DAM REMOVAL

A VIABLE SOLUTION FOR THE FUTURE OF OUR EUROPEAN RIVERS

DAM REMOVAL EUROPE

DAM REMOVAL EUROPE

Acknowledgements
The authors are grateful for valuable contributions made by Bart Geenen (WWF the Netherlands), Arjan Berkhuysen (World Fish Migration Foundation), Matthijs de Vos (water authority Rijn en IJssel); Niels Brevé (Dutch Angling Association); Kim Aarestrup (Technical University of Denmark, Institute of Fisheries Research); and Corinne Ronot (ERN European Rivers Network).

Authors
Peter Gough (World Fish Migration Foundation)
Pao Fernández Garrido (World Fish Migration Foundation)
Jeroen van Herk (Dam Removal Europe)

Design
Studio Hands

Citation
Gough, P., Fernández Garrido, P., Van Herk, J., 2018.
Dam Removal. A viable solution for the future of our European rivers. Dam Removal Europe.

ERN European Rivers Network · WWF · The Rivers Trust · Rewilding Europe · World Fish Migration Foundation

CONTENTS

EXECUTIVE SUMMARY

Removal of Yecla de Yeltes Dam, Spain.
©Confederación Hidrográfica del Duero

There are many dams, weirs and sluices in our European rivers, and they have a strong negative impact on river ecology. On the basis of recent analysis and field validation, it is estimated that there is almost **one barrier for each river kilometre in Europe**. A survey of nearly 1,000km of rivers across Europe, in which different databases were combined and compared with fieldwork, was carried out for the first time, and it was concluded that the density of barriers was much higher than previously indicated in the usual national databases.

To date, river fragmentation has been assessed on the basis of dams higher than 10 m, but these dams represent less than 3% of the total number of existing barriers (Amber, 2018). **The very large number of small dams has a profound negative impact on the physical and environmental quality of European rivers.** This has not yet been widely recognised by water, river and nature professionals as the focus has been mainly on large dams.

Man-made dams, weirs and other impounding structures typically have the following negative effects on the environment of our rivers: -

- **Habitat loss:** natural dynamics and river habitats are lost upstream of dams as they are 'drowned', or suffer depleted flows downstream as water flow conditions are altered.
  As a result, aquatic flora and fauna are dramatically altered;
- **Fragmentation:** rivers are transformed into a series of ponded sections; dams block migration routes for fish in both up and downstream directions and habitats are isolated through fragmentation. This transforms natural fish faunas and leads to local extinction of fish species;
- **Sediment:** dams block transport of sediments in rivers, leading to accumulation and poor water quality in the reservoir, deprivation of sand and gravels downstream of dams, higher risk of erosion downstream of dams and in river deltas, and to a decrease in habitat quality upstream and downstream of the dam;
- **Water quality:** storage of organic material and nutrients in reservoirs often leads to a decrease in water quality, changes in temperature and the capacity to dissolve oxygen, and sometimes to seasonal stratification.

Dams were built to supply water for consumption, to provide water power for mills and, later, for the generation of electricity, to facilitate trade through better provision for navigation, or to protect citizens from flooding. Many dams have been of great benefit to mankind. However, it is estimated by European experts that in France, Spain, Poland and the UK alone, there are up to 30,000 mainly small dams which are now obsolete. There is no comprehensive study yet on the total number of obsolete dams in Europe, but the real figure is most probably many times higher. And yet they remain, constraining fish populations and other features of our aquatic environment, suppressing the natural functioning of our rivers and depriving people of enjoyment of the benefits healthy free-flowing rivers provide.

The time is now right to re-appraise the existence and role of dams and to remove those that no longer have a beneficial function for society yet continue to suppress the healthy functioning of our rivers. Moreover, rivers with good ecological status are considered of vital importance by many people. To achieve good ecological status, rivers need to be restored. Recent reports from Europe and the USA conclude that the **removal of dams is a very effective ecological restoration measure:**

- "No other action can bring ecological integrity back to rivers as effectively as dam removals" (Yale Environment 360, 2015);
- "Rivers recover faster than expected after dam removal" (Foley et al., 2017).

The case studies in this report substantiate these findings. **For river systems both large and small and across different geographical European regions,** the removal of dams has great potential benefits, including:

- **Ecological restoration of the river system:** restoration of natural flow regimes, hydrodynamics, dynamic river habitats and fish migration routes (both up and downstream);
- **Contribution to the objectives of the Water Framework Directive:** currently only 40% of river water bodies across Europe are achieving the target set for 2027 - at the latest - of 'good' ecological status;
- **Economies and communities:** contribution to regional economic development and strengthening of communities through appreciation of higher environmental quality and engagement in activities that promote associated health and wellbeing.

Furthermore, it is becoming increasingly clear that **dam removal is often a highly cost-effective measure.** A recent study in the USA concluded that the removal of large dams would be 10 – 30 times cheaper than the ongoing repair and maintenance of these dams (Grabowski, 2018). The value of this approach is now becoming increasingly recognised:

- "If you are looking at the most economical way to gain watershed restoration, dam removal on its own jumps ahead of many things on the list" (Ohio Environmental Protection Agency, 2017).

For the future of our European rivers, Dam Removal Europe proposes to implement the following four key strategies to catalyse the removal of obsolete dams across Europe:

1. Mapping of all small and large dams in Europe and creation of a priority list for dam removals;
2. Dam removal is integrated into River Basin Management Plans;
3. Involvement of local communities in dam removals;
4. Alternatives to building new dams should be seriously considered and prioritised.

Salmon back in the Varde River, Denmark
© Jan Kamman

International Dam Removal community, Spain
© Herman Wanningen – WFMF

Kirkton Weir, river Almond West Lothian, UK
© Forth Rivers Trust

SIX THINGS YOU SHOULD KNOW ABOUT DAMS IN EUROPE

1

There is almost one dam per kilometre of river!

2

Dams have long-term negative impacts on river landscapes, nature and fish.

3

Dams have been useful for society, but many are now obsolete.

4

Removing obsolete dams can be safer and cheaper than maintaining them.

5

Experience shows that after dam removals, there have been spectacular recoveries of river habitats and returns of fish.

6

Removing obsolete dams can be of great benefit for the identity of local communities and economies.

1 SETTING THE SCENE

Tibi Dam, Alicante Province, Spain
© Fran Mercader Román - www.masalladelaciudad.com

1.1 DAMS IN EUROPEAN RIVERS

Rivers are perhaps the most pressurised and damaged ecosystems in Europe. Rivers have always provided fundamental and vital services for mankind, and since the Middle Ages these have been protected and supported through physical modifications and through the construction of dams. Massive growth in the number of water mills was driven by the energy required for refining agricultural products, and a multitude of other industrial uses followed, each of them creating their own demands for a water supply and consequently for dam construction.

In most locations, this placed fish stocks at risk through disruption of their migratory routes and breeding success. By ignoring potential damage and taking for granted the resilience of fish stocks, the era of dam construction set the scene for wide-scale declines in fish and other river wildlife (Lenders et al., 2016).

People usually envisage dams as large vertical concrete walls impounding many hectares of water upstream. This is true in many cases, however low dams, or weirs, are far more prevalent. These have similar individual impact and, in combination, may completely transform the functioning of river catchments.

Many impounding structures in our rivers no longer have a functional role, but they remain in place and are even regarded by some as natural heritage. Many of these structures have been present for a long time and now form part of a familiar landscape. Many people do not even consider them an issue, and yet their impact on the environment prevails.

1.2 DAMS DAMAGE OUR RIVERS

Dams disrupt the natural functioning of our rivers by transforming the hydrology and sediment transport of the river system and disrupting the migration of fish up and downstream. Given the profound impact on river environments, it might be expected that we know precisely how many dams there are, and where they are located. And yet this is not the case - there are no reliable data on dam numbers in Europe. It has previously been estimated that there are about 1 million dams, weirs and sluices in European rivers and waterways (Garcia de Leaniz, 2008) but there may be many more. Based on surveys of 1,000 km of European rivers, Belletti et al. (2018) now estimate that there may be up to one barrier per kilometre of river.

1.3 DAM REMOVAL – A CLEAR SOLUTION

There has been growing recognition of the value of natural rivers, and as a consequence, river restoration measures are now routinely carried out to restore environmental quality in many countries. The removal of dams is a very attractive restoration measure as it fundamentally restores natural water and sediment flows in rivers, leading to re-creation of high-quality natural river habitats and wildlife. Dam removal is therefore now clearly in the spotlight as a key initiative for river restoration.

This report has the following structure: -

- Description of the current situation, problems and developments;
- Presentation of successful dam removal case studies from different parts of Europe and conclusions that may be drawn from them;
- Recommendations for the future.


Elche Dam built in 1632, Alicante Province, Spain © www.masalladelaciudad.com


Kirkton Weir in River Almond, West Lothian, Scotland, UK © Forth Rivers Trust


Small weir, Valladolid Province, Spain © Pao Fernández Garrido


Tibi Dam, Alicante Province, Spain © www.masalladelaciudad.com


Alcalá del Río dam, Spain © RÍOS CON VIDA


Ancient weir in River Almond, West Lothian, Scotland, UK © Forth Rivers Trust

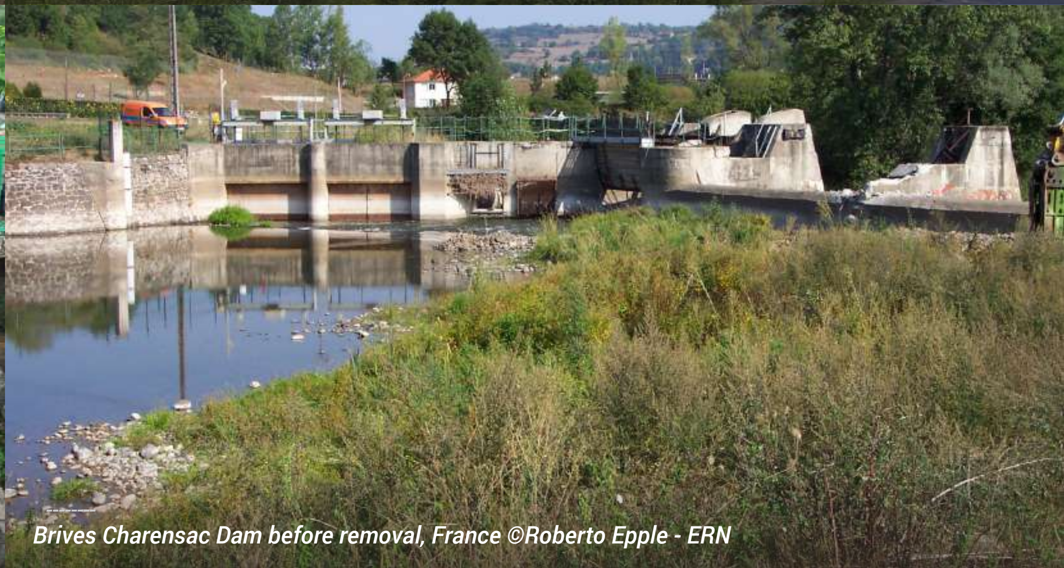

Seafield Weir in River Almond, West Lothian, Scotland, UK © Forth Rivers Trust


La Retuerta Dam before removal, Spain ©Confederación Hidrográfica del Duero


Knowes Weir, River Tye, East Lothian, Scotland, UK © Forth Rivers Trust


Dinham Weir at Ludlow Castle, UK © Charles Crundwell - Environment Agency


Dam, Caceres Province, Spain © RÍOS CON VIDA


Brives Charensac Dam before removal, France ©Roberto Epple - ERN

Fish eating birds in wetland
© WWF

BIODIVERSITY DECREASE IN RIVERS & WETLANDS

Free-flowing rivers are the arteries of Europe's richest ecosystems. A large part of our inheritance of biodiversity in Europe is present in its rivers, wetlands, estuaries and deltas. Free-flowing rivers in particular host an enormous variety of wildlife, and the estuaries of these rivers are of crucial importance for the migration, spawning and feeding of many species. Iconic and important European species such as salmon, sturgeon and other fish, geese, cranes and other wading birds, and otters depend on these rivers and deltas.

Biodiversity is declining at an alarming rate. Populations sizes of freshwater species have declined by 81% in the period between 1970-2012 (Living Planet Report, WWF, 2016). When comparing to de decline in marine species (-36%) or decline in terrestrial species (- 38%), it is clear that the freshwater ecosystem is in danger! (Figure 1). For migratory fish (diadromous and potamodromous species), the reduction is equally alarming: a 55% loss in population abundance of monitored fish species. The main threats to freshwater biodiversity are habitat loss and degradation due to dams, pollution, invasive aquatic species and unsustainable water extractions (WWF, 2016).

On a European scale, biodiversity loss in freshwater systems is no better, and in fact is probably worse. European rivers are among the most modified in the world, and the loss of wildlife is at least as bad as on other continents. This is reflected in the study The Geography of Future Water Challenges, which looks ahead to 2050. It demonstrates that only a small minority of European freshwater ecosystems have high biodiversity levels (PBL Netherlands Environmental Assessment Agency, 2018).

However, there now appear to be tentative signs that the decline in biodiversity in European fres-hwater ecosystems may be coming to an end. Over the last couple of decades, the trend has shown some signs of reversal, though many populations are still in poor condition. This suggestion of good news across Europe is interpreted as the result of investment in the freshwater environment and habitats over the last two decades. However, to substantially restore populations of endangered species, much more is needed.

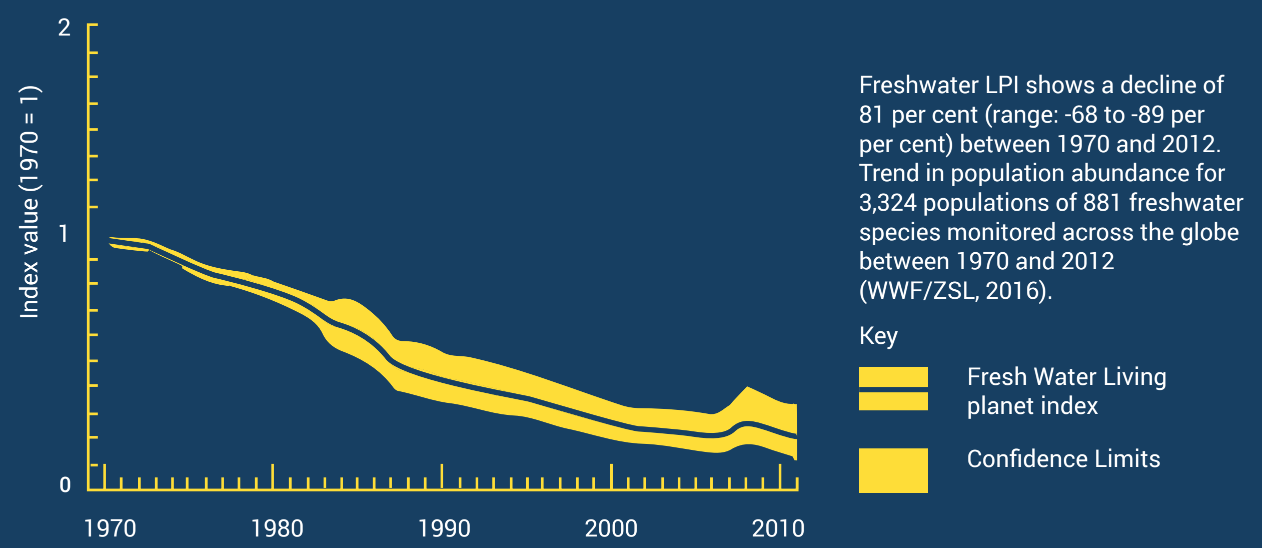
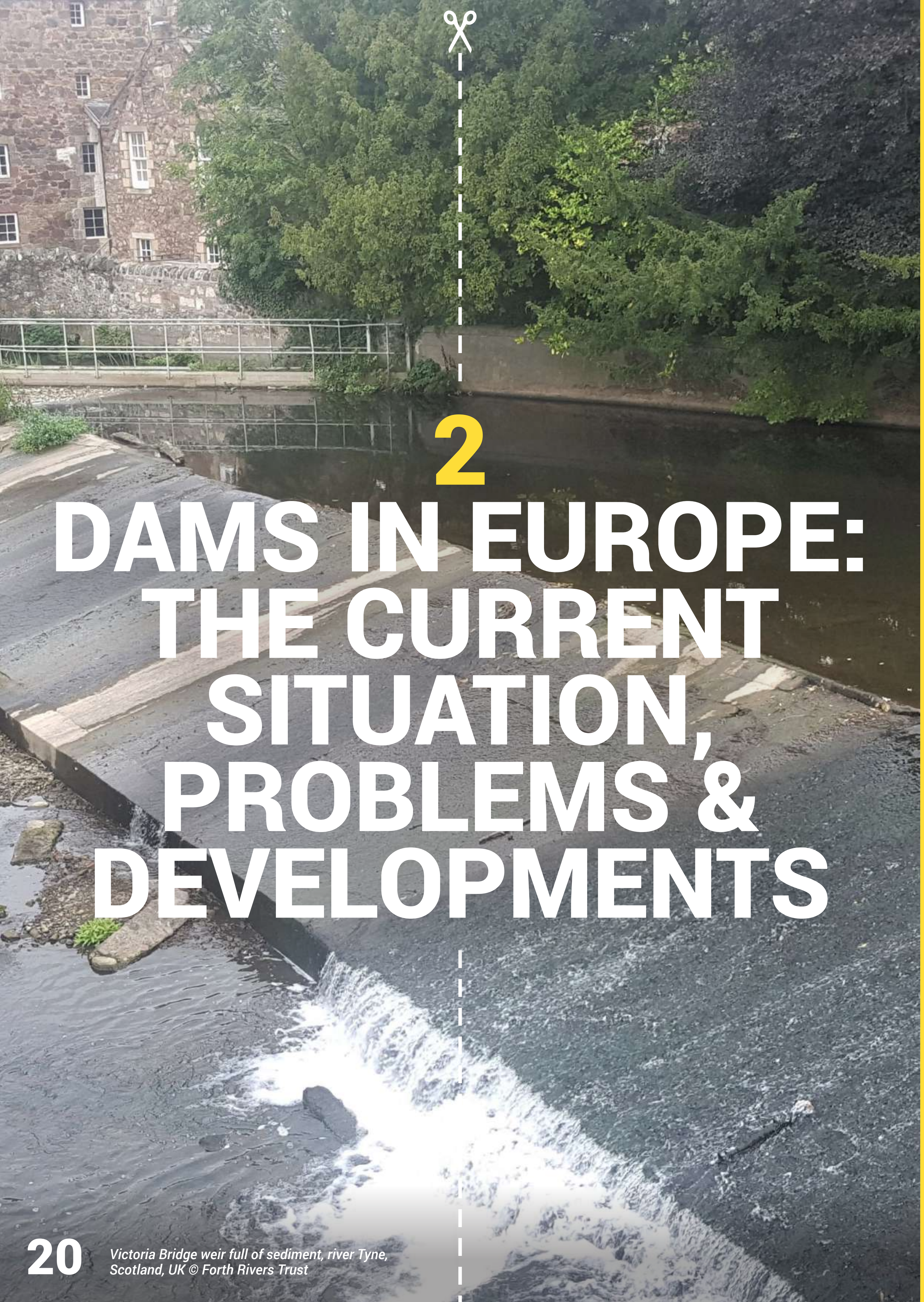


Figure 1. Trend in population abundance in freshwater ecosystems across the world (WWF, 2016).



2 DAMS IN EUROPE: THE CURRENT SITUATION, PROBLEMS & DEVELOPMENTS

Victoria Bridge weir full of sediment, river Tyne, Scotland, UK © Forth Rivers Trust

2.1 WHAT IS A DAM?

There are a great number of different types of dam, ranging from high-head structures of a hundred metres or more to low weirs as little as 1 m high. However, they all disrupt the continuity of the river and are barriers to migrating fish. We define dams as: -

Any structure that impounds a river and thereby changes the natural hydromorphology and, often through the abstractions they support, the hydrology of a river. Through its physical impact, a dam has a negative impact on natural river habitat, sediment flows, water temperature and physical connectivity for the river's fauna.

The structures in question include dams, weirs, water flow-regulating structures and any other physical structures that result in a head drop and thereby disrupt the river. In this report, we simply call them dams. The function of these structures can be water storage, water supply, irrigation, energy production, enabling river navigation, flow regulation and flood protection. Chemical or thermal barriers are not included in this definition.

2.2 FUNCTION AND ROLE OF DAMS IN EUROPE

Man has been constructing flow control structures in rivers for a range of purposes for over 2,000 years. In the UK alone, in 1086, the Domesday Book recorded approximately 6,000 water-powered mills used to grind corn or for the fulling process associated with manufacturing cloth. The use of hydropower contributed substantially to the wellbeing of communities, as it was key to the mechanisation of many processes. As communities grew, so the demand for water supply increased, and trading routes became more established. Both placed further demand on water resources and this in turn led to the construction of greatly increasing numbers of water control structures. The Industrial Revolution saw massive proliferation of these, and the impacts of dams and weirs built at this time are still present today in the form of hundreds of thousands of structures found across Europe.

2.3 HOW MANY DAMS ARE THERE IN EUROPE?

There is no single inventory showing the total number of existing dams and weirs. The total number of dams has been estimated at 0.6 – 1.8 million (Garcia de Leaniz, 2008). The EU Horizon 2020 project, AMBER (Adaptive Management of Barriers in European Rivers (www.amber.international), was set up in part to bridge this knowledge gap and to generate a first realistic estimate of the true extent of river fragmentation in Europe.

Understanding of river fragmentation has largely been based on dams exceeding 10 m (Vörösmarty et al., 2010). However, on the basis of preliminary analyses of existing databases in Europe, it is likely that these dams represent less than 3% of the total number of barriers in existence. The greatest impact on river hydrology, sediments and ecological connectivity therefore inevitably comes from the abundance of smaller barriers whose location, density, and typology are largely unknown for most European countries.

On the basis of a survey of nearly 1,000 km of rivers across Europe, in which different databases were combined and compared with field validation, it must be concluded that the density of barriers is much higher than previously indicated in the usual national databases. Estimates from the field validation suggest that there might be, on average, up to one dam per river kilometre in Europe (Belletti, et al, 2018). Furthermore it is estimated by European experts that in France, Spain, Poland and the UK alone, there are up to 30,000 mainly small dams which are now obsolete.

There is no comprehensive study yet on the total number of obsolete dams in Europe, but the real figure is most probably many times higher (Pao Fernández Garrido, World Fish Migration Foundation, personal correspondence).

2.4 HOW MANY DAMS HAVE BEEN REMOVED?

Just as there is currently no database on the number of dams present in Europe, there is also no record of the number of dams that have been removed. For some countries however databases are being developed.

There are some figures for several countries where the removal of dams for river restoration has been underway for some time. Experts working in this area estimate that between 4,000 – 5,000 dams in total have been removed

Estimates from field validation suggest that there might be, on average, up to 1 dam per river kilometre

Figure 2. The number of man-made barriers in rivers in France. Source: http://www.eaufrance.fr/IMG/pdf/obstacles_201405_A4_EF.pdf.

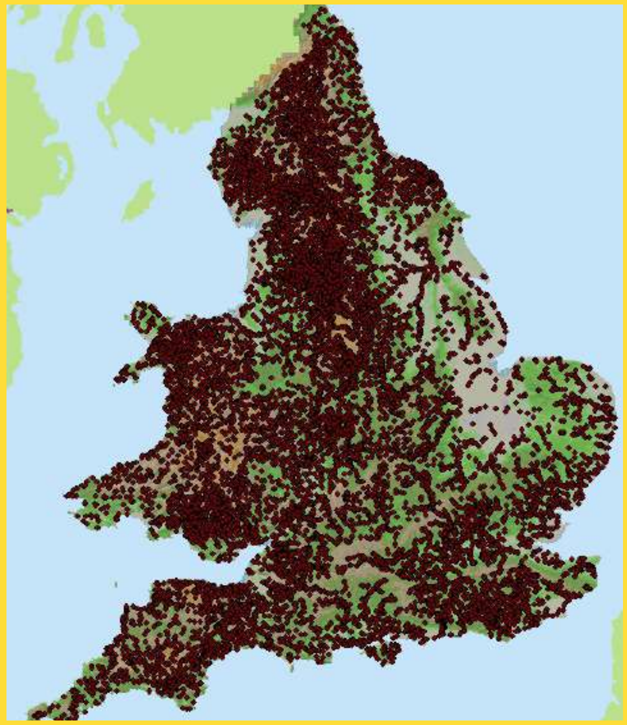


Figure 3. The number of man-made barriers in rivers in England and Wales. Source: Environment Agency.

in Europe (Fernández Garrido, WFMF, personal correspondence). Better records from France and Sweden indicate that 2,300 and 1,600 dams respectively have been removed (Dam Removal Europe (DRE), personal correspondence; https://damremoval.eu/wp-content/uploads/2017/10/Dam-removal-europe_Bart-Geenen_WWF_-NL.pdf)

2.5 THE IMPACT OF DAMS

Man-made dams, weirs and other river-impounding structures have a profound influence on river ecosystems.
The key impacts are: -

- Habitat loss;
- River fragmentation;
- Sediment flow;
- Water quality;
- Local identity and culture.

2.5.1 HABITAT LOSS

Dynamic river systems are fragmented by each dam and, where there is a series of dams, the river length is transformed into a series of ponded sections with completely altered hydrodynamics. This has a clear negative impact on all river wildlife as natural habitats are “drowned” and disrupted, and connectivity is lost. In some cases, the amount of damming exceeds one structure per kilometre, and this has a profound impact on the natural state of rivers (Belletti, et al., 2018).

Transformed habitats and hydrology within reservoirs generally lead to a complete change in the flora and invertebrate fauna, with species characteristic of greater depth and reformed hydrology replacing typical stream fauna. A similar effect is seen downstream of impounding dams,

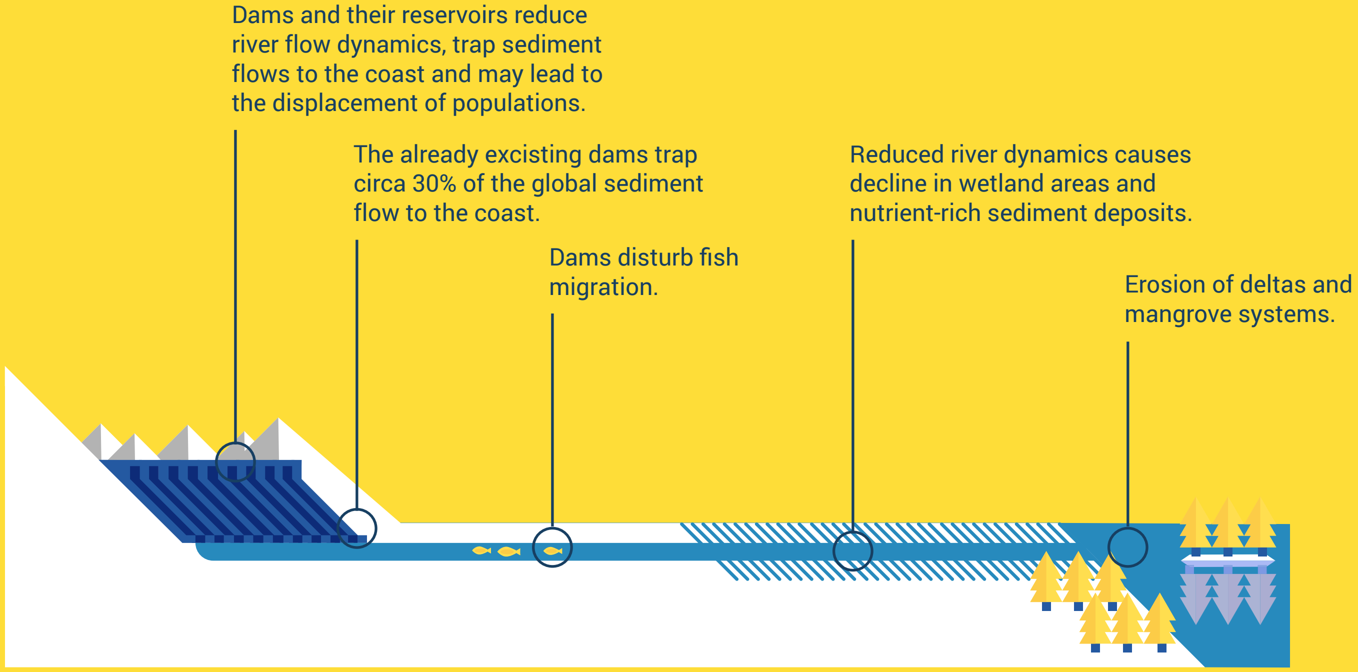


Figure 4. Infographic illustrating the problems associated with dams.

where the invertebrate fauna includes species taking advantage of the modified chemistry and biology in the reservoir upstream and those that adapt to different water quality and localised hydrological conditions downstream of the dam.

Damage is also clearly seen for migrant rheophilic fish species, many of which, in addition to safe passage, depend on gradient and fast flowing waters for habitat quality and therefore for reproductive success and early development. The loss of river habitat is particularly important in lowland streams, where gradient is often limited (Figure 5). In some cases, the vertical and horizontal loss of river habitat can be up to 20 – 40% of the total habitat previously available (Birnie-Gauvin et al., 2017).

To improve and restore the natural functioning of rivers, it is necessary for river managers not only to address the migration of fish up and downstream but also to ensure restoration of river habitat. Restoring migration is only conducive to river restoration if functional breeding habitats are also available to enable fish communities to thrive (Fjeldstad et al., 2012).

2.5.2 FRAGMENTATION

A second issue is the fragmentation of the river by dams. Migrating fish clearly need free passage in both directions. For anadromous fish such as salmon and sea trout, adults ascend rivers to breed but their offspring also need to descend rivers to the sea.

The construction of dams and weirs has been estimated to account for 55 – 60% of the known causes that lead to freshwater fish decline in Europe (Birnie-Gauvin, 2017). In all cases, the changes in habitats and fragmentation due to dams brings about changes in aquatic fauna, and often flora, resulting in an ecology differing from that which would occur naturally.

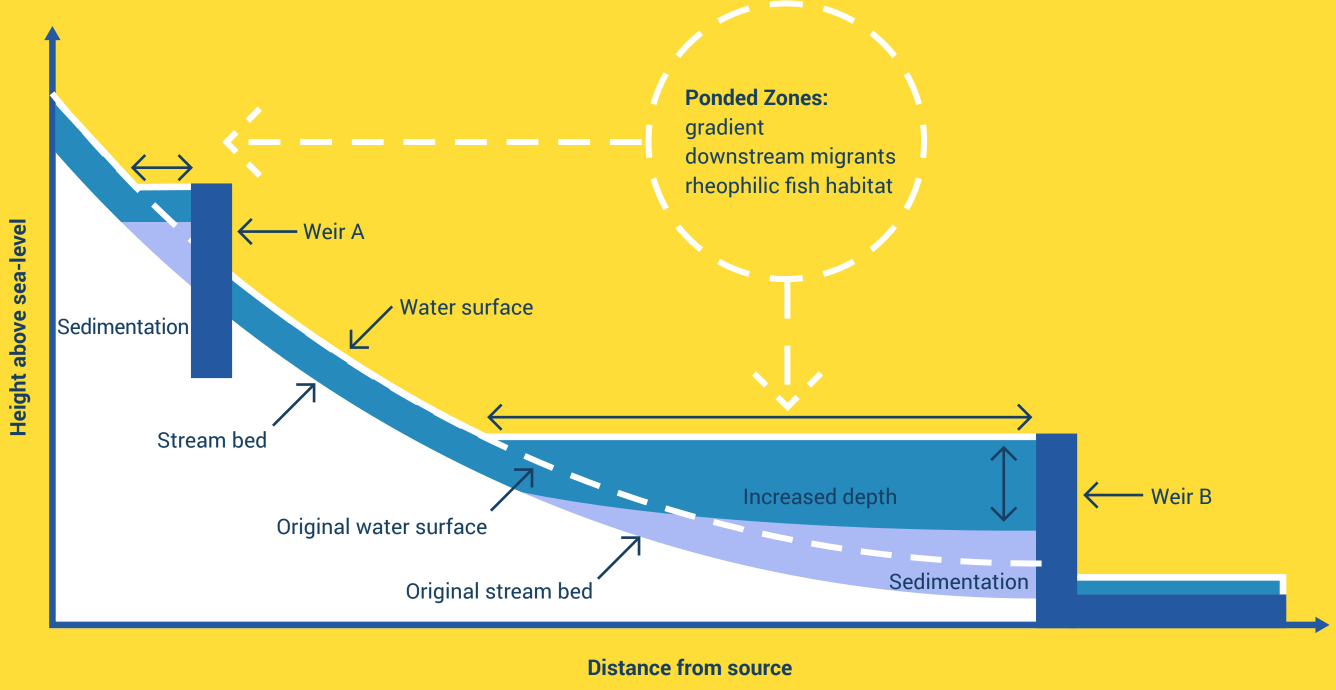


Figure 5. The effects of dams on rivers. A conceptualised diagram of the effects of dams on rivers showing two identical weirs (A and B). The ponded zone differs depending on the gradient of the river (Birnie-Gauvin et al., 2017).

Serpis River totally dry before reaching the sea, Spain
© Francisco Martínez Capel

Diglis Weir in River Severn by Worcester, UK
© Environment Agency

Fish are physically obstructed or blocked by dams and may therefore fail to migrate up and downstream in the river. All fish migrate for the purposes of feeding and reproduction, and if this is inhibited, then the population will be negatively affected. Dams impact all local fish species, but it is the iconic diadromous species that attract most attention and concern. Populations of migratory fish on a global level have declined by 55% in the period 1970 – 2012 (WWF, 2016), and it is very clear that man-made barriers are one of the key reasons for this.

Upstream fish migration
To mitigate the negative effects of dams and weirs on the migration of fish, fish passes have been constructed throughout the last century, but with greater consideration over the last few decades. There are several fish pass designs, from technical vertical slot and baffled passes to nature-like bypass channels. They function with varying levels of efficiency, but most such fish passes work only for part of the fish fauna, for a proportion of the individuals that wish to migrate, and for part of the year.

Technical passes, and even nature-like bypasses, cannot alleviate the impact of dams on river dynamics, river morphology, the loss of river habitats and their effect as physical barriers. Nor can they adequately offset potentially severe in-combination effects of multiple barriers on fish migration. A small effect at one dam, repeated over a series of dams, will have a strong cumulative impact on fish migration. This is the case even for species with great migration capacities such as the salmon, and even when very well-designed fish passes with high passage efficiency are incorporated in dams.

Downstream fish migration
Most focus has been on enabling upstream fish migrations. However the effect of connectivity disruption and morphological change is also significant for many downstream migrant phases. Delayed and failed downstream migration can have a serious impact on several species (Breve, 2013; Gauld et al., 2013; Birnie-Gauvin et al., in press). Weirs and ponded river sections are known to delay downstream migration, making smolts much more vulnerable to predation. The proportion of fish reaching the sea from impounded rivers is now known to be lower than in unimpounded rivers, as shown in Dutch studies on salmon smolts in a section of the Meuse river (Breve, 2013).

2.5.3 SEDIMENT TRANSPORT
Dams block or amend the transport of sediments and nutrients in rivers. Sediments accumulate in the reservoir over the years, sometimes leading to a decline in water quality, and this deprives the river of sediment, including fine gravels, downstream.

The lack of sediment delivery can lead to an increased risk of river bank erosion downstream of dams and in the delta area. River deltas are built and maintained with sediment transported by the river, and a lack of this leads to deltas becoming more vulnerable to erosion.

The lack of sediment has a negative ecological impact downstream of the dam. The absence of gravels downstream of many reservoir dams leads to a decrease in the quality of river habitats, and this has a negative impact on river invertebrates and migratory fish spawning at these sites.

2.5.4 WATER QUALITY
Dams often have a profound negative effect on water chemistry and quality in rivers. Dams lead to:

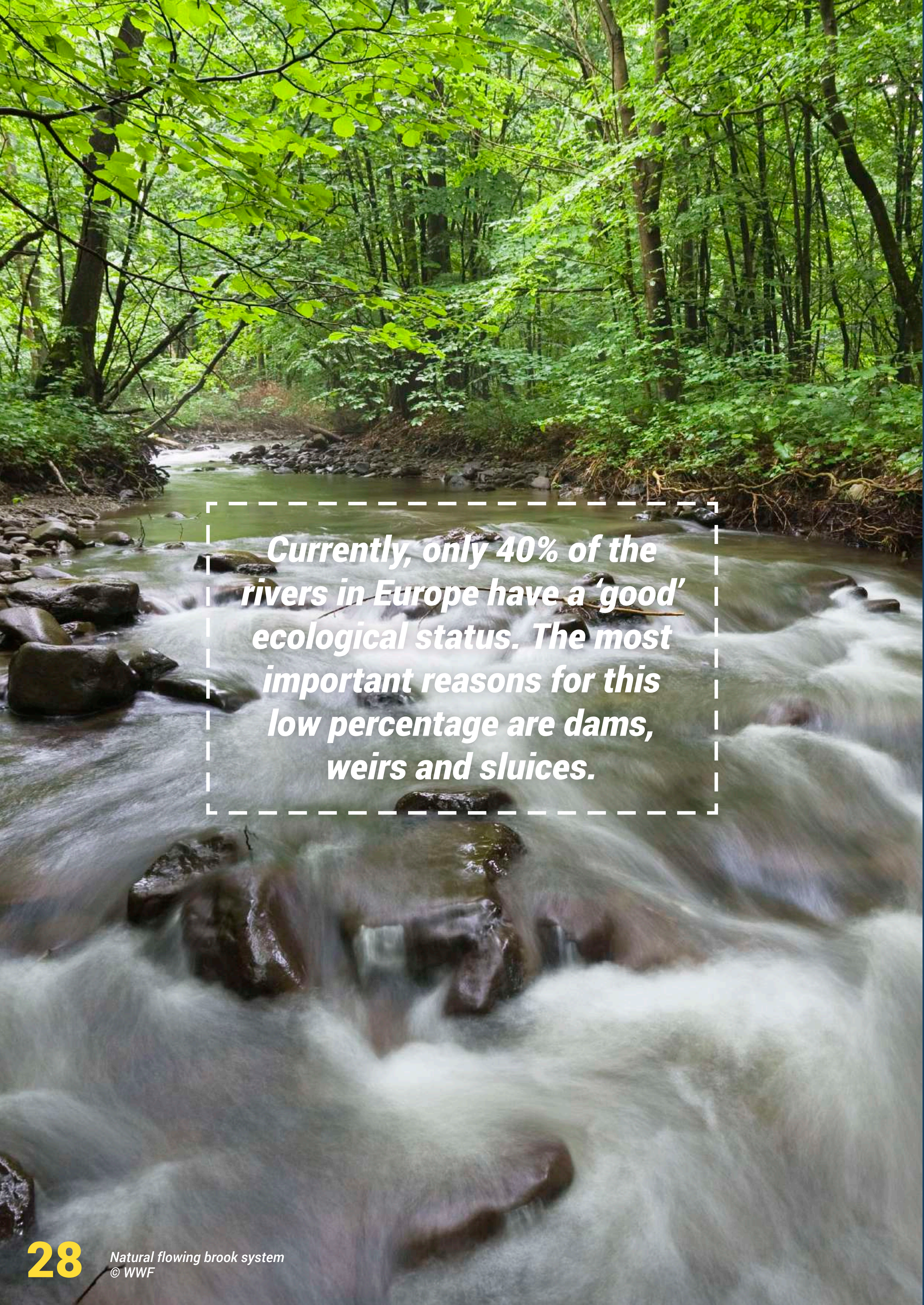
- Transformation of the river invertebrate fauna as a result of hydrodynamic and water quality changes in the impoundment;
- Storage of organic material and nutrients in the reservoir, often leading to a algal bloom in the summer;
- Changes in water temperature in the reservoir and the river downstream;
- Changes in capacity to dissolve oxygen as hydrodynamic influences and biological processes are changed;
- Possible seasonal stratification in the case of deep, cold water reservoirs.

The effect of water impoundment is dependent upon the size of the dam and the size and topography of the upstream reservoir or impounded river length. This means that the effects above can occur in all reservoirs but the extent depends on local circumstances.

2.5.5 LOCAL IDENTITY AND CULTURE
Free-flowing rivers and their fish often play an important role in local identity and culture. Studies around dam removals in the USA (Druschke et al., 2017) show that projects to remove dams often depend very much on community values and beliefs. The native communities in New England, for example, have deep cultural, spiritual and historical connections to specific free-flowing rivers, to features along those rivers, and to the animal and plant species they support.

In Europe, it is not hard to find local culture and identity reflecting the previous importance of migrating fish species. For example, names of species like salmon, shad and sturgeon can be found in street names, river stretches and even family names of people. The removal of dams can strengthen local identity, the sense of local connection and pride in local heritage. Also, there are communities which value dams that have been in place for a long time, celebrating their cultural heritage. Removing dams can be an emotional issue for communities, depending on local circumstances and societal values.


Knowes Weir with debris and no working fishway, River Tye, Scotland, UK
© Forth Rivers Trust



Currently, only 40% of the rivers in Europe have a 'good' ecological status. The most important reasons for this low percentage are dams, weirs and sluices.

Natural flowing brook system
© WWF

THE STATUS OF THE EU WATER FRAMEWORK DIRECTIVE

The Water Framework Directive (WFD) came into force in 2000 and seeks to ensure ecological and chemical improvement of surface water and groundwater and quantitative improvement of groundwater, whilst ensuring no deterioration. Current assessments are that 40% of surface water bodies have an ecological status of 'good' or 'high' (Figure 6), with lakes and coastal water bodies having a better status (approx. 50%) than rivers and transitional water bodies (approx. 40%) (EEA, 2018).

Despite the progress made, our European waters remain under pressure from water pollution, over-abstraction and structural modifications from a range of human activities. These pressures affect the functioning of ecosystems in a negative way and thereby contribute to biodiversity loss, threatening the valuable benefits water provides to society and the economy.

The most important pressures that constrain progress towards objectives for rivers are the impact of pollution and hydromorphological changes. Dams and their impact on river connectivity cause the majority of the hydromorphological changes. Physical alteration of surface waters by dams, locks, and channelling etc. has a severe negative impact on the quality of our European water bodies. For many rivers, this represents a significant risk of not achieving the WFD objectives by - at the least - 2027 (EEA, 2018). Political will is needed to take action and implement effective measures in order to achieve the WFD objectives.

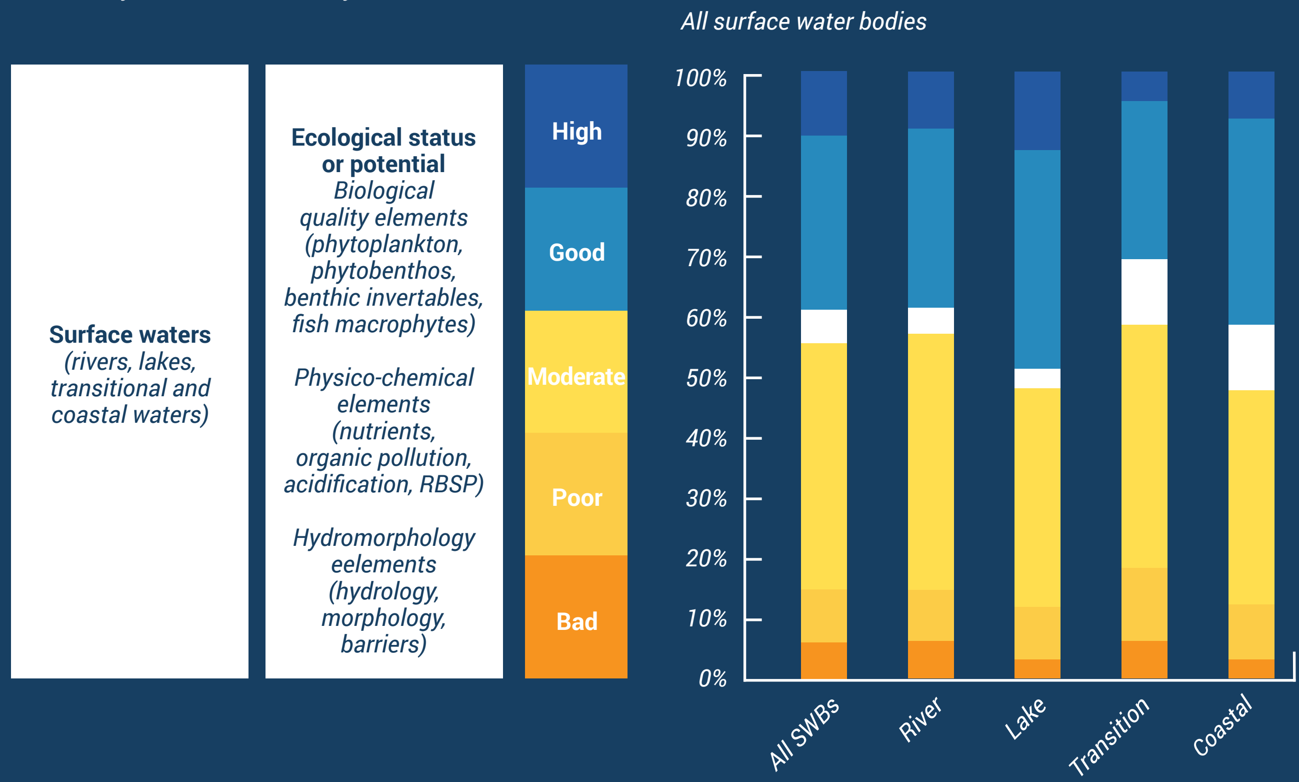


Figure 6. Ecological status/potential of rivers, lakes, transitional and coastal waters in the second RBMPs (EEA, 2018).

A natural, undammed river
© WWF

3.1 INTRODUCTION

It is clear that not all dams can, or have to, be removed because many have important functions required by society, including water supply and water safety. However, in most cases the removal of obsolete dams is a viable solution for river restoration.

Dam removal restores local river morphology and results in a return to natural functioning for sediment dynamics and river wildlife. No other restoration measures, for example fish passes, can do this. This can lead to the rapid restoration of fauna and flora that have been suppressed since the structures in question were first built. In the following cases, the removal of dams is a viable option to consider:

- **Nature improvement and restoration.** In protected sites across Europe, including the Natura 2000 network and national parks, the focus for management is on the protection and improvement of environmental quality. The removal of a dam will restore the natural dynamics of the river, protect and restore river habitats and banks, reconnect flood plains, restore natural flow patterns, restore sediment and energy flows and open up fish migration routes. It will also improve resilience when faced with pressures such as the impact of climate change.

- **Contribution to the objectives of the Water Framework Directive and water quality improvement.** One WFD objective for each surface and groundwater body is that they must be in good condition by 2027. As noted, 60% of the rivers in Europe do not yet meet the requirements of 'good' ecological status. The removal of dams can be an effective measure for water managers to improve the status of a river in terms of biological, ecological, physicochemical and hydromorphological quality.

- **Improvement to fish migration routes and fish populations.** Migratory fish populations are performing poorly across much of Europe for a variety of reasons and their in-combination effects. Various initiatives, including the Eel Recovery Plan, the IUCN Red List and the WFD, all strive for improvement. A crucial, basic aspect of restoring fish populations is the re-connection of upstream and downstream habitats and the free migration of fish between them. The removal of dams is the most effective measure to restore both up and downstream migration of fish.

- **Lowering maintenance and repair costs.** Dams and weirs are often long-lived, frequently remaining in place for over 100 years, and require regular inspection and maintenance programmes if they are to remain in good working condition. This is very important in urban situations where many properties may be located close to river channels.

  A recent study on this by Portland State University, USA, found that billions of dollars could be saved if dams were removed rather than repaired. The study estimates that the cost of removing 36,000 dams by 2050 in the USA would be 10 – 30 times cheaper than repair and maintenance of the dams (Grabowski, 2018).

- **Improved regional economies on the basis of a high-quality rural landscape.** Rural areas with high-quality landscapes provide important resources for recreation and tourism. Clean, free-flowing rivers full of fish and other natural flora and fauna are clear assets for recreational development, bringing economic benefit to the countryside. The sport fishery sector attracts visiting anglers, often to rural areas, bringing local benefit through income generated by visitors to the area.

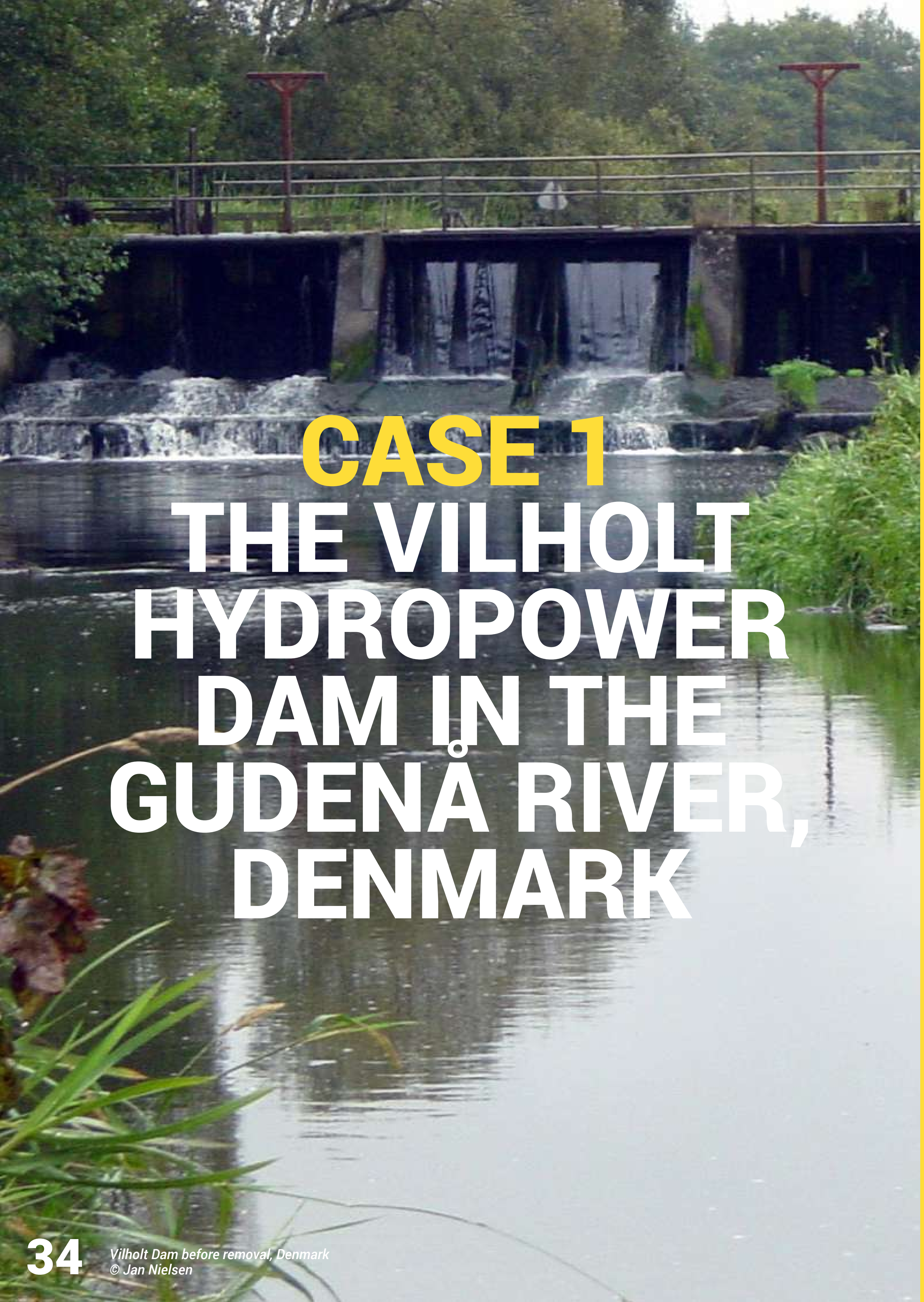
- **Increasing community values and an increased sense of local connection and pride.**
  Studies in Maine (USA) have shown that dam removals can have strong social benefits (McClenachan et al., 2015). Restoration can lead to a collective remembering of past states of abundance of fish species, enhanced attachment to past and place, and an increased sense of well-being. The study quotes a local citizen, saying "anybody who is 55, 60, and over can remember a time in their childhood of either fishing and seeing the fish or stopping at a general store and seeing them smoked and eating them." It is not difficult to find similar reactions throughout Europe, connecting to the past and demonstrating the cultural value in many communities arising from strong fish stocks.

3.2 CASE STUDIES OF DAM REMOVAL

Dam removal has already been implemented in several EU countries, but it is not yet a common measure across the whole of Europe. There are good examples from Spain, France, Denmark and the UK where dams have been removed in the past decade, however in other parts of Europe there has apparently been little implementation of this measure. Some of the removal programmes would be good case studies for a future dam removal policy for the benefit of nature and society.

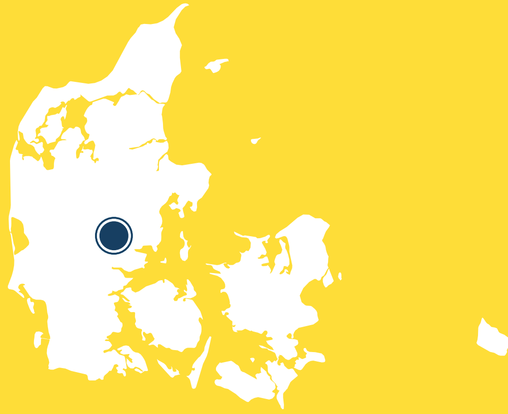
Salmon
© WWF

CASE 1
THE VILHOLT HYDROPOWER DAM IN THE GUDENÅ RIVER, DENMARK



Vilholt Dam before removal, Denmark
© Jan Nielsen

Name	Vilholt dam
Location	Jutland, north Denmark
Type of dam	Hydropower station
Measurements	4 m high
Aim	Improvement of fish populations
Year of removal	2008



INTRODUCTION

Denmark is a relatively lowland country with several small river systems flowing to the Wadden Sea (North Sea) on the west side of the country, or the Baltic Sea on the east side of the country. Historically, there has always been an abundance of fish populations in Danish waters, with healthy salmon and sea trout populations.

Over the past few decades, however, the migratory fish populations have declined significantly. Specifically in the Gudenå river, the development of dams led to a significant decrease in the migrating fish populations and extinction of the salmon population in the river (Birnie-Gauvin et al., 2017).

The Gudenå river is one of the longest rivers in Jutland, Denmark, with a total length of approximately 149km from its source to Randers Fjord. The Vilholt hydropower dam (Vilholt Mølle) was established in 1866.

To restore natural conditions and fauna passage in the river, the removal of the hydropower station was proposed and has been debated since 1987. The project promoters were 2 local authorities and the Danish Nature Agency. In 2008, the dam was finally removed, which created a free-flowing river system all the way to Mossø lake.

The dam had an impoundment a few kilometres long, within which water flows and velocities were very low and sand and silt had accumulated, resulting in a depth of approximately 0.7 m. After the dam was removed, the impounded zone disappeared and the natural shallow water habitat (10 – 30 cm deep), a higher flow velocity and the water riffles were restored. This is the natural spawning and nursery habitat of brown and sea trout.

RESULTS

The situation before and after removal, up and downstream of the dam, was subject to a thorough scientifically-based monitoring programme. The Technical University of Denmark (DTU) carried out electrofishing surveys, and this resulted in good data on fish migration and fish populations over a period of 30 years.

The results have been spectacular. Removal of the dam led to a spectacular increase in the trout population upstream of the removed dam, the number of fish increasing from zero to approximately 4 – 5 fish per square metre). After a few years from 2011 onwards, the numbers of fish downstream of the removed dams also improved significantly as individuals returned to spawn and their young dispersed downstream from the upper river (Figure 7: Birnie-Gauvin, 2017).

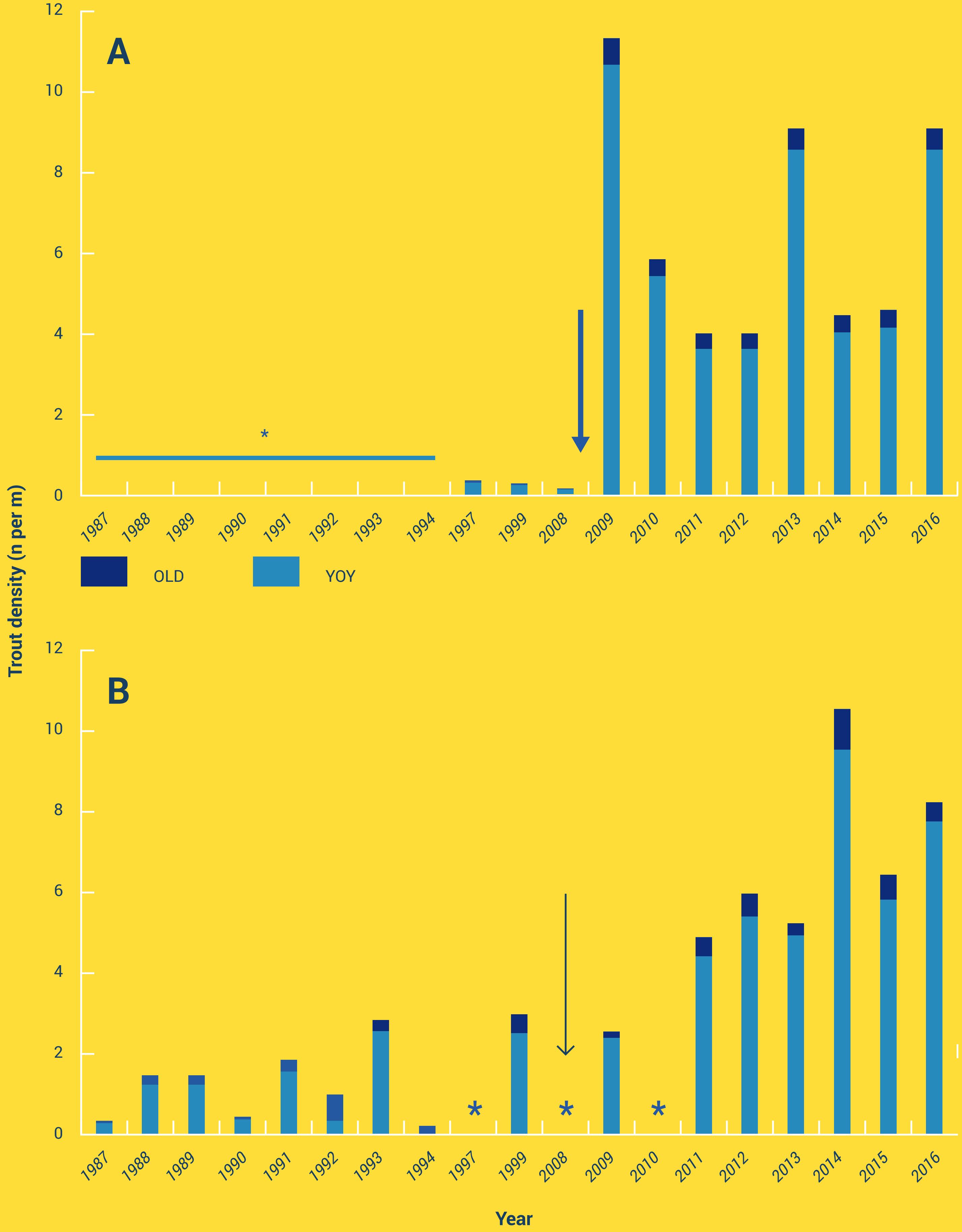
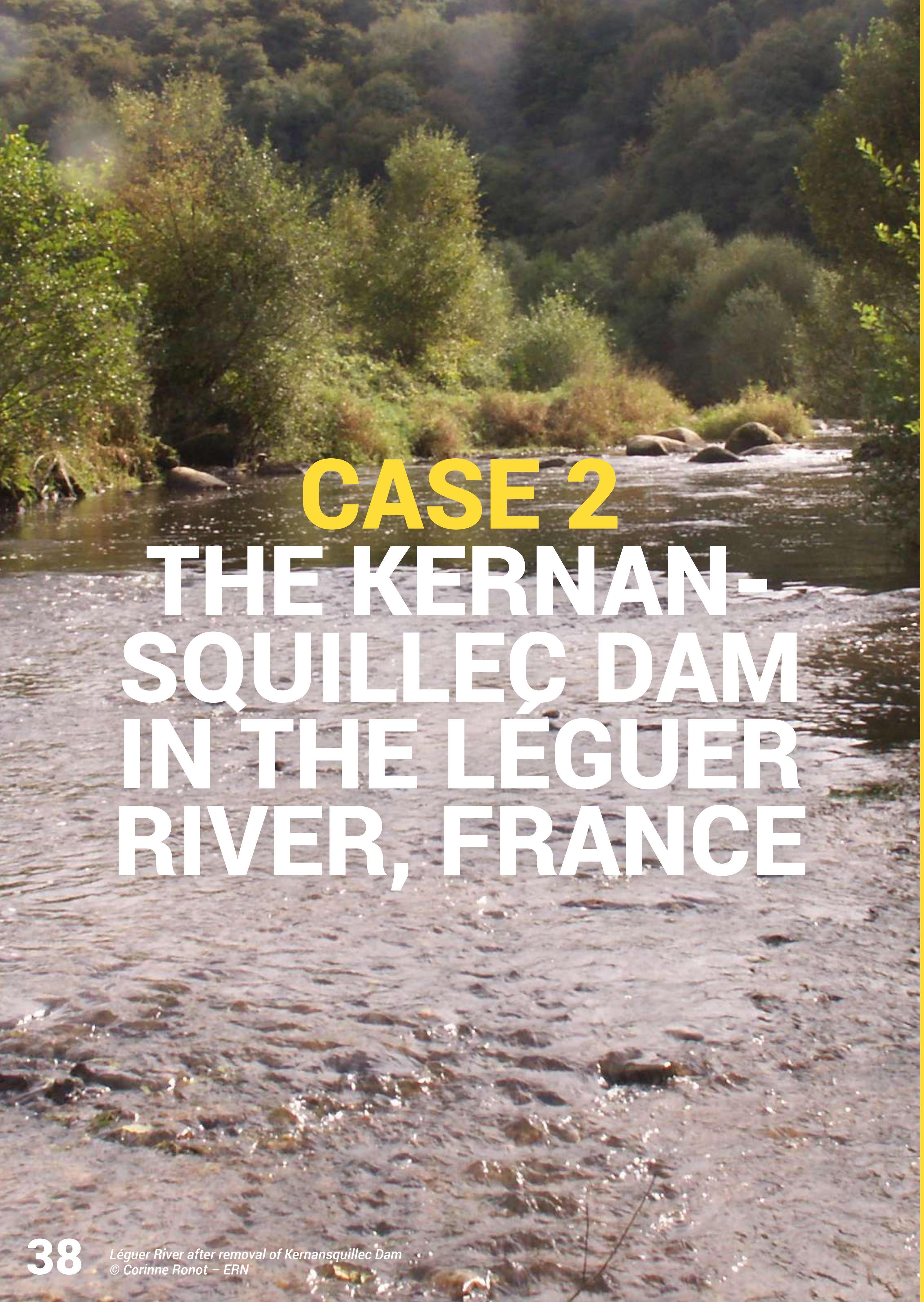


*Figure 7. Brown trout (Salmo trutta) density (number of individuals per metre of river) upstream (A) and downstream (B) of the Vilholt dam; dam removed in 2008; * indicates no data (Birnie-Gauvin, 2017).*

Vilholt Dam during removal works, Denmark
© Jan Nielsen

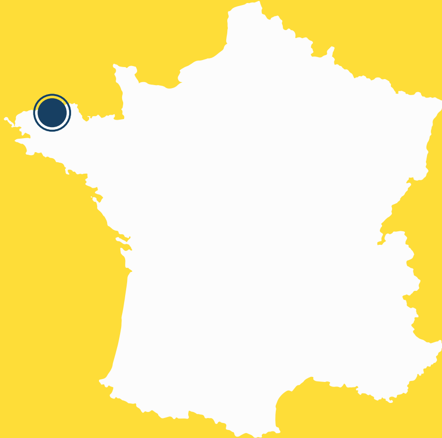
Gudenå River after removing Vilholt Dam, Denmark
© Jan Nielsen



CASE 2
THE KERNAN-SQUILLEC DAM IN THE LÉGUER RIVER, FRANCE

Léguer River after removal of Kernansquillec Dam
© Corinne Ronot – ERN

Name	Kernansquillec dam
Location	Léguer river, Brittany, northwest France
Type of dam	Hydropower station
Measurements	15 m high; 10 m wide; impoundment 1.5 km long
Aim	• River restoration, improve river connectivity and re-establish fish migration routes • Improve water quality. The water quality in the reservoir was poor (eutrophication) and filling up with sediment • Avoid risks of dam collapsing and maintenance costs.
Year of removal	1996 – 2001



INTRODUCTION

The Léguer is a small river in Brittany, France, which flows along 58 km into the English Channel after passing through the town of Lannion. The 280 km² catchment area consists of a narrow, entrenched granite valley. The river is historically one of the region's most renowned salmon rivers. The Vallée paper mill, one of the biggest industrial units in the area, was located on the banks of the Léguer at Belle-Isle-en-Terre. Between 1920 and 1922, a dam was built across the Léguer in order to supply the mill with electricity. Providing a livelihood for over a thousand people, the mill and dam symbolised the progress and prosperity of the region.

The dam, approximately 15 m tall, created a reservoir with a length of approximately 1.5 km. Despite the presence of a fish pass, it was difficult for salmon to cross and the dam also formed an impassable obstacle for eels. In 1965, the paper mill went out of business. The dam then supplied electricity to EDF, but when it was time to renew the licence, the dam was in poor condition and there was limited economic interest. The former licence-holder decided not to renew its application and the dam then became a public asset with associated responsibility for maintenance (source: www.onema.fr).

The dam, the river and the reservoir had 3 different problems: -

• River connectivity and fish populations. The river was fragmented due to the large dam, and the natural flow of water, sediment and energy was disturbed. This was reflected negatively in the river habitats. Migratory fish were negatively impacted due to the dam, and the salmon and eel populations were limited;

• Water quality and sediment trap. The dam resulted in sediment trapping and the reservoir had silted up significantly. This resulted in a shallow and enriched reservoir that suffered from algal blooms in the summer;

• Safety and maintenance costs. The risk of the dam failing became a growing concern and, due to the lack of maintenance, the dam started cracking and became a direct threat to houses and property situated downstream. Following significant flooding in the winter of 1995, the government announced plans to dismantle the dam on the grounds of public safety.

The demolition permit was granted by the prefect on 17 September 1996 (source: www.onema.fr).

RESULTS

Fish populations

No pre-works monitoring was carried out, however during the works, water quality was continuously monitored and the results were regularly released to the public. After removal of the dam, studies of invertebrates were carried out upstream and downstream. The collection of fish data allowed evaluation of re-colonisation by migratory species and showed re-colonisation of at least 27km of river with improved populations of salmon, sea lamprey and eel. However, it is clear that due to other structures downstream of the site of the Kernansquillec dam, fish population recovery has not yet reached its full potential.

Overall, the visible but unquantified results of the different elements (water quality, ecological condition etc.) are highly satisfactory. The site has been rehabilitated, and five years after the drainage of the reservoir, the banks had stabilised and the river had re-established its meanders, as well as its flow and gradient having been restored (www.onema.fr).

River restoration

The removal of the Kernansquillec dam was the beginning of various actions to restore the ecological and chemical quality of the water, including removal of further weirs. Since actions have been completed, the Léguer river has recently received the prestigious "Wild River" label. This certifies rivers which are close to their natural state - less than 1% of rivers in France are in this state (source: www.ern.org).

Water Framework Directive

The water quality of the Léguer river is managed by the Agence de l'eau Loire-Bretagne (Loire-Brittany Water Agency). Using WFD methodology, as of 2013, the river was considered to have 'good' ecological status. This was achieved through removal of the dam. The chemical water quality is also excellent and was not negatively affected by sediment dispersal following dam removal.

Communities and economic development

Initially, local residents reacted quite negatively to the dismantling of the dam, which they considered to be destroying a reminder of past industrial heritage. The Léguer Valley Association then decided to rehabilitate and enhance the former dam and mill site.

Public relations announcements on the project's progress ensured that local residents would remain informed and would accept and take ownership of the project. Large numbers of visitors now come to see the Kernansquillec site. Since the removal of the dam, the site has become popular with canoeists and the general public (www.onema.fr).

Kernansquillec Dam after removal
© Corinne Ronot – ERN

Kernansquillec Dam after removal
© Corinne Ronot – ERN

CASE 3
KENTCHURCH WEIR, WALES, UK

Kentchurch Weir during removal works
© Peter Gough - Natural Resources Wales

Name	Kentchurch Weir,
Location	River Monnow (Wye basin), Monmouthshire on the Wales/England border, UK
Type of dam	Former supply to a mill
Measurements	3 m high; 35 m wide; approximately 1km of ponded river upstream
Aim	• River restoration •Improve fish populations •Avoid maintenance costs of degraded weir • Address minor sediment accumulation
Year of removal	2011

INTRODUCTION

Kentchurch Weir was one of the last two remaining milling weirs on the River Monnow, a tributary of the River Wye in southeast Wales (within the Severn River Basin District). Another ten weirs in this tributary had been destroyed during floods during the past century or had been removed. The weir supplied water to a local mill, though this role had ended about 40 years earlier and the weir had since deteriorated through lack of maintenance and was showing signs of breaching on both banks. The weir prevented upstream migration of fish in the catchment, thereby excluding diadromous fish from approximately 100 km of functional habitat.

The weir was located in a very rural area and its removal was proposed by the owner of the structure and supported by the owner of the adjacent land and river users. Removal was carried out using standard techniques: a partial breach of the weir and gradual lowering of the upstream water level and removal of some of the stored sediments. The remainder of the weir was then removed, whilst ensuring minimal disturbance of stored sediments.

Good communication with river users, including trout anglers, was maintained throughout the project to ensure thorough briefings on progress and outcomes. Good relationships were maintained throughout the whole project process.

Upstream Kentchurch Weir before removal
© Peter Gough - Natural Resources Wales

River channel restored after removal
© Peter Gough - Natural Resources Wales

RESULTS

Fish populations

Routine fish surveys prior to removal confirmed the absence of salmon upstream. Following construction of a nature-like fish pass around the other main-stem weir 3 years earlier, migrating salmon had been observed leaping at Kentchurch Weir but failing to ascend it. The absence of progeny upstream confirmed that they had not been able to further ascend the river.

Surveys after removal showed that adult salmon had ascended the site at the first opportunity and juvenile salmon were observed at all except 1 of the 10 monitored sites. Young eel were also widely distributed.

River restoration

The effect of weir removal on sediment fill and river channel morphology was studied after removal and showed significant change to the river morphology with bank erosion and a sediment-wave effect. The materials were re-distributed and channel widening occurred as the river reverted to its earlier natural state (Thomas et al., 2014), and the impact of earlier river diversion was ameliorated.

Water Framework Directive

The ecological status of the River Monnow was constrained by barriers to fish migration and diffuse pollution from intensive agriculture and excess nutrients. In this case study, the removal of the dam restored connectivity for migrating fish and eliminates loss of connectivity as a potential cause of failure of upstream water bodies.

The inevitable improvement to fish migration and distribution was forecast and has since become apparent. However, in this case, monitoring was focused on hydromorphological processes, as more persuasive case studies are urgently required in this area. It was shown that the river's re-naturalization was rapid and contributed to the achievement of relevant ecological targets.

Presence of fish species upstream of Kentchurch Weir	Before removal	After removal
Adult Atlantic Salmon	Not present	Present
Juvenile Salmon	Not present	Present, distributed up to 20 km upstream
Glass Eel	Not present	Present
Young Eel	Very limited presence	Present

CASE 4
DAMS IN BOVEN SLINGE, THE NETHERLANDS

Boven Slinge weir
© water authority Rijn en IJssel

Name	Dams Boven Slinge
Location	Winterswijk, the Netherlands
Type of dam	Weirs
Measurements	0.5 – 1 m high; 6 m wide
Aim	River restoration, improvement of water quality and fish populations
Year of removal	2015

INTRODUCTION

Boven Slinge is a small brook in the eastern part of the Netherlands, flowing through an agricultural landscape and forestry areas. The brook was managed using technology, and was equipped with 2 weirs to precisely control water levels. This resulted in poor-quality river banks, completely altered flow conditions (often with no flow in summer), insufficient water quality and no migration options for water fauna.

To tackle these problems, the water authority, together with the Gelderland regional authority and the private landowner, decided to reconstruct the waterway to recreate a more dynamic brook system. Two small weirs were removed, the river banks were redeveloped, old brook meanders were reconnected, and new forest was planted. To prevent excessive erosion of brook soil, gravel and pebble riffles were introduced.

RESULTS

Fish populations

To evaluate the effect on the fish populations, 4 transects of 250m were monitored using electrofishing, with the same method used at the same time of year.

The number of species present increased, on average, by 30% and the number of individuals increased by 148% (see table below).

New species identified were eel, ten-spined stickleback, Gibel carp, dace, brook lamprey, brown trout and stone loach (source: Rijn en Ijssel Water Authority, 2016). It is clear that the fish population directly responded to the improved hydrological conditions.

Hydrological conditions

Flow velocities during the summer are critical for rheophilic fish species. Flow velocities were measured in a period of low water levels with a base flow before and after removal. Natural flow velocity significantly increased throughout the entire redeveloped area of brook from 0 - 0.1 to 0.20 - 0.25 m/sec (Figure 8). The flow velocities are very low as it is a small brook system, but the 100 – 250% increase in flow velocity and the fish fauna’s response is impressive. It is an example of the difference a small improvement can make.

Habitat variation

The variation in structure was assessed before and after removal. Before removal, the main structures present were sand and underwater vegetation. After removal, the variation in structures was much greater, with sand, large and small pebbles, riffles and dead wood.

Groundwater

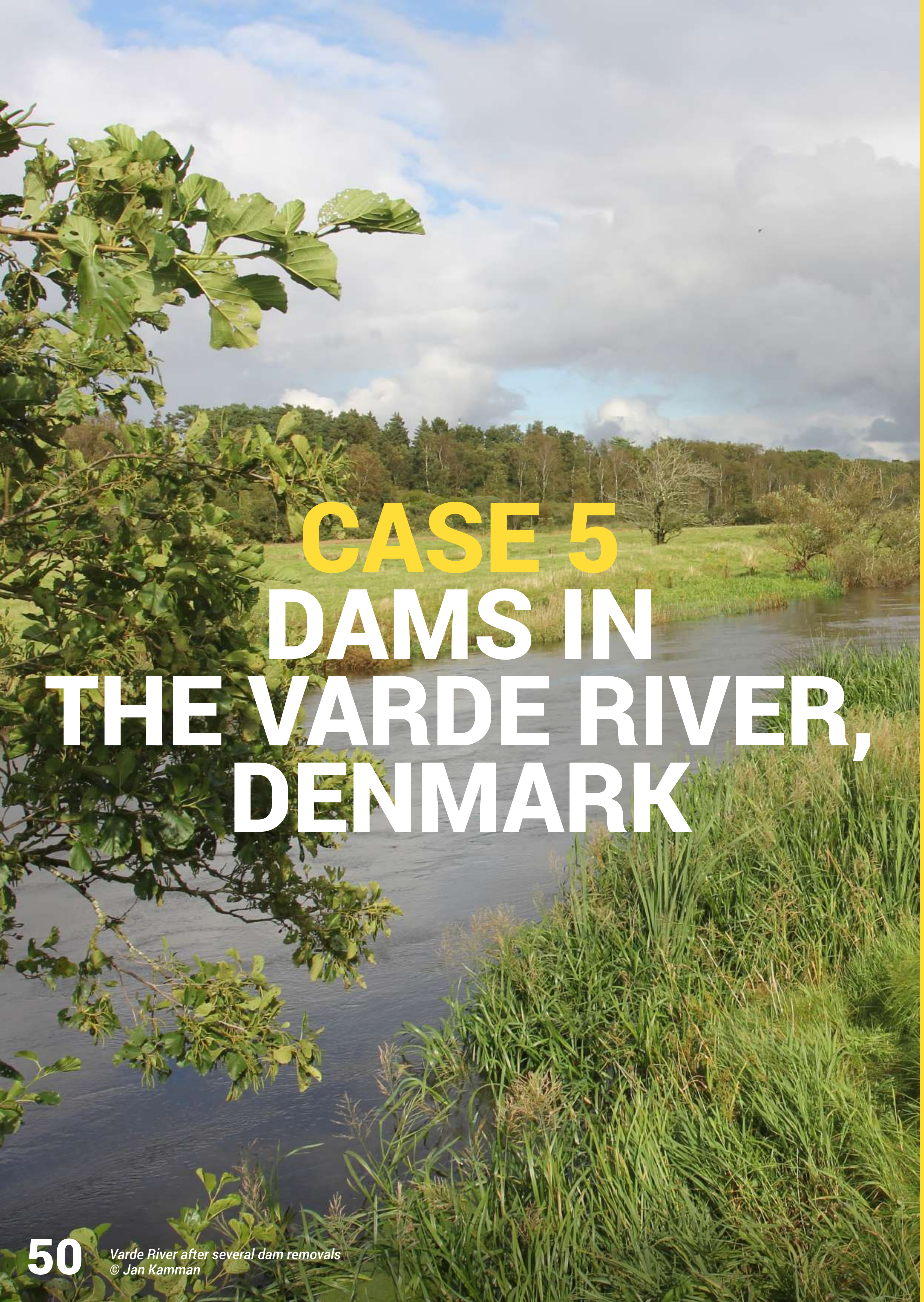
When dams or weirs are removed, the average brook water level is lowered. The effects on groundwater in the surrounding area were monitored, as this has implications for land use and the natural environment of the surrounding area. Removal of weirs and redevelopment of the brook system did lead to a lower groundwater level, however this change was modest. At 100m from the brook, the groundwater level was 25 cm lower over the summer. For the remainder of the year, the effects were smaller.

Presence of fish species in the redeveloped part of Boven Slinge	**Before removal, 2015**	**After removal, 2016**	**After removal, 2017**	**Average increase after removal and redevelopment**
Average number of fish species present in 4 monitored segments	6.75	10.25	7.25	30%
Average number of individual fish present in 4 monitored segments	193	448	510	148%

Figure 8. The flow velocities in Boven Slinge brook before (left) and after removal (right) (source: Rijn en IJssel water authority, 2016).

Removal works of Boven Slinge weir.
© water authority Rijn en IJssel

After Boven Slinge weir removal
© water authority Rijn en IJssel



CASE 5 DAMS IN THE VARDE RIVER, DENMARK

Varde River after several dam removals
© Jan Kamman

Name	Removal of dams in the Varde river
Location	Esbjerg, west Denmark
Type of dam	Different dams and weir
Measurements	Average: 2 m high, 20 m wide
Aim	River restoration
Year of removal	Started in 2005

INTRODUCTION

The Varde river system is the largest river system flowing into the Danish section of the Wadden Sea. The river system's total catchment area is approximately 1,100km2. The main tributaries originate west of the Jutlandic ridge, from where they run to the west through moorland plains and moraine islands. The Varde's mean water flow at its outfall in Ho Bay is 16,200 l/s, varying from a minimum of 4,200 l/s to a maximum of 60,600 l/s. The Varde is the only river system where water exchange with the Wadden Sea is not regulated by a sluice. Since there are no summer dikes along the river banks, the hydrological regime in the lower parts of the river and adjacent areas is in its natural state.

The river fish populations were in poor condition, though the Varde system was still of international importance regarding its populations of Atlantic salmon, twaite shad, sea lamprey, brook lamprey, otters and a small population of houting, all protected species under Annex II of the Habitats Directive. Water flow in the river was manipulated to a significant degree, with 90% directed towards an artificial lake and Karlsgårde hydropower station. After being used for power generation, the water is returned to the Varde approximately 24 km upstream of the outfall to the Wadden Sea. As a consequence, the natural hydrology of the river was significantly impacted, and demands for water to the hydropower station courses severely reduced flow along a 16 km stretch of the river.


Fishing in the Varde River after removal with fish stocks recovered
© Jan Kamman


People in the restored Varde River
© Jan Kamman

Although the weir at Karlsgårde power station was equipped with fish ladders, passage conditions for migratory fish were very poor due to the dams and disturbance of the natural hydrology. Houting could not pass at all, thus preventing access to 75% of their potential spawning grounds upstream of the hydropower station.

The houting project

To save the houting from extinction and to significantly improve other migratory fish populations, an ambitious project was designed to renaturalise the Varde river. This was undertaken by the Danish Nature Agency, in cooperation with Ribe County and Southern Jutland County, and supported by the European LIFE Programme.

The project's objective was to restore hydrological continuity and the condition of the Varde river to improve the populations of houting, Atlantic salmon, twaite shad, sea lamprey, brook lamprey and otters. The follow activities were carried out: -

- Redirection of all water to the Varde river and closure of the hydropower channel;
- Removal of Karlsgårde power station and dam;
- Removal of dams along 13 km of the heavily modified stretches of the Varde and remeandering of the reach into a natural watercourse approximately 18 km long;
- Reestablishment of free passage for all fish at a fish farm at Sig town (source: http://naturstyrelsen.dk).

RESULTS

The results were impressive. The hydrodynamics of the river were rapidly restored and migratory fish found their way back to their spawning grounds. The fish populations, including houting, have improved significantly over the last 10 years. The population of Atlantic salmon improved significantly, as demonstrated through the results of monitoring between 1987 and 2016 (Figure 9). In 2016, 1,000 mature salmon were caught on their return to the river to spawn. Removal of the dams and renaturalisation of the river were key to achieving these results.

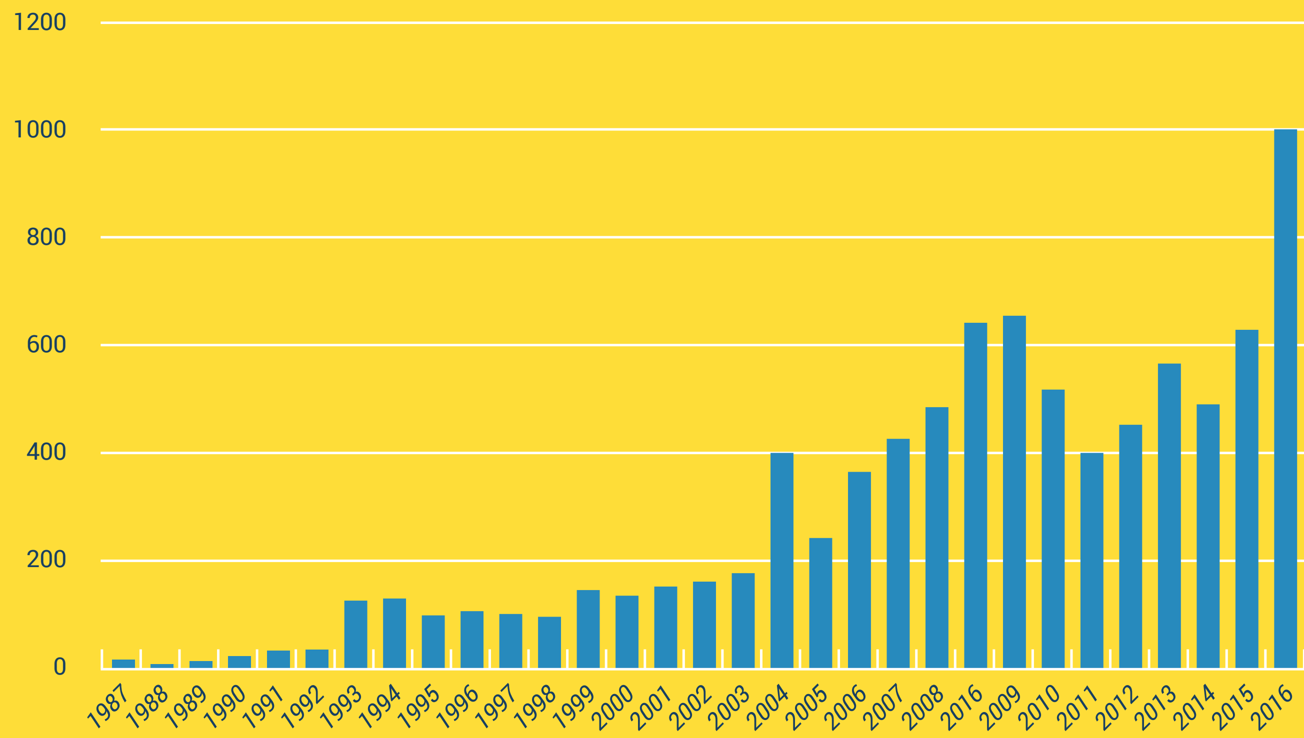
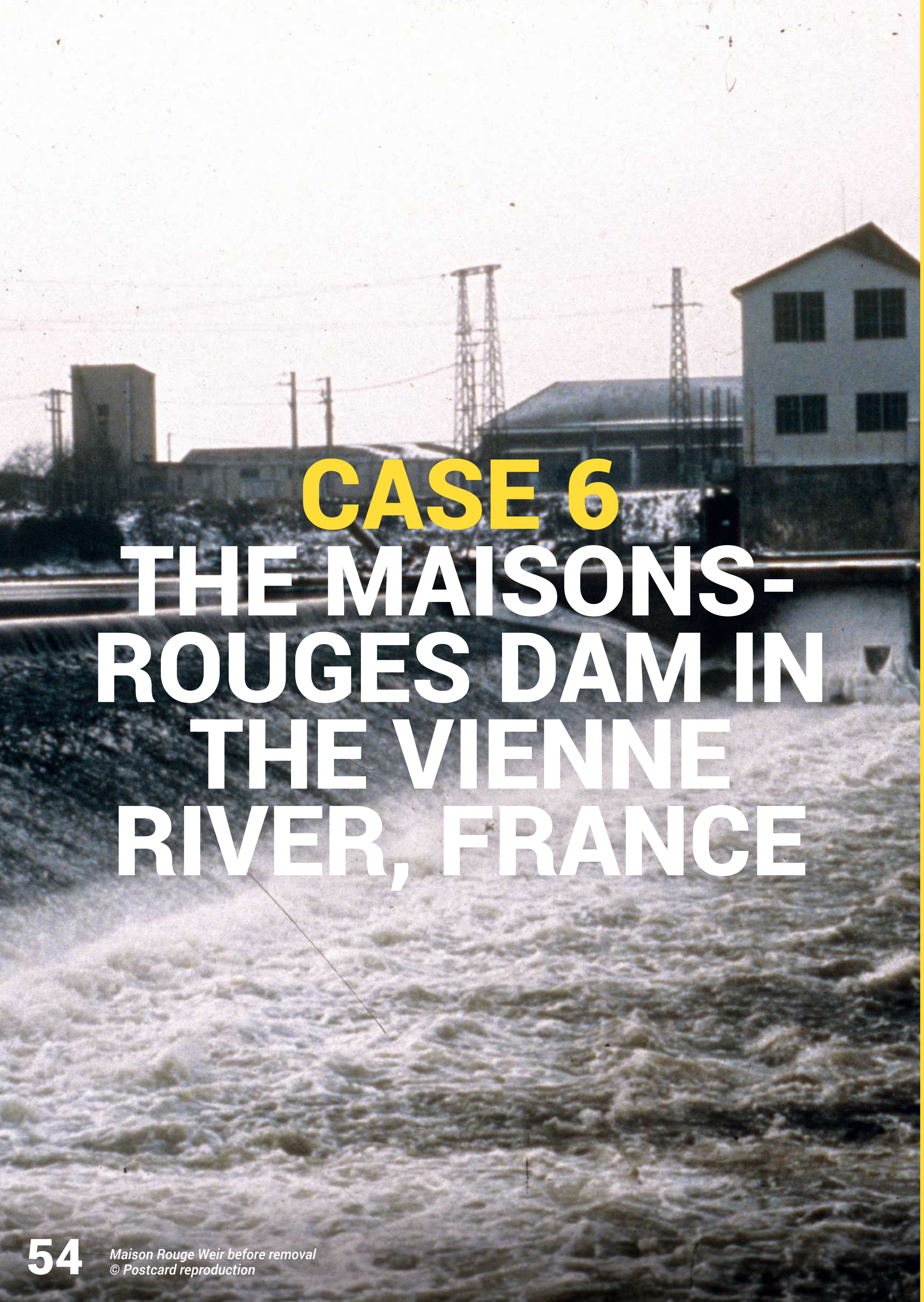


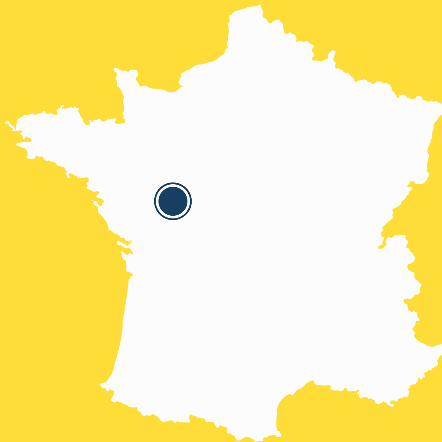
Figure 9. Presence of Atlantic salmon in the Varde river 1987 - 2016 (source: https://varde-sportsfiskerforening.dk)



CASE 6
THE MAISONS-ROUGES DAM IN THE VIENNE RIVER, FRANCE

Maison Rouge Weir before removal
© Postcard reproduction

Name	Maisons-Rouges dam
Location	Vienne river (Loire basin) – Brittany, northwest France
Type of dam	Hydropower station
Measurements	3.8m high; 200m wide
Aim	River restoration, improve migratory fish populations and avoid maintenance costs
Year of removal	1998 – 1999



INTRODUCTION

The Loire is one of the largest rivers in France. The Vienne and Creuse rivers are important tributaries of the Loire, their confluence occurs just west of Tours, in the region of Brittany. The Maisons-Rouges dam was erected in 1922, about 800m downstream from the confluence of the Vienne and Creuse rivers. The dam maintained a head-level difference of about 4m. Built initially to supply a paper factory, it was integrated into the assets of EDF (Electricité de France [EDF Energy]) in 1950 as a hydropower plant. As the dam was the obstacle closest to the sea and at the confluence of major rivers, it had a substantial impact on numerous species of migratory fish, particularly the salmon, which was already suffering from limited access to part of its spawning grounds. The shad populations had persisted in remaining spawning sites downstream of the dam (source: www.ern.org).

To restore fish migration, fish passes were constructed and a salmon reintroduction program was undertaken in the Gartempe river (one of the Vienne river's tributaries), but these initiatives had no significant positive impact. To further improve the Loire river environment as required in the "Loire Grandeur Nature" plan (Natural Loire River Plan, 1994), which was developed after a long period of debate, the national government decided not to renew the hydropower licence when it expired in 1994. The dismantling of the dam was then announced.

The project did not meet with universal approval, particularly from locally elected representatives and residents who feared that the dismantling would lead to a loss of business tax revenues and jobs, and disappearance of the lake and loss of associated tourism benefits and scenic value. After four years of negotiations and enquiries, the removal of the Maisons-Rouges dam was scheduled.

To restore fish migration, fish passes were constructed and a salmon reintroduction program was undertaken in the Gartempe river (one of the Vienne river's tributaries), but these initiatives had no significant positive impact. To further improve the Loire river environment as required in the "Loire Grandeur Nature" plan (Natural Loire River Plan, 1994), which was developed after a long period of debate, the national government decided not to renew the hydropower licence when it expired in 1994. The dismantling of the dam was then announced.

The project did not meet with universal approval, particularly from locally elected representatives and residents who feared that the dismantling would lead to a loss of business tax revenues and jobs, and disappearance of the lake and loss of associated tourism benefits and scenic value.

After four years of negotiations and enquiries, the removal of the Maisons-Rouges dam was scheduled (source: www.onema.fr).

RESULTS

The removal of the Maisons-Rouges dam was the first major operation of its kind in France. The technical arguments concerning the impact of the structure on large migratory fish and river continuity were the key reasons for the project. The results for all of the assessed components were very positive and verified the operation's success.

Migratory fish

After the removal of the dam, there were spectacular observations of shad and sea lamprey recolonising the Vienne and Creuse rivers. Allis shad began to recolonise the 35 km of watercourses that had been made accessible (11km along the Creuse and 24 km along the Vienne) and began rediscovering sites that were favoured for spawning. Today, the Vienne basin is home to 80% of the Loire basin's sea lamprey population (source: www.onema.fr). Observations for Atlantic salmon are also very positive, with the population increasing from zero to today's position in which 15 – 20% of the Loire's Atlantic salmon population is located in these two basins (source: www.ern.org).

Fish species	**Number of fish monitored in the Vienne river (fish passage and automatic counting station 20km above the Maisons-Rouges site)**			
	Before 1999	End of 1999	2004	2007
Allis shad	very limited		3,500	9,500
Sea lamprey	very limited		8,300	41,600
Trout (brown/sea)	very limited		2	12
Atlantic salmon		9	57	

Maison Rouge Dam during removal works
© Postcard reproduction

The number of fish entering the Vienne river was assessed at an automatic fish counting station 20km upstream of the Maisons-Rouges location. This gives a partial indication of the numbers of fish present, but the total number of fish benefitting from the removal of the Maisons-Rouges dam is probably higher than shown in the overview below.

River habitat

River habitats have also been restored to their natural state since the removal of the dam. The impoundment disappeared and riffles, small gravel islands and natural banks have re-emerged and reformed. The natural water and sediment flow conditions have also been restored and are now the basis of a natural river landscape.

Water Framework Directive

The Agence de l'eau Loire-Bretagne (Loire-Brittany Water Agency) is responsible for water management and implementation of the WFD in the Vienne river. Each water qualitycomponent is evaluated annually and in the period 2009 – 2015, the ecological, biological and physico-chemical status was still improving (Figure 10). Removal of the dam took place in 1998 – 1999, before implementation of the WFD. It was carried out to restore river connectivity for the return of large migratory fish. This was monitored in the period 2000 – 2015 in a local WFD programme. The good status of the river cannot relate only to the removal of the dam, however it is clear that the removal was crucial in the restoration of the river's basic conditions, upon which the quality could further improve.

ECOLOGICAL STATUS

Year	Ecological status	Biological status	Physical chemical status
2015	very good	very good	very good
2014	very good	very good	very good
2013	good	very good	good
2012	good	very good	good
2011	average	very good	average
2010	average	average	good
2011	unknown	good	

Figure 10. The WFD status of the Vienne river (source: Agence de l'eau Loire-Bretagne (Loire-Brittany Water Agency)).

Vienne River after the removal of Maison Rouge Dam
© Roberto Epple – ERN

3.3 CONCLUSIONS

The case studies presented range from large to small dams. There are several different outcomes that can be seen: -

Fish species respond swiftly and react strongly after dam removal

The effects are immediate and can be seen even from the first year or two. The fish often return in large numbers and in many cases endangered, iconic fish species as Atlantic salmon, sea trout and eel find their way back to the river very quickly. The effects are greater if the removed dam is the last barrier to connection to the sea. Measures such as fish ladders do not come close to the positive effects achieved by dam removal. Moreover, dam removal works for all species of fish all year round, which is not the case for most fish ladders.

Dam removal restores river habitats, up and downstream of the dam

The removal of a dam has a positive effect on the river habitat upstream of the dam: an impoundment is transformed into a flowing river once more. The effects can be seen on both larger and smaller rivers. The flow velocities in the upstream part are directly restored, leading to greater variation in river habitats with sand, large and small pebbles, riffles and dead wood. The effect is seen through the return of river fish and mammals. Surprisingly, it also has a positive effect on the river habitat downstream of the dam: the natural hydrological and sediment flow is restored, as is the ecological connection.

The removal of dams can be beneficial for regional economies and local communities' identities

The removal of dams and the restoration of a natural river is a potentially key asset for successful regional economic development. Natural rivers strengthen opportunities for recreation & tourism. The effects are clearly seen in the number of tourists visiting a region, the amount of money spent and the number of camping places/beds available in a region. The effects are not immediate, but become visible after a period of 5-10 years. An effective communications and marketing strategy is also necessary.

Furthermore, rivers are part of people's and regional identity. The removal of dams and the restoration of the natural rivers has, in different places, strengthened community spirit and sense of identity.

The removal of dams is a delicate and often emotional issue for communities

Dams have often been present for centuries and are sometimes considered part of an area's cultural heritage. The removal of a dam is not an easy issue. Local community involvement from a project's inception clearly helps that community to accept the dam removal project.

Contributions of dam removal to the environment

On the basis of these case studies and the supporting evidence and research presented in this report, we conclude that the removal of dams is a very effective measure for river restoration.

In the absence of other confounding issues, dam removal leads directly to rapid naturalisation of river catchments and makes an important contribution towards the achievement of WFD and other policy objectives. More specifically, dam removal has the following benefits for the riverine environment, policies and communities: -

Restoration of natural flow regimes and hydrodynamics

By removing a dam, natural hydrodynamics and sediment transport are restored. This is a key development for further ecological improvement.

The benefits of dam removal are not always dependent on the size of the dam; removing small structures can often lead to benefits similar to those which come about after large dam removal.

Restoration of river habitats

River habitats are quickly restored following dam removal. This is the case in small and large rivers and in different European regions. Natural flow regimes result in improvement of river habitats up and downstream of the removal site as the impoundment is replaced by renaturalised habitats and river banks. The removal of a dam is a good start for restoration of a river.

Restoration of fish migration routes

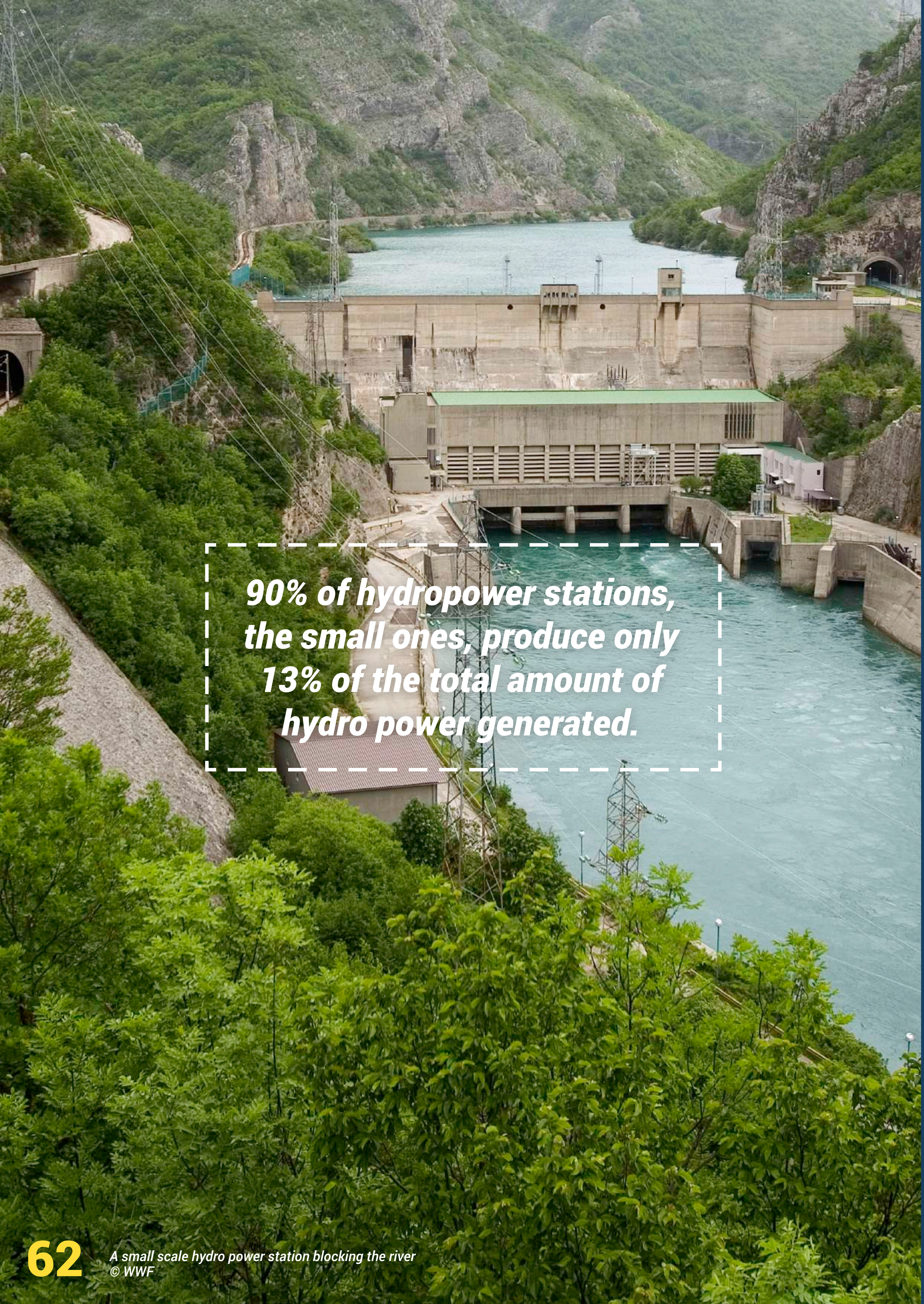
Dam removal restores free migration for all aquatic species in both up and downstream directions, for both weak swimmers and powerful migrants. In many cases this has led to an immediate and incredible return of migratory fish such as salmon, sea trout and lamprey.

Contribution to securing objectives under the Water Framework Directive and other policies

Dam removal contributes to objectives under the WFD, the Eel Recovery Plan and to the objectives for Natura 2000.

Contribution to economic development and communities

The restoration of rivers through removal of dams can benefit regional economies and local communities as a result of a more productive riverine and natural environment. Sport fisherman and other tourists are attracted to an area, and this brings increased local economic activity. Communities benefit from an enhanced quality of their landscape and the opportunity to connect to their natural heritage.



A small scale hydro power station blocking the river
© WWF

THE LARGE NUMBER OF SMALL-SCALE HYDROPOWER STATIONS

At present, a large number of the dams present in Europe are small hydropower stations. More of these small-scale hydropower stations are planned for the future.

Small hydropower plants produce disproportionately less electricity than large stations: 10% of the largest hydropower stations produce 87% of all the hydro energy in Europe (source: Arcadis, 2011). This means that 90% of all hydropower stations, the small-scale ones, produce only 13% of the overall amount of hydroelectricity generated (Figure 11).

Small hydropower stations, however, can have a strong negative effect on river systems and their environment. A dam 5 m high will disrupt migratory connectivity and damage local aquatic habitats just as effectively as a larger one. An additional problem is that small-scale hydropower stations are more abundant, and are often built in series, leaving the river as a series of isolated sections, each dam acting as an ecological barrier, instead of a continuously flowing river.

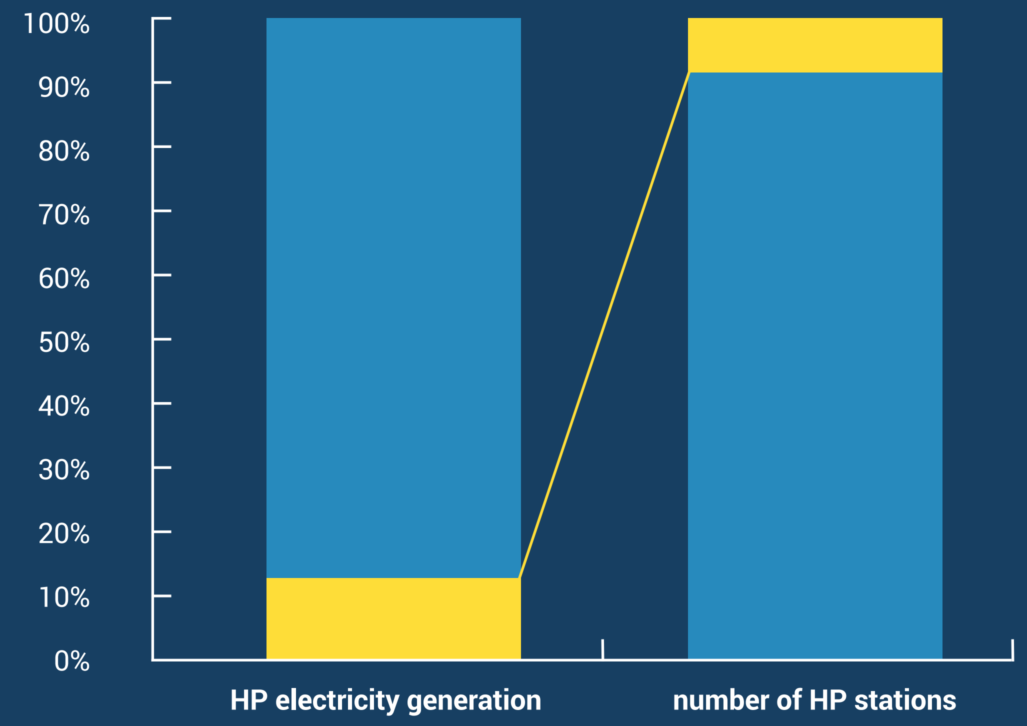


Figure 11. Proportion of electricity generation and number of hydropower stations for Small Hydropower Plants (< 10 MW) and Large Hydropower Plants (> 10 MW) in the EU 27 in 2005 (source: Arcadis, 2011).

Allier River recovered after removal dam in Saint-Étienne-du-Vigan ©Roberto Epple - ERN

4.1 INTRODUCTION

River restoration is the promise for many European rivers, because it will immediately result in huge biodiversity gains to an extent not yet seen among our present generation. We could reverse the trend of extremely decline of freshwater species (now 81%) and start to see rivers with large fish populations that can once again migrate across large distances. Of course, people will benefit immensely in terms of an attractive landscape, a healthier environment and as a result of new opportunities for economic development. Dam removal is clearly one of the most cost-effective measures with which to achieve this desired river restoration, but if we do not act, these dams will remain exactly where they are now.

For the future of our European rivers, Dam Removal Europe proposes to implement to following four key strategies to catalyse the removal of dams across Europe:

4.2 WHAT IS NEEDED

1. Mapping of all small and large dams in Europe and creation of a priority list for dam removals

Studies show that dam removal is a viable solution. However, there remains a lot of uncertainty about where the dams are located, which are obsolete, and which are the most appropriate for removal. Therefore the following actions are to be taken by appropriate water management authorities at a river basin level:

- Mapping of all dams in the river basin, data is stored in a transparent, easily accessible open-source database (building upon the database developed by the Horizon 2020 AMBER project);
- Development of a priority list of dams to be removed, based on an assessment of their impact, potential future benefits, viability and function.

2. Dam removal is integrated into River Basin Management Plans

European countries are obligated to produce River Basin Management Plans. Removal of obsolete obstacles is an attractive and viable solution, however in most countries this is not yet a mainstream measure. It is proposed that European Union Member States ensure:

- Development of an action plan for the prioritised removal of dams, and integration of this plan within the 3rd River Basin Management Plans;
- Redirection of finances to make funds available for dam removal in the 3rd River Basin Management Plans;
- Delivery of status reports on the progress of dam removal, including presenting the positive benefits of dam removal.

3. Involvement of local communities to remove dams

Case studies have shown that restoration of free -flowing river stretches and the return of migrating fish can improve community wellbeing and increase a sense of connection to and pride in the local environment. In Article 14 of the EU Water Framework Directive, Member States are required 'to encourage the active involvement of all interested parties in the production, review and updating of river basin management plans'. Participation can really be crucial in improving our rivers, and dam removal in particular is a measure that needs community participation and can be carried out by local people. Dam Removal Europe proposes that the appropriate water management authorities support the community in dam removal initiatives and that communities are encouraged to become more involved in dam removal projects.

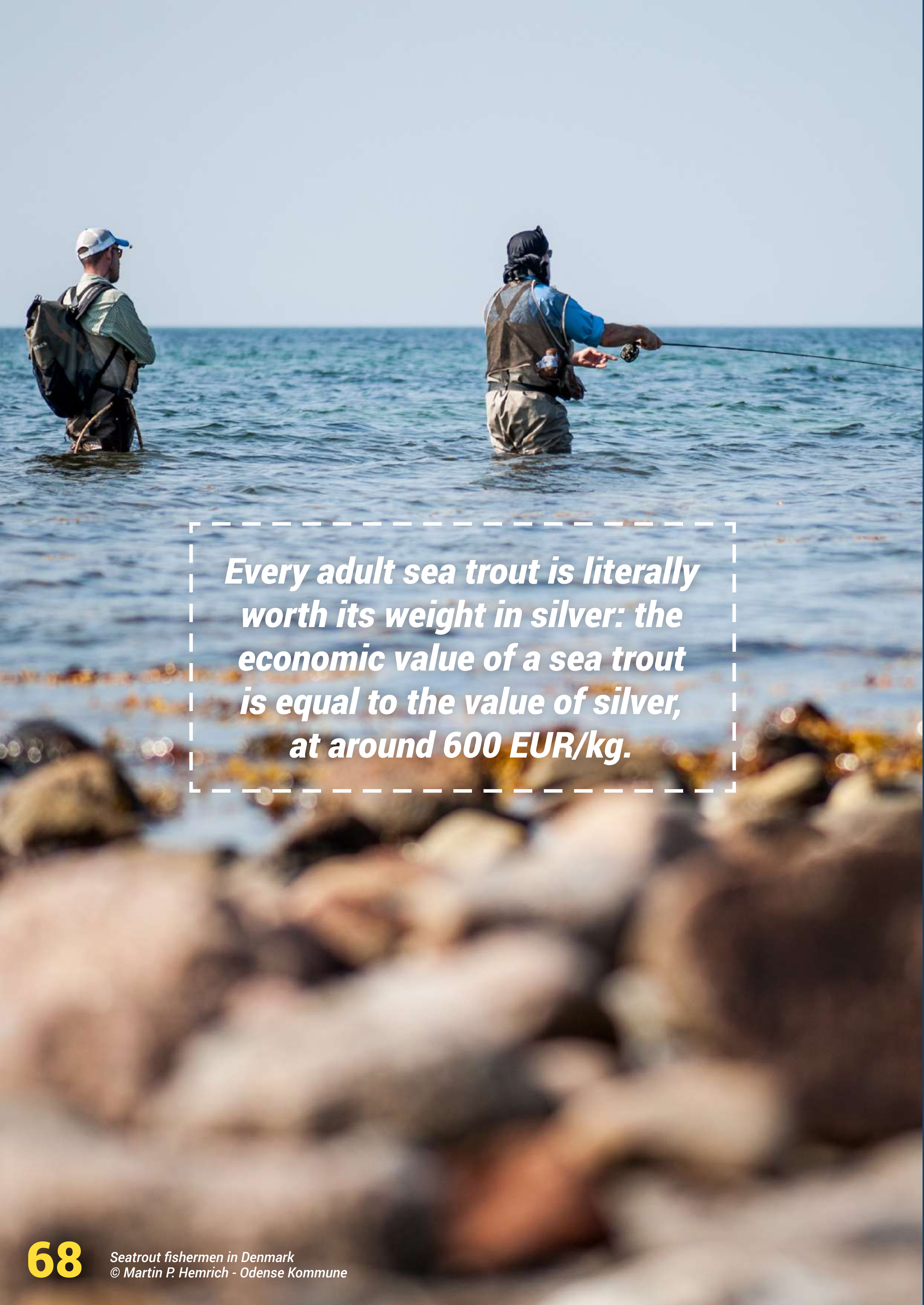
4. Alternatives to building new dams should be seriously considered and prioritised

While an increasing amount of evidence on the benefits of free-flowing rivers, and specifically the removal of dams, is becoming available, thousands of new dams are still being planned and promoted in Europe. Dam Removal Europe proposes that alternatives to building dams should first be seriously considered, and that reports of these studies should become available to the authorities and general public.

One of the many factors to be taken into account in these studies is the already extremely significant decline of freshwater species by 81%. For instances in which dams are considered by far the best or only alternative, all plans for modification of existing or construction of new dam infrastructure, large and small, must be fully evaluated by the relevant water management authority according to best international practice. This includes transparent reporting on its findings and full participation from stakeholders and civil society organisations. In this way, the cumulative effects can be assessed at river basin level, and priority should be given to maintaining the ecological integrity and functioning of the river and its wetlands.

© WWF

Returned salmon to the river
© Jan Kamman



Seatrout fishermen in Denmark
© Martin P. Hemrich - Odense Kommune

DAM REMOVAL SUPPORTS DEVELOPMENT OF "SEA TROUT ECONOMY"

On the Danish island of Funen, a unique and successful ecotourism project was set up to initiate recovery of the sea trout population and development of a "sport fishery economy". The project has been very successful in terms of ecology and economy. Today, tens of thousands of tourists visit the island each year to enjoy the landscape and fish for sea trout in the rivers and adjacent shallow coastal waters. Every adult sea trout is literally worth its weight in silver (the economic value of a sea trout caught by an anglers is equal to the value of silver, at around 600 EUR/kg).

In the 1980s, the rivers and fish populations were in a very poor state, both on the island and in Denmark more generally. To change this, the rivers were substantially improved. Local authorities and communities saw an opportunity for the development of the regional economy.

The removal of dams, weirs and other obstacles was an important part of the improvement plan, as were the improvement of water quality, river bank improvement, re-stocking of fish and fishery-free zones. Alongside this, a well-designed communications and marketing campaign was implemented for anglers in northwest Europe.

The "Sea Trout Funen" project is now a sound ecological and economic business venture. The project has had clear ecological benefits for migratory fish and other wildlife living in the brooks and rivers. In economic terms, it strengthened Funen's regional economy and the project is funded sustainably.

The economic business case consist of the following parts:

- Investment of 0.5 million EUR/year as base funding of the programme;
- Additional overnight stays (hotels, B&Bs, camping) of 64,000 "sea trout tourists", who spend an average of 640 EUR/person/visit;
- Additional "sea trout economy" turnover of 5.3 million EUR/year and 28 FTE jobs;
- Additional 0.5 million EUR/year in tax income for the regional authorities.

An additional benefit brought about by "sea trout tourism" is that it extends the recreational season, as sport fisherman come between September and May, when there are few other tourists in Denmark. Entrepreneurs and regional authorities consider the project to be very successful (source: Sport Fisheries NL, www.seatrout.dk and the municipality of Odense).

REFERENCES

AMBER (2018). https://amber.international/

American Rivers (2002). The Ecology of Dam Removal – a summary of benefits and impacts. American Rivers, Feb 2002.

Arcadis (2011). Hydropower Generation in the context of the EU WFD Contract N° 070307/2010/574390 EC DG Environment Project number 11418 | version 5 | 12-05-2011

Balian, E.V., Segers, H., Lévèque, C. and K. Martens. 2008. The Freshwater Animal Diversity Assessment: an overview of the results. Hydrobiologia 595 (1):627-637. Doi: 10.1007/s10750-007-9246-3.

Belletti,B., Bizzi,S., Castelletti,A., Garcia de Leaniz,C., Borger,L., Jones,J., Olivo del Amo,R., Segura,G., Tummers,J., va der Bund,W., and the AMBER consortium (2018). Small isn't beautiful: the impact of small barriers on longitudinal connectivity of European rivers. Geophysical research Abstracts 20: EGU2018-PREVIEW, 2018.

Birnie Gauvin, K., Aarestrup,K., Riis,T.M.O., Jepsen,N. and Koed,A. (2017). Shining a light on the loss of rheophilic fish habitat in lowland rivers as a forgotten consequence of barriers, and its implications for management. Aquatic Conserv: Mar Freshw Ecosyst. 2017;1–5.

Birnie-Gauvin, K., Candee,M.M., Baktoft,H., Larsen,M.H., Koed,A. and Aarestrup,K. (in press). River connectivity re-established: effects and implications of six weir removals on brown trout smolt migration. River Research and Applications.

Breve, N., Vis H., Spierts, I., de Laak, G., Moquette, F., and Breukelaar,A. (2013). Exorbitant mortality of hatchery-reared Atlantic salmon smolts Salmo salar L., in the Meuse river system in the Netherlands. Journal of Coastal Conservation

Deemer,B.R., Harrison,J.A., Li,S., Beaulieu,J.J., Del Sontro,T., Barros,N., Bezerra-Neto,J.F., Powers,S.M., dos Santos,M.A., Vonk,J.A (2016). BioScience, Volume 66, Issue 11, 1 November 2016, Pages 949–964,https://doi.org/10.1093/biosci/biw117

Druschke, C.G., Lundberg,E., Drapier,L. and Hychka,K.C. (2017). Centring fish agency in coastal dam removal and river restoration. Water Alternatives 10(3): 724-743

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A., Soto, D., Stiassny, M.L.J. and C.A. Sullivan. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. Biological reviews 81 (2): 163-182. Doi: 10.1017/S1464793105006950.

Environment Agency (2010). Mapping Hydropower Opportunities and Sensitivities in England and Wales Technical Report Final Report February 2010

EC (2016). Study on Technical Assistance in realisation of the 2016 Report on Renewable Energy, in preparation of the Renewable Energy Package for the Period 2020-2030 in the European Union - Task 3

EC, 2011. Water management, Water Framework Directive & Hydropower. Common Implementation Strategy Workshop. Brussels, 13-14 September 2011. Issue Paper (final version)

European Environment Agency (2018). European waters – assessment of status and pressures 2018 – third complete draft. State of Water Report.
Fieldstad,H.P., Barlaup,B.T., Stickler,M., Gabrielsen,S.E., and Alfredsen,K. (2012). Removal of weirs and the influence on physical habitat for salmonids in a Norwegian river. River Res and Applic. 28: 753-763.

Foley, M.M., Bellmore, J.R., Connor, J.E., Duda, J.J., East, A.E., Grant, G.E., Anderson, C.W., Bounty, J.A., Collins, M.J., Connolly, P.J., Craig, L.S., Evans, J.E., Greene, S.L., Magilligan, F.J., Magril, C.S., Major, J.J., Pess, G.R., Randle, T.J., Shafroth, P.B., Torgersen, C.E., Tullos, D., and Wilcox, A.C. (2017). Dame removal: listening in. Water Resour. Res., 53.doi:10.1002/2017WRO20457

Garcia de Leaniz, C.(2008). Weir removal in salmonid streams: implications, challenges and practicalities. Hydrobiologia, September 2008, Volume 609, Issue 1, pp 83–96
Garcia de Leaniz,C (2016). The damming problem of re-connecting European rivers: https://theconversation.com/the-damming-problem-of-reconnecting-europes-rivers-69913

Gauld,N.R., Campbell,R.N.B., and Lucas,M.C. (2013). Reduced flow impacts salmonid smolt emigration in a river with low-head weirs. Science of the total environment, 458-460: pp 435-443
Grabowski, Z; Heejun Chang; Elise L. Granek, 2018. Fracturing dams, fractured data: Empirical trends and characteristics of existing and removed dams in the United States. Portland State University.

KPMG (2010). Energy and natural resources – central and eastern European hydropower outlook. www.KPMG.com

Lenders,H.J.R., Chamuleau,T.P.M., Hendriks,A.J., Lauwerier,R.C.G.M., Leuven,R.S.E.W., and Verberk,W.C.E.P. (2016). Historical rise of waterpower initiated the collapse of salmon stocks. www.nature.com/scientific reports. 6:29269/DOI: 10.1038/srep29269

McClenachan,L., Lovell, S., and Keaveney,C. (2015). Social benefits of restoring historical ecosystems and fisheries: alewives in Maine. Ecology and Society 20(2):31. http://dx.doi.org/10.5751/ES-07585-200231

McCully, P., 2001). Silenced Rivers: The Ecology and Politics of Large Dams. Zed Books, London
Natural Loire River Plan (1994).Plan Loire Grandeur Nature. River Net. European Rivers Network.

Ohio Environmental Protection Agency (2017). Dam removal trend is major economic growth opportunity for the United States and its cities. The Journal of Urban, Rural and Environmental Resilience issue #48 April 2017. https://revitalizationnews.com/article/dam-removal-trend-huge-economic-growth-opportunity-america-cities/#.Wy4yMqdKiUk

PBL Netherlands Environmental Assessment Agency, 2018. The Geography of future water challenges. PBL, Deltares, Wageningen University, IVM Amsterdam, IHE Delft, Clingendael, Utrecht University, Blue Land. 2018

REN21. (2016). Renewables 2016 Global Status Report (Paris: REN21 Secretariat). ISBN 978-3-9818107-0-7

Schweiger, P.G. (2011). Saving lives while improving fish passage at "killer dams". The Journal of Dam Safety: 9 (20. ISSN 1944-9836

Thomas,R.J., Constantine,J.A., Gough,P. and Fussell,B. (2014). Rapid channel widening following weir removal due ot bed material wave dispersion on the River Monnow, Wales. River Res. Applic. DOI: 10.1002/rra.2803.

Tranvik, L. J., Downing, J. A., Cotner, J. B., Loiselle, S. A., Striegl, R. G., Ballatore, T. J., ... Weyhenmeyer, G. A. (2009). Lakes and reservoirs as regulators of carbon cycling and climate. Limnology and Oceanography, 54(6 PART 2), 2298-2314.

Water authority Rijn en Ijssel, 2016. Redevelopment Boven Slinge. First results. The Netherlands. 2016.

Vorosmarty,C.J., McIntyre,P.B., Gessner,M.O., Dudgeon,D., Prusevuch,A., Green,P., Glidden,S., Bunn,S.E., Sullivan,C.A., Liermann,C.R., and Davies,P.M. (2010). Global threats to human water security and river biodiversity. Nature 467: 555-561.

WWF (2016). Living Planet Report 2016. Risk and resilience in a new era. WWF International, Gland, Switzerland.

Yale Environment 360 (2015). https://e360.yale.edu/

DAM REMOVAL EUROPE

www.damremoval.eu