.

The Ardales Cave was discovered in 1821 after the great earthquake in Alhama de Granada. The cave has not suffered any changes for the last 30,000 years. A visit to the cave will reveal an authentic labyrinth of columns, permanent lakes, and beautiful stalactite and stalagmite formations. There are also some paintings and engravings dated from over 64,000 years ago.

Where to stay: The area has plenty of cozy accommodation in typical houses in the area, called “Cortijos,” which will add an authentic taste of Spanish culture to the visit.

Something unique: Both El Caminito del Rey and Ardales Cave are two breathtaking miracles of nature thanks to the unique geology of the area and the hydrological regime.

Travel Tips: This area is very sunny, bring sun cream, a good hat, and water! Getting to Malaga is easy from all around Europe and connects with charming cities such as Córdoba, Granada, or Ronda. If you prefer the beach, rent a car and drive along the coast. Simply beautiful. Stay for lunch or dinner at beach-front restaurants where you can have "espeto” of sardines, which is sardine brochette cooked on the fire that is lighted on a boat on the beach, close to the restaurant. Very unique.

Where: River Karstoft, Western Jutland, Denmark

When: May to September

What to do: Take a stroll on the beach, go fishing off the west coast, check out the lighthouses around Ringkøbing fjord.

Where to stay: Stay at the Skarrildhus Hotel located right next to the running river.

Something unique: The River Karstoft is a tributary of the River Storaa, which has the only completely self-sustaining Atlantic salmon population in Denmark. Also, there are world-famous sand sculpture exhibitions in Søndervig – with sculptures as long as 200m and as high as 7m.

Travel tips: The west coast is famous for being windy (trees almost grow sideways), so bring a good jacket!

Where: Vistula River, Tczew, Poland

When: Late summer

What to do: Birdwatch, bike, hike, or kayak along the river; closer to the mouth of the river, go out with local fishers net fishing in the early hours of the morning; or fly fish for salmon or sea trout.

Where to stay: Camp along the river with a camper or tent! Plenty of nice sites to choose from.

Something unique: This is the least regulated large river in the European Union – unmodified, sand beaches, flowing water.

Travel tips: Visit Gdansk, which is the second-largest city in Poland, right on the coast. Visit Malbork's old medieval castle of crusaders. Collect amber on the beaches. Continue upstream by driving to Wyszogrod and kayak downstream towards the Wloclawek Dam.

Painter's mussel (*Unio pictorum*) in the middle of a small tributary to old Danube. Danube Delta, Romania © Magnus Lundgren/Wild Wonders of Europe

RIVERS AT HOME

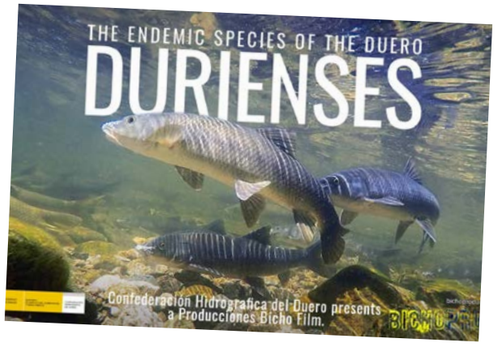
© Pexels

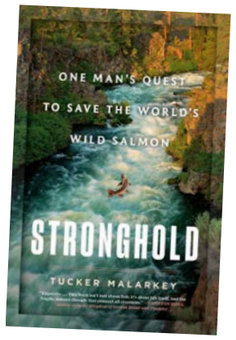
Tips from the editors on what to do when you are not outdoors but still eager to connect to rivers, fish, or like-minded people.

Durienses: The Endemic Species of the Duero

Directed by Carlos Rodriquez

This film is the culmination of three years of observation, and underwater exploration in the Duero River basin summarised in an hour. This story is what director Carlos Rodriguez wanted to share with scientists who are interested in rivers and fish, as well as people living along or near the river. The documentary shows how several fish species have developed skills and habits that adapt to the unique characteristics of certain Portuguese and Spanish rivers. The film allows the audience to perceive the world from an underwater perspective and learn about the lives of fishes. So, put on your headset, forget about deadlines and daily stress, and experience the beauty and complexity of a world that we usually do not see, but is present around us all the time.





Stronghold

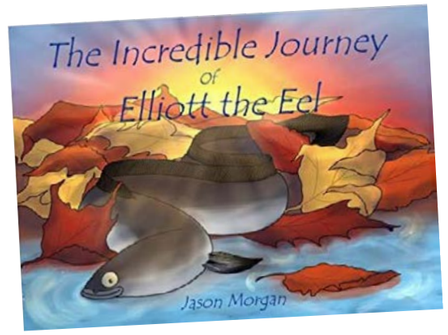
Written by Tucker Malarkey

Tucker Malarkey's book is effectively a biography about her cousin Guido Rahr. Guido is an avid fly fisherman since his youth and is now the first executive director of the Wild Salmon Center based in Portland USA. The story describes the underlying concept of Rahr's work to establish 'strongholds' for wild salmon. These strongholds would work to protect rivers and habitats around the Pacific rim from the ravages of damaging development and unsustainable fishing of salmon. He gives worrying insight into the pressures even the wildest and most remote rivers face, but Mularkey describes how there is also hope for these places too. This book is about hard work and passion for protecting beautiful habitats and stocks of Pacific salmon and, thereby, the fundamental ecosystem role of abundant salmon populations.

The Incredible Journey of Elliot the Eel

Written by Jason Morgan

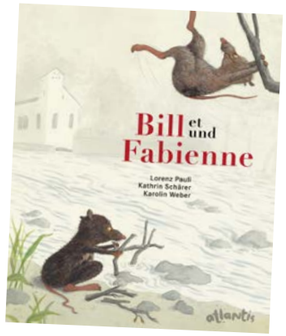
This children's book is a must-have for anybody who wants to both entertain and educate their children. The story is beautifully illustrated and engaging while accurately describing the incredible journey that eels undertake as juveniles and adults. The editing team of this magazine asked Dr Jim Kerr, who is not only an aquatic research scientist but also a young father, to test the book. Jim: "My 18-month-old son loves it, and I expect it will be a favourite for years to come. We need more children's books like this!" The good news for Jim and his son is that there are more books indeed. The editors would also like to highlight the children's book, Ann Guillidae: A European eel story, recently published by Eva Lucía Bayarri, teaching children about the friendship, braveness, and impressive life cycles of eels.



Fish Protection Technologies and Fish Ways for Downstream Migration

Written by Beate Adam and Ulrich Schwevers

For those people who cannot go on holiday without taking a book about their work or passion, this book gives an excellent overview of the current systems for fish protection and downstream migration. Originally written by German experts, it was recently translated into English. The authors wrote the book to support biologists, hydraulic engineers, planners, public authorities as well as environmental consultants.



Bill und Fabienne / Bill et Fabienne

Written by Lorenz Pauli, Kathrin Schärer & Karolin Weber

This bilingual book, in German and French, is about two rats exploring hydropower stations and learning about energy. It includes ideas for crafting and experiments. It's a lovely book for younger and older kids to get a few insights on the production of hydropower.

Dart

An audiobook by Alice Oswald

If you love rivers and the people around them, you should read this-whether you enjoy poetry or not. The writer Alice Oswald describes the soul of the River Dart in the UK. She describes the voice and music of the river and its people as it flows from moor to sea. Although you can listen to this at home, the editors advise listening to the audiobook while travelling to work or during a well-deserved walking holiday in riverine landscapes.

Frozen II: Dam Removal for kids

Directed by Chris Buck and Jennifer Lee

In Walt Disney's celebrated animated film, Frozen II, the two sisters, Elsa and Anna, plan to destroy a dam built in the mythical river Ahtohallan. To destroy the dam, Anna attracts the rage of the Earth giants who throw boulders at her, but miss and breach the dam. This sends a flood down the fjord, threatening the kingdom of Arendelle, but Elsa diverts the flood and saves the kingdom, freeing the resources of the Enchanted Forest and restoring the peace with the Northuldra tribe.

N-Sedge Grannom, *Brachycentrus subnubilus*, River Towy, Dryslwyn, SN5520 2025

© Jimmy Powell / Jones River Watershed Association

IT'S ALL ABOUT

THE PEOPLE

The potential for adaptive management in European rivers is large and important. This potential can only be realized if local communities are involved from the start.

When I went to Europe in September last year to talk about American experiences with river restoration, I found myself facing a blockade of angry citizens. I was one of the participants of a seminar on dam removal that was taking place on the Selune River in France. I was sitting in one of the two conference buses when I saw a group of over twenty local people waiting for us with picket signs, drums, and a skeleton. There has been a reservoir at the dam removal site for ninety years. When I saw this crowd, I realized how much anger and real fear they felt over the loss of this reservoir.

There were protests ninety years ago when the local community fought to keep their river free-flowing and not flooded by the Vezins Dam. The people knew that the dammed river would destroy salmon habitat and the fishes' capacity to migrate upstream. Now, ninety years later, the people are fighting again for what they got used to; a large reservoir where they can boat and fish for other non-migratory species.

They feel a real connection to the reservoir and the dam after just a few generations. It shows that for any change in the community, and for river systems which people are passionate about, there is a strong need to work with local communities from the start to ensure that you hear their concerns and are completely transparent about the process.

An unprecedented project

As a senior scientist at The Nature Conservancy in the USA, I have much experience in river restoration projects. I am one of the partners that helped bring science to the restoration of the Penobscot River, a project that balanced fisheries restoration and hydropower production in Maine's largest watershed. Dam removal, the building of bypasses and other restoration work, continues to open up more than 3,000 kilometres of rivers for species like Atlantic salmon, blueback herring, alewives, and American shad, while hydropower production in the system was not only maintained but increased slightly.

In 2019, 2.9 million river herring were counted travelling upstream in the Penobscot. Before the restoration, most years saw less than a thousand, and then only making it upriver into 4-5% of their former habitat. Dam removal in the Kennebec River, Maine, brought a non-existent river herring run up to 5-6 million per year, currently the largest run in the Northwest Atlantic. I'm hopeful the Penobscot will eventually have twice that many, that more rivers in Maine could have multiple millions of fish returns and, with the restoration of additional rivers, multiple millions of fish will return to Maine's waters.

Finally, we have arrived at a moment when we can look back and reap the benefits of these projects, not only for nature but also for people.

Economics: hydropower and bait for Maine's half-billion Euro lobster industry

As the availability of river herring increases significantly, especially in the Kennebec River drainage, one of the 24 rivers in Maine that now have commercial harvests, there are revenues to each of the towns that support that harvest. The Maine Department of Marine Resources uses count data to establish a reasonable and sustainable catch to determine the amount of permitted harvest (quota).

For some towns, like Benton, the sale of permits for river herring harvesting now brings in one tenth of their annual budget. Harvesters sell the fish locally, usually to be used for lobster bait. The lobster industry is Maine's top marine fishery–a 450 million Euro industry and an iconic Maine symbol. This industry is a product that defines Maine for many people.

In the springtime, when other sources are often scarce, the river herring harvest accounts for roughly half of the lobster bait demand. This past year, due to shortages of other bait, the river herring were even more important. Some of the river herring harvested were shipped to Haiti as part of food relief efforts there. This shipment restored a 120-year-old connection between Maine and the Caribbean, where salted fish was a welcome spring food source that was historically part of the trade for molasses and rum.

It's important to note that Maine's second most valuable marine fishery (8.2 M Euro) is from the harvest of elvers, juvenile American eel, which are hatched in the Sargasso Sea and make their way into estuaries and rivers from Brazil to the Canadian Maritimes. When humans dam rivers, eel can lose access to the needed habitat to mature. Worse still, when adult eels migrate downstream to return to the Sargasso to spawn, they tend to swim in the deepest and darkest part of the channel, which commonly leads to increased risk of injury or death as they end up passing through the rotating turbines. There are many cases where the autumn migration of adult, usually female, eels is almost destroyed due to dams.

Social: restoring treatise fishing rights

When Native American communities around North America had their lands and many of their rights taken away, one of the rights that was hard fought for repeatedly, and sometimes granted, was treatise fishing rights. Stream barriers broke that promise to communities by blocking the passage of fish upstream. But dam removal, 180 years later, is providing the Penobscot Indian Nation access to searun fish that are generally healthier to eat than fish that were trapped between dams in water often polluted by industrial and municipal waste. With searun fish running back upstream as they did for thousands of years, another part of the ecosystem that these river peoples depend on has been restored.

Future

The seminar at the Selune last year provides another start of a new future. After discussions and listening to each other, the participants of the seminar and the protesting people started to mingle. During dinner and drinks, there were talks about what the new situation could bring for the local community.

What we are beginning to see here adds to a growing list of attractive examples, in the US, Europe and around the world, that show a different and hopefully better future. These examples include improvements to recreation, more riverside parks, river walks, and bike trails. Most examples show how beautiful and healthy free-flowing rivers are, and how much safer transportation networks are when the stream crossings are improved to pass the more-frequent floods and more fish and wildlife too.

I know there is still much to learn. The potential for river restoration around the world, but especially in the US and Europe, is enormous. But this can only be successful if people can see the benefits, not only for nature but also for themselves and their communities. I think sharing best practices and listening to each other is a prerequisite for effective adaptive management and the restoration of healthy rivers. And that's a great thing to look forward to as we work together in the years to come.

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DREAMS FOR THE FUTURE

We hope you enjoyed reading about rivers, barriers, and all related subjects in this magazine! For us, it was a new experience creating a magazine, but a nice one. We hope to produce more in the future so that our community can continue to share results, thoughts, and future ambitions.

We would like to keep others updated on future events such as:

- Sharing the final findings of the AMBER project in Lisbon during the Fish Passage Conference on the 29th of June 2020;
- Starting a new project called Blue Rivers, focusing on identifying the natural value of the best EU rivers, helping EU citizens to take ownership of their national rivers and feel proud of their rivers again;
- Hosting a first Global Swimways Conference around the opening of the Fish Migration River in the Netherlands in 2023;
- Receiving a new update on the Barrier Atlas Inventory in 2024!

If you are interested in helping to make these dreams reality, check our contact details on *amber.international*

White pelican also known as eastern white pelican or rosy Pelican breeds in swamps and shallow lakes. Danube Delta, Romania.
© Magnus Lundgren / Wild Wonders of Europe

Let it Flow is a publication of the Amber Horizon 2020 project (Adaptive Management of Barriers in European Rivers), coordinated by one of the project partners, the World Fish Migration Foundation.

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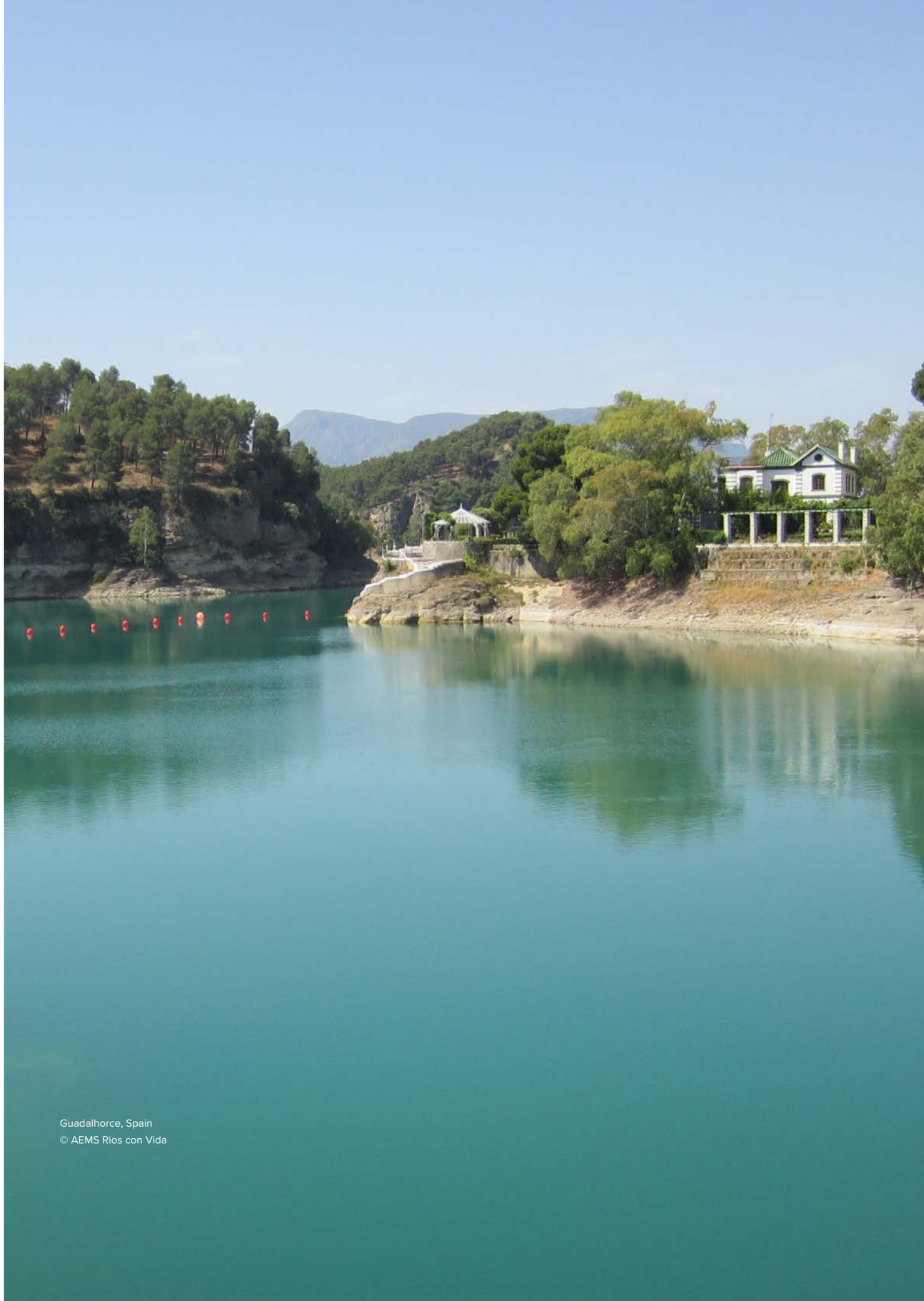

Guadalhorce, Spain
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THE AMBER MANTRA

1. Rivers rank among the most threatened ecosystems in the world, but they are also the most useful to society
2. Healthy rivers are flowing rivers
3. Rivers are more than fish
4. Fish are more than salmon
5. Barriers are not just hydropower dams
6. Large dams get most of the attention... small barriers do most of the damage
7. Prevention is better than cure
8. Not everyone is averse to dams

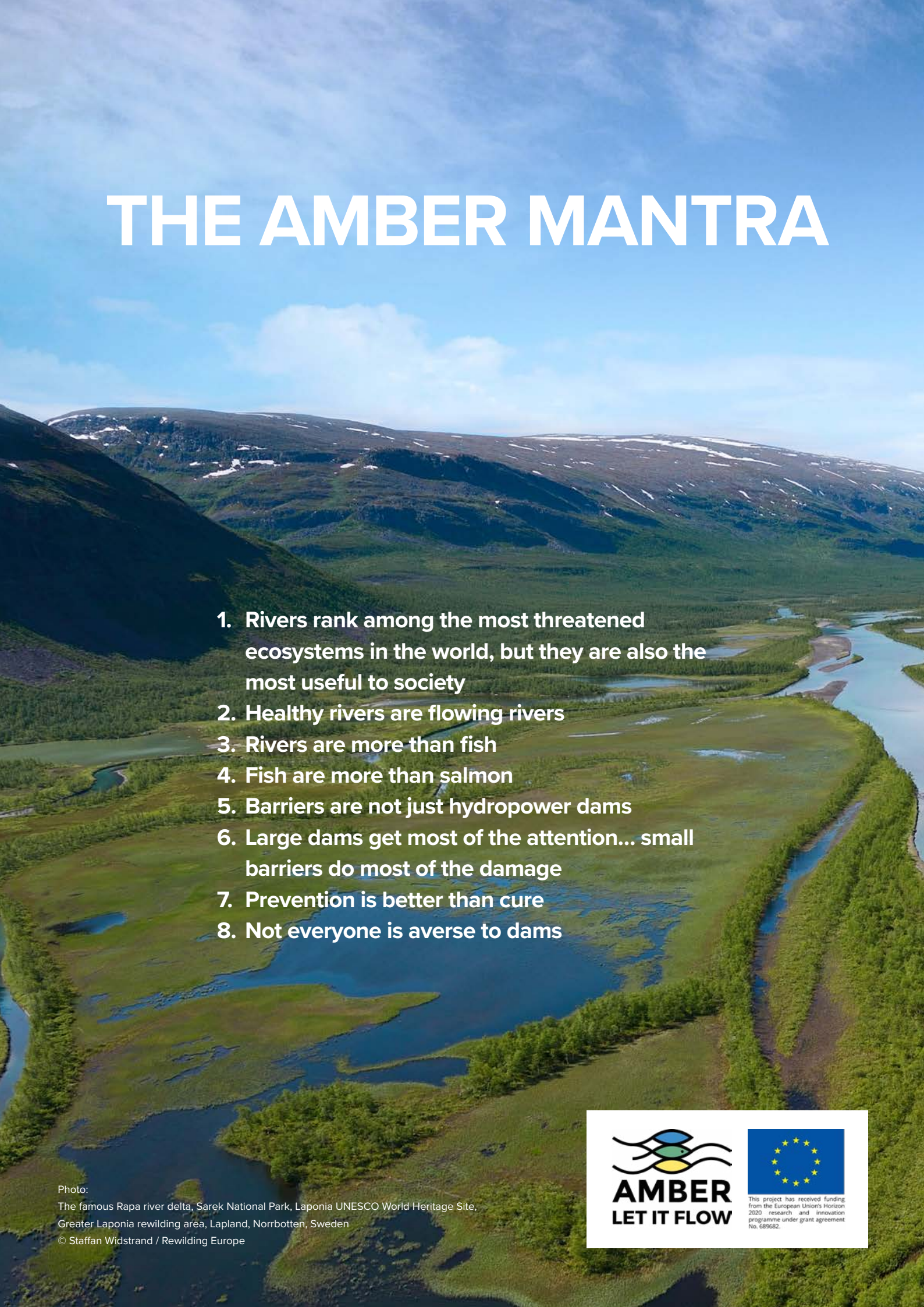

Photo:
The famous Rapa river delta, Sarek National Park, Laponia UNESCO World Heritage Site, Greater Laponia rewilding area, Lapland, Norrbotten, Sweden
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AMBER
LET IT FLOW

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