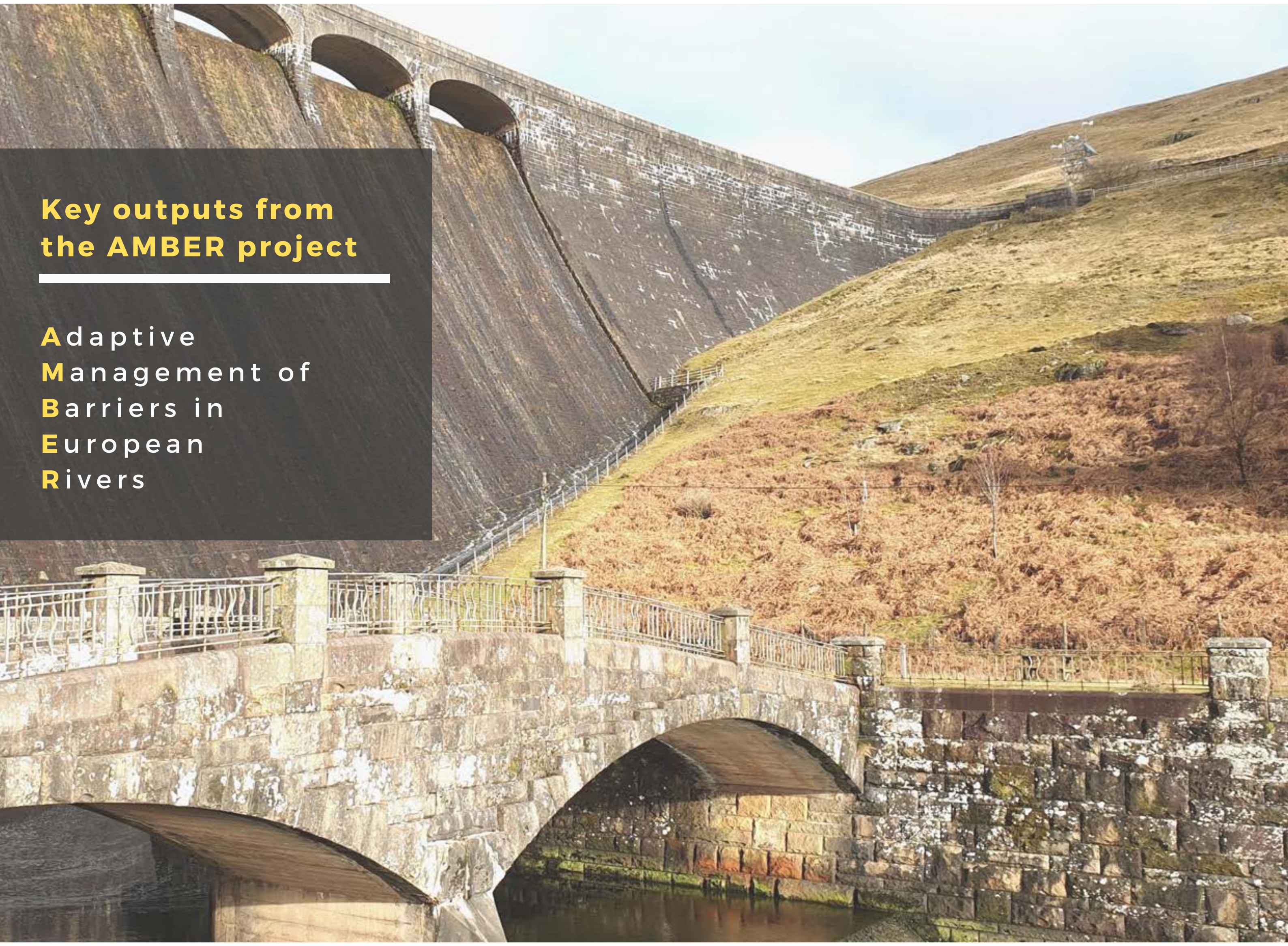
AMBER POLICY BRIEF 3



IMPACTS OF BARRIERS ON BIODIVERSITY OF RUNNING WATERS

This policy brief summarises the main impacts of artificial instream barriers on the biodiversity of running waters, derived from work carried out in WP2 and WP3 as part of the H2020 AMBER project

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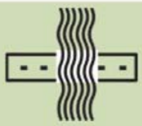
1. INTRODUCTION

The fragmentation of riverine habitats caused by barriers is one of the five main causes of biodiversity loss (Baudoin et al., 2014). Although barrier impacts are most obvious in the case of fish, it is important to also consider impacts on other biota to properly understand the impact of fragmentation on river biodiversity. ECOSTAT (2016) has stressed that fish should not be the only biological quality element used to assess Good Ecological Potential within the Water Framework Directive, even if barrier impacts on fish will usually be greatest.

Barrier impacts on river biota vary widely depending on species, habitats and barrier types, making global assessments difficult. For this reason AMBER developed a conceptual model that takes in account different river habitats and barrier types (Parasiewicz et al. 2018; Parasiewicz et al. 2019), and reviewed barrier impacts on different components of biodiversity (AMBER Deliverable 2.1., v2.0 https://amber.international/deliverables-2/).

Artificial barrier types can be grouped into six main functional types (Jones et al., 2020a), that differ in their impacts and call for different mitigating solutions (Table 1).

Table 1. The six functional types of longitudinal instream barriers identified in the AMBER project and potential solutions to reduce their impacts.

Barrier type	Description	Pictogram	Appropriate solutions
Dam	A barrier that blocks or constrains the flow of water and raises the water level resulting in permanent ponding		Side channels, engineered fish ways and nature-based solutions that ensure upstream and downstream passage over a wide range of flows and for the largest possible number of species, sizes, and life stages
Weir	A barrier that regulates the flow and water level where water flows freely over the crest		
Sluice	A movable barrier aimed at controlling water levels and flow rates in rivers and streams		Left open most of the time, so that it does not block fish movements
Culvert	A structure that carries the stream flow under an obstruction or river-road crossing		Connected to the river bed, it has a natural substrate, a low velocity and sufficient water depth to make it passable all year
Ford	A structure in a river or stream which creates a shallow place for crossing		There must be enough depth to guarantee fish passage all year
Ramp/ bed-sill	A structure designed to stabilize the channel bed and reduce bank erosion, recognizable by its stairway-like shape		There must be corridors between blocks to permit fish passage all year

2.BARRIER IMPACTS ON FISH

Recognising that there is substantial variation in barrier impacts is key for minimising the impacts of river fragmentation and also for designing more efficient fish passes, which are in many cases inefficient. Research on barrier impacts and fish passage has traditionally focussed on salmonids and other strong swimmers, largely ignoring other fish (Kemp, 2016). This partly reflects the common misconception that only migratory fish are affected by barriers (Birnie-Gauvin et al., 2018). However nearly all riverine fish undertake longitudinal movements along river networks to complete their life cycles and will be impacted by instream structures that impede their movements (Lucas et al., 1999).

European rivers can be classified into 15 different macro-habitat classes that differ in fish communities and in the predicted habitat alterations caused by barriers (Figure 1)

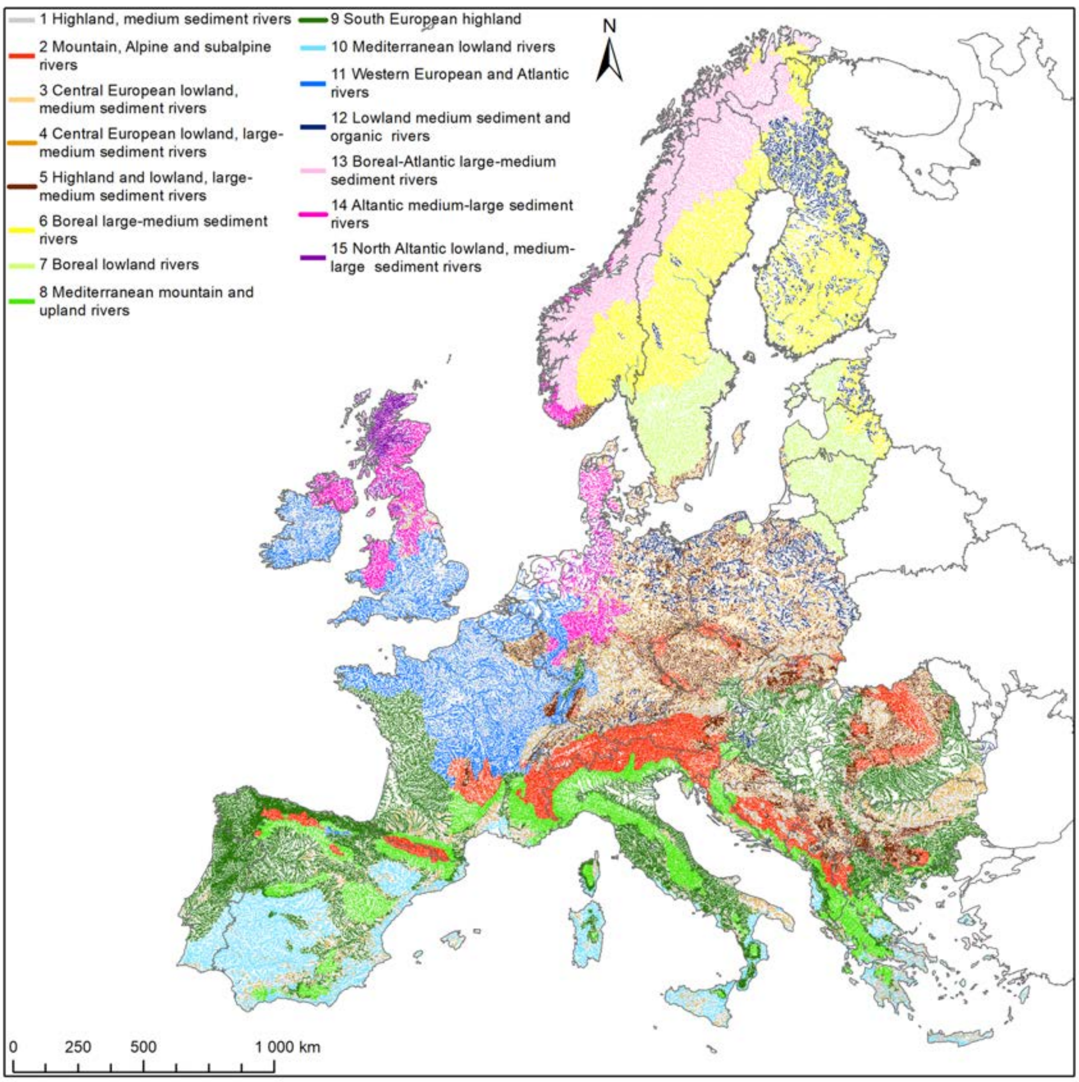
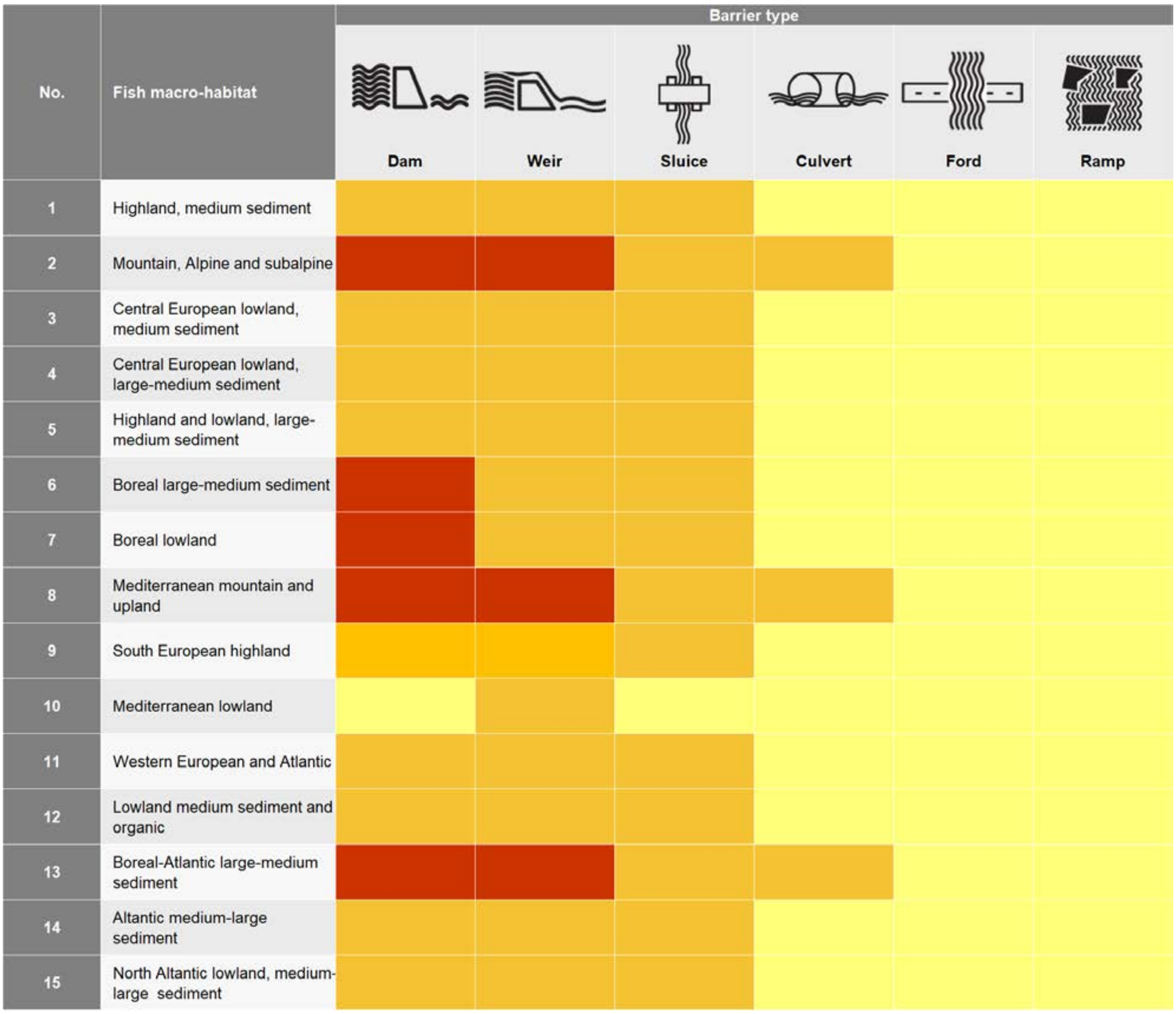


Figure 1. European rivers classified into 15 Macrohabitat types (AMBER D2.1, version 2.0).

The expected impact of different instream barriers on different fish macro-habitats are summarised in Table 2 in terms of loss of habitat.

Table 2. Predicted impact (penalized by loss of connectivity) of different instream barriers on the availability of 15 main fish macrohabitats present in European rivers red – severe habitat loss (>90%), orange – major habitat loss (50-89%), yellow – significant habitat loss (25-49%). AMBER Deliverable 2.2.



2. BARRIER IMPACTS ON FISH

2.1. DAMS AND WEIRS

Dams and large weirs (Figures 2-3) tend to impact fish and other biota to a greater extent than any other barrier as they affect both the habitat, the flow, and the movement of organisms. They can be particularly damaging on high energy rivers, where macro-habitats No. 2, 6, 7, and 13 are most common (Table 2), but also on lowland rivers where their effects can extend over longer distances (Birnie-Gauvin et al. 2017).

Figure 2. Examples of dams (photos: I.Wagner, ERCE; K. Suska, SSIFI, Poland).

Figure 3. Examples of overflowing weirs (photos: I.Wagner, ERCE; K. Suska, SSIFI, Poland).

2. BARRIER IMPACTS ON FISH

2.1. DAMS AND WEIRS

IMPACTS

CHANNEL BLOCKING

Channel blocking by dams and weirs can result in the extirpation of migratory fish if they are not able to reach the spawning areas, but also in a reduction in the abundance of freshwater resident fish which may not be able to complete their life cycle in parts of the river.

PONDING

Ponding caused by dams can shift fish communities as running waters are slowed down and converted into reservoirs. Ponding alters the macroinvertebrate communities and increases plankton abundance which favours the colonisation of planktivorous fish.

CHANGES IN CHANNEL MORPHOLOGY

Engineered structures associated with dams (like channels, dykes and levees) can cause the loss of floodplains and associated habitats (e.g. oxbow lakes) which can affect the growth and reproduction of obligate floodplain spawners, reducing fish diversity and overall productivity.

FLOW REGULATION AND CHANGES IN WATER VELOCITY

The operation of some dams alters the natural flow regime and this can disrupt the spawning of some fish, changing the fish community structure from seasonal spawners to more flexible species that are better able to cope with unnatural flows caused by flow regulation and hydro-peaking. Fish mortality can occur due to stranding after periods of extreme discharge. A frequent fluctuation of water velocity in the channelised reach downstream from the dam can alter fish communities due to the colonisation by resistant generalist species and loss of habitat for drifting larvae. The reproductive success of some species may decrease due to rapid flooding of nesting sites.

SILTING AND CHANGES IN WATER QUALITY

The growth of vegetation in the reservoir along with increase silting may cause a change in fish community structure. Increased erosion below the dam may also result in a reduction of non-visual predators. Substrate armouring and siltation can impact on benthic species and fish larvae. A shift in spawning time and reduction of reproductive success may occur due to increasing variation in water temperature. Thermal stratification in the reservoir may impair fish migrations, while oxygen starved waters may render the habitat unsuitable for many species. Fish mortalities may also occur in the reservoir due to water pollution and toxic algal blooms, especially in reservoirs with a high retention time. Flushing of anoxic waters, toxic sediments and hydrogen sulphide can reduce growth and cause fish mortalities downstream of the dam.

2.1. DAMS AND WEIRS

OPERATIONAL IMPACTS

Turbines, screens and pumps can damage fish.

SOLUTIONS

The main mitigating solutions include:

REMOVAL OR PARTIAL BREACHING

This will typically be the preferred solution in the case of abandoned structures, whenever possible.

NATURE-TYPE FISHWAYS, SIDE CHANNELS, AND ENGINEERED FISH PASSES

These need to ensure that upstream and downstream passage is possible over a wide range of flows and for the largest possible number of species, fish sizes, and life stages.

RE-NATURALISATION AND COMPENSATION MEASURES DOWNSTREAM

Re-naturalisation of the channel downstream can increase habitat availability under modified flow conditions and support appropriate fish communities. The creation of spawning channels may offer some compensation for lack of access to spawning areas upstream.

OPERATIONAL MEASURES

Maintenance of appropriate environmental flows, coupled with a reduction in the frequency and magnitude of flush flows and an extension of peak rise times will help to support downstream fish communities.

2.2. SLUICE GATES

IMPACTS

Sluice gates (Figure 4) can block streams temporarily (but also permanently) and cause significant losses of fish habitat (Table 2). Rapid flow fluctuations may result in the drying up of fish habitat or the washing out of sensitive life stages downstream. Particularly damaging are the flow releases at navigation locks or the release of water at reservoirs during clean-up.

SOLUTIONS

With adequate management, the impact of sluices can be reduced, for example in some places sluice gates can be left open during critical times to avoid blocking fish migrations.

Figure 4. Examples of sluice gates (photos: Z. Kaczkowski (ERCE; Polish Waters Warsaw).

2.3. CULVERTS

IMPACTS

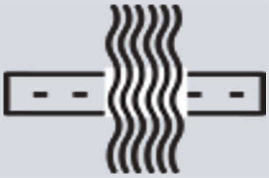
Culverts are a popular and cheaper alternative to bridges at river-road crossings (Figure 5), but can have negative impacts on river morphology, hydraulics and biota, particularly on macro-habitats No. 2 (mountain, alpine and subalpine), No. 8 (Mediterranean mountain and upland) and No. 13 (Boreal-Atlantic large-medium sediment; Table 2). Culverts may hinder fish passage due to high water velocities, low water depth, lack of shelter, high outflows and debris jams (Kemp and Williams, 2008). This can increase fish energy expenditure, vulnerability to predators, angling mortality, and risk of diseases below culverts. Particularly problematic are perched culverts, where there is a head drop at the outflow. Culverts can also affect fish habitat by altering the transport of sediment, woody debris, and organic material.

SOLUTIONS

Some culverts and bridges can be modified to allow fish passage at road crossings, but not all can maintain sediment and wood transport, and many may affect channel morphology. Open-bottom culverts or embedded (e.g., countersunk) pipe-arch culverts allow a natural substrate to form within the channel (Figure 5) and can improve fish passage (Roni et al., 2002).


Figure 5. Examples of culverts (left) and one of the mitigating solutions (right). Photos: Z. Kaczkowski, AMBER.

2.4. FORDS



IMPACTS

The impact of fords on biota, especially on migratory fish, has only recently started to be investigated (Figure 6). Fords can alter the transport of sediments and block the movements of organisms.

SOLUTIONS

In some cases, the removal of unnecessary fords, or improved ford design, can help mitigate their impacts. For example, fords can be redesigned so that they include a section with enough water depth to guarantee fish passage all year.

Figure 6. Examples of fords (photos: Z. Kaczkowski; SSIFI; AMBER).

2.5. RAMPS

IMPACTS

Ramps are ubiquitous in European rivers to reduce bank erosion under bridges and in modified river channels (Figure 7 left), but can disrupt connectivity and migration opportunities for some fish species.

SOLUTIONS

Ramps can be modified to incorporate corridors to allow fish passage in low-flow channels (Figure 7 right; Plesiński et al., 2018).

Figure 7. Examples of a ramp under bridge (left) and mitigating solution (right) (photos: Z. Kaczkowski, SSIFI; AMBER).

3.BARRIER IMPACTS ON NON-FISH BIOTA

Compared to fish, much less is known about the impact of barriers on non-fish biota such as macroinvertebrates and macrophytes. This is in part due to the common misconception that only fish need to disperse and that macroinvertebrates and macrophytes are sedentary and therefore not impacted by barriers.

The impact of dams and weirs on invertebrates is mostly through changes in water quality, hydraulics and river morphology below impoundments, particularly downstream of nutrient-rich (eutrophic) reservoirs. In non-eutrophic reservoirs, the greatest impact comes from changes in summer temperatures that may disrupt development. Nutrients released from the bottom of eutrophic reservoirs can make the river downstream eutrophic and increases the abundance and richness of submerged macrophytes and algae.

Weirs can also impact on the diversity and abundance of macroinvertebrates. For example, some freshwater mussels disperse as larvae attached to the gills of some fish, and if fish movements are disrupted, freshwater mussels cannot colonise new habitats. Likewise, dams and weirs can also have major impacts on the composition and diversity of macrophyte communities (Figure 8) and studies have shown that heavily fragmented rivers tend to have impoverished macrophyte communities.

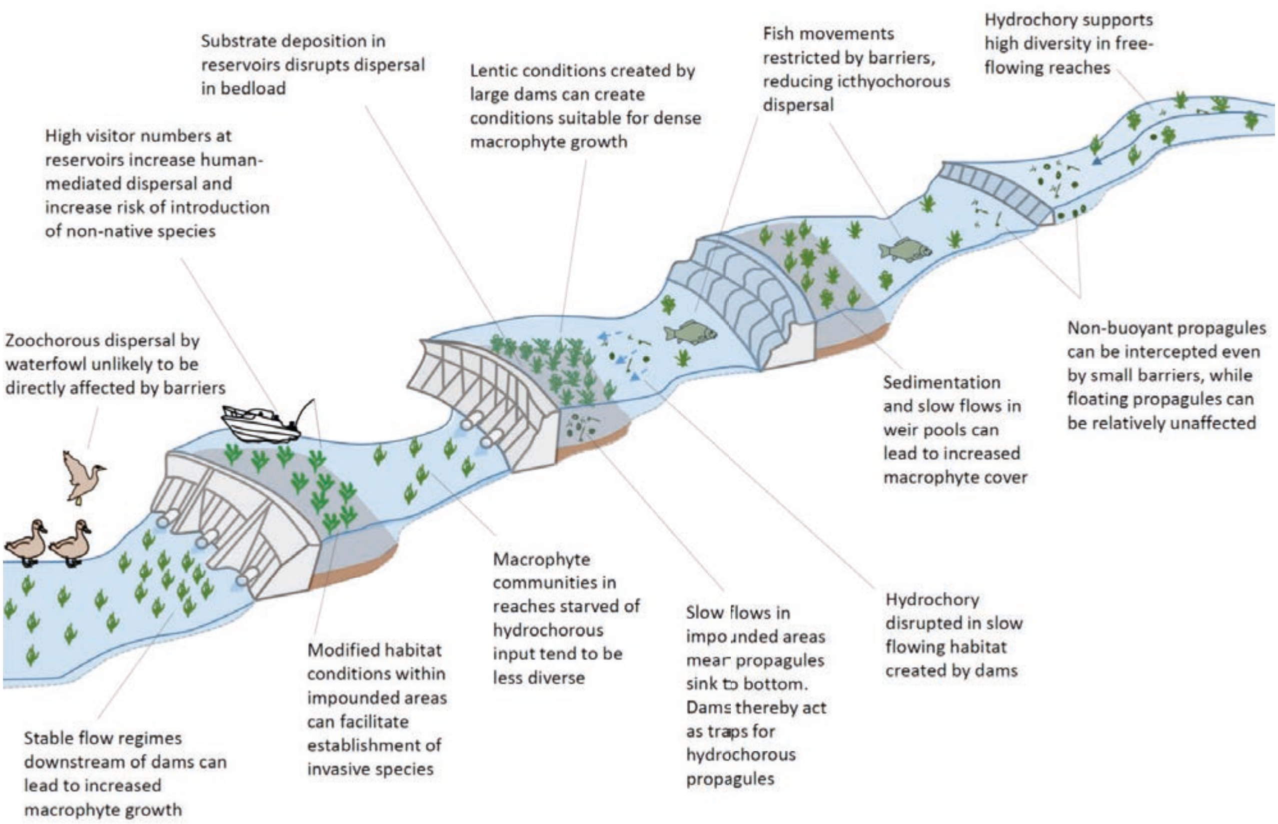


Figure 8. Some impacts of barriers on aquatic macrophytes (adapted from Jones et al,. 2020b)

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