Fully functional fishways

Executive summary

Migratory fishes provide essential ecosystem services as well as economic and ecological benefits along their swimways [1, 2]. Their importance in ecosystem functioning is recognized across multiple EU policies which directly or indirectly aim to conserve and improve the status of their populations and habitats, and the ecosystem services they provide 75% decline in migratory fish populations over the past 50 years. This is mainly caused by disrupted connectivity and habitat loss due to hydrological changes. Thus, restoring fish migration routes, i.e., swimways, is key to meeting the ecological objectives of the EU environmental policy framework. Although restoring natural connectivity would be the ideal solution, fishways can be a second-best option when barriers are deemed un-removable. numerous fishways have been poorly implemented, limiting their effectiveness despite high construction and maintenance costs. This brief makes the case for the urgent need for proper (re)placement of fishways—prioritising nature-like designs and only considering technical solutions where necessary—to ensure lasting ecological improvements along swimways. While this brief builds onto the EU environmental policy framework to suggest recommendations, a decision-tree and timeline, best-practice can derived from its content to be adapted for swimways located beyond EU borders.

Recommendations

1. Prioritise connectivity solutions based on ecological gain, costs and local perception, as detailed in the connectivity priority list;
2. Where fishways are to be implemented or refurbished, to respect the seven key ecological principles for up- and -downstream passage;
3. Use the decision-tree and follow the suggested timeline ensuring legal requirements are fulfilled and swimways connectivity has been restored wherever possible by 2040.

Introduction

Migratory fishes[1] provide essential ecological and economic benefits, from sustaining local fisheries to altering nutrient flows across ecosystems, impacting food webs across swimways[2]. This influence at an ecosystem level highlights the importance of healthy populations of migratory fishes [2,3,4], whose health and conservation contribute to meet the objectives Water Framework Directive (WFD) [5], the Nature Restoration Regulation (NRR) [6], the Habitats Directive (HD) [7] and the EU Biodiversity Strategy for 2030 (EU BDS) [8].

Despite their importance, populations of migratory fishes in Europe have declined by a staggering 75% in the past 50 years [9], largely due to habitat degradation and human pressures [10]. In particular, the disrupted connectivity induced by the construction of dams and weirs, alteration of rivers' hydromorphology drive the loss of suitable habitats [2]. Conversely, restoring these freshwater habitats and the routes that support migratory fishes enhances connectivity, and aids the recovery of fish species and thus contributing to the objectives of the WFD, NRR, HD, and EU BDS [5,6,7,8,11] and enhances the ecosystem services they provide.

More than 1.2 million barriers fragment European rivers and fish habitats [34] – removing all of them will not be possible in in time to address the crisis freshwater fishes are facing. Best practice solutions, such as fishways, can alleviate the impacts of unremovable barriers and contribute to restore connectivity along swimways. [12]. However, poor planning, design, and placement, together with insufficient admission flow, have often led to ineffective fishways, despite significant investments [13, 14]. To meet EU policy goals, future fishways must be strategically designed and implemented.

Fish migration in EU policy

Migratory fishes are featured in several essential EU environmental policies. Under the WFD [5], migratory fish fauna is among the biological indicators of the Good Ecological Status (GES) of EU surface waters. Restoring fish habitat condition through barrier removals or the installation of fully functional fishways could directly benefit some of the 63% of EU surface waters in poor ecological condition [35].

The protection of migratory fishes in the EU is also enshrined in the HD [7], with 69 species of freshwater migratory fish listed on its annexes II, IV, and V. Moreover, the EU BDS [8] aims to improve the conservation status of at least 30% of species and habitats listed in HD annexes and not currently in Favourable Conservation Status (FCS), such as migratory fish species and freshwater habitats, while the NRR sets requirements to restore the habitats of those species not in FCS, as well as, the restoration 25 000 kms of free flowing rivers [6]. The European Eel Regulation [17] supports connectivity restoration to aid the recovery of the globally Critically Endangered European eel for their ecological, economic and cultural significance.

Even the Revised Renewable Energy Directive (REDIII)–aiming to facilitate the rapid deployment of renewables in designated areas, i.e 'renewables acceleration areas' (RAAs)–requires compliance with environmental safeguards to avoid jeopardizing the uncertain future of migratory fishes.

Migratory fish in ecology and economy

Beyond EU environmental policy, migratory fishes provide ever important ecosystem services and tangible ecological, economic and cultural benefits. Economically, improving and safeguarding fish populations will support regional development through tourism and fisheries.
Approximately 20 million EU citizens are anglers and many of their most prized targets such as the salmons, sea trout and graylings are migratory species. Recreational angling for Atlantic salmon in Germany and Finland boasts average expenditures of €2750 to €3461 per angler/boat, while minimizing impact on the salmon stocks [19]. In parallel, connectivity improvements benefit a majority of riverine freshwater species, most of which undertake some form of migration, enhancing populations and unlocking sustainable commercial harvest and recreational fisheries potential.

[1] In this publication migratory fishes are defined as all potamodromous and diadromous species that undertake both long and short distance longitudinal or lateral migrations (3), in line with the European species identified by Heather Bond and Szabolcs Nagy [15]

[2] The rivers and their associated ecosystems that support the entire migration routes of freshwater migratory fishes [1]

Culturally, migratory fishes are deeply embedded in European heritage, as widely reflected in culinary and community traditions [20,21,22]. These fascinating species are praised throughout Europe during celebrations like the Scottish salmon festivals [23], the West Wales Coracle Caught Sewin [24], and the Fockbeck Aalversuuperdaag in Germany [25], through representations in heraldry and civic symbols [26] and in creative expressions, ranging from song and poetry to artworks and literature [20,21,22]. Conserving and restoring migratory fish populations actively contributes to the preservation of our cultural identity.

Ecologically, migratory fishes are critical for ecosystem functioning through nutrient cycling and transport between ecosystems. For instance, through transporting marine-derived nutrients inland or through lateral migrations between waterways and their connected wetland habitats, they support broader food web dynamics. This benefits predatory fauna, detritivores, and riparian vegetation [2, 27]. Investing in effective fish passage solutions therefore delivers cross-cutting policy returns, strengthening biodiversity, ecosystem health, and socio-economic value across the EU.

Fish passage solutions

Despite large-scale efforts to restore migratory fish populations, their continuing decline over the past 50 years highlights the need for more effective measures along swimways. Barrier removal remains the most effective, and often the cheapest, solution. Beyond fish migration, barrier removal provides a multitude of co-benefits, from habitat restoration to improving water and disaster risk resilience. When this is not feasible, alternative measures aiding fish migration have been sometimes implemented. While helpful, trap-and-release methods applied require sustained effort and offer no long-term fix. Stocking programmes are widely used to support population enhancement, yet lack long-term viability without habitat and connectivity restoration. These limitations reaffirm the need to prioritise fishways that are as close as possible to fully functional and free swimways, to secure access to essential spawning and foraging habitats where barrier removal is not an option [2].

Achieving effective fishway implementation in the EU

1. Lessons from the past

Historically, limited knowledge, a narrow focus on select species, and mismatches between projects' objectives have undermined fishways' functioning. Fishways primarily targeted economically valuable anadromous species[3], leaving broader fish communities unsupported. Furthermore, emphasis was placed on upstream migration, overlooking active and passive downstream passage (e.g. of drifting eggs and larvae) and lateral migrations on which some species rely to access floodplains for spawning or nursery habitats. These gaps were compounded by underestimation of species-specific needs and the assumption of technical fishways[4] sufficing regardless of context. Frequently, unclear objectives, poor design choices, and insufficient consideration of fish attraction, hydrology, and behaviour have led to ineffective fishways [13, 28, 29]. Social and economic constraints often deprioritize functionality, reducing gains in biodiversity, ecological status, and support for species under the HD. To meet regional ecological, economic, and policy goals, future fishways must be strategically and correctly implemented, to cater for the full range of species' needs.

[3] Anadromous fish reproduce in freshwater, while migrating to sea to fulfill their lifecycle. Besides anadromous fish, the classification of diadromous fish contains catadromous fish, reproducing in saltwater and migrating into freshwater, and amphidromous fish, residing in saltwater and migrating into freshwater for refuge or feeding purposes [2].

[4] Fishways can either be nature-like, like bypasses or technical, like fish ladders or other technical structures to aid fish passage at barriers [28].

2. Ecologically aligned fishways

To improve passage, fishway design must align with both the capacities and behaviour of all target species of conservation concern, of cultural importance and/or of economic importance. Successful passage depends on placement, size, swimming ability, and abiotic conditions in and around fishways. This makes fishway design and correct placement critical to ensure functioning. To achieve multispecies fishways, effectively supporting all species, seven ecological principles for up- and downstream passage must be met [2,29,30,31](See Box 1).

By following these principles, fishways can effectively improve fish passage and support riverine biodiversity.

Box 1: The seven ecological principles to achieve multispecies fishways

1. **Attraction** → Fish must be able to find the opening of the fishway. A strong attraction flow, ideally above 10% mean flow all while placing the opening in the natural migration route as far upstream as possible.
2. **Willingness to enter** → Fishway entries must align with species-specific behavioural needs, possibly by including different entry points.
3. **Ability to enter** → Entrance must match the capacities and sizes of all target species.
4. **Willingness to pass** → Fishway conditions must invite - by having the design streamlined to the behaviours of all target species - passage by reflecting natural conditions.
5. **Ability to pass** → Design must entail suitable flow, resting areas, and size - aligned to all target species - to allow full passage.
6. **Willingness to exit** →Exit design must meet behavioural needs - of all target species - for successful migration.
7. **Ability to exit** → Exits must allow physical passage for all sizes and swimming strengths.

3. Priority list: from barrier removal to technical fishways

When improving fish migration in drought-resilient waterways[5] , a best-practice approach should prioritise solutions based on ecological gain, costs, and local perception. Barrier removal is the most effective option but is not always feasible. Fully functional nature-like fishways, ideally combined with habitat restoration, provide a next-best alternative if barrier removal is not feasible within the next 10 years. Where these are not feasible, technical fishways may serve as a last resort. Based on these factors, the prioritisation of measures detailed in Box 2 is advised.

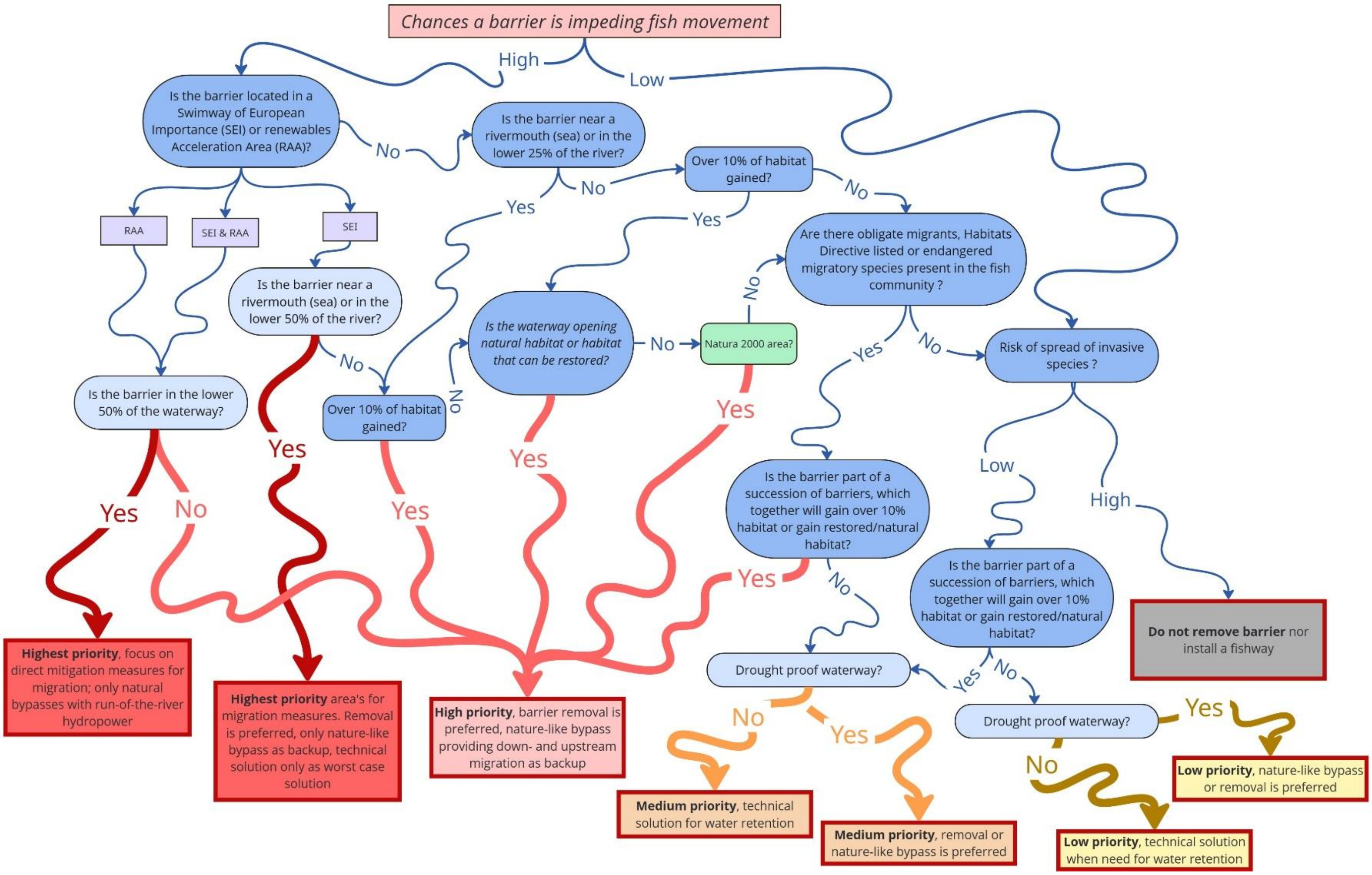
Box 2: Connectivity priority list [2, 30, 31]

1. Barrier removal with habitat restoration to restore natural flow and niche-rich environments;
2. Barrier removal without additional habitat restoration efforts;
3. Nature-like bypasses with downstream migration facilities;
4. Nature-like bypasses without downstream migration facilities;
5. Bidirectional fishways designed to suit all local species of concern;
6. Unidirectional fishways, if downstream migration is relatively safe, designed to suit all local species of concern;
7. Bidirectional fishways designed for the broadest aquatic community of concern;
8. Unidirectional fishways designed for the broadest aquatic community of concern.

[5] With climate change, waterways can also become more susceptible to droughts. In case a waterway is resillient enough to droughts, a nature-like solution to mitigate fish migration should be prioritised, yet in waterways where water retention is a main driver of connectivity loss, a technical fishway will be preferred.

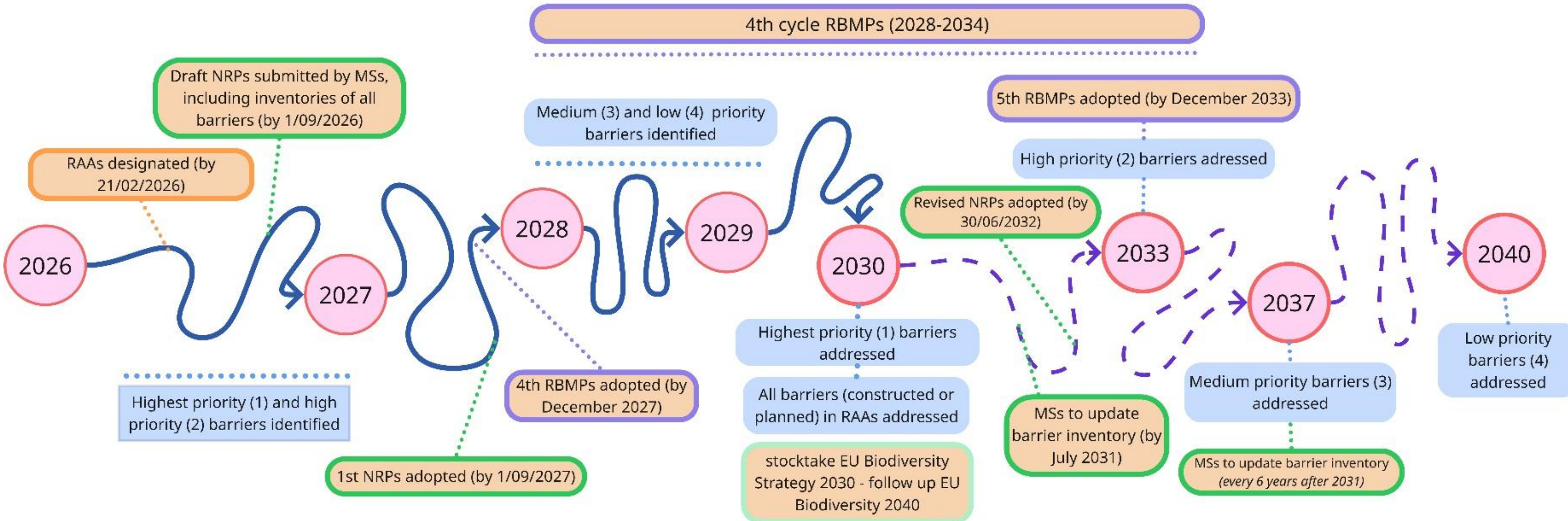
4. Where should efforts be focused on

Not all barriers hold equal weight. Highest priority should be given to barriers in the lower reaches of all swimways, often blocking numerous species, and barriers in RAAs and along major swimways. High-priority sites consisting of barriers that block a high diversity of highly migratory species, or species of conservation concern or protected under the HD, should then be targeted. Lastly, both barriers unlocking access to large areas or high-quality habitats and barriers whom, in succession, block these habitats, should be addressed to achieve the greatest ecological return and enhance aquatic biodiversity. This leads to the following decision tree [32].



5. When to address which barrier

With key policy milestones on the horizon, highest priority and high priority barriers shall be identified as soon as possible to ensure (1) their inclusion in the draft NRPs and 4th cycle of RBMPs while (2) respecting public consultation requirements under both processes. From mid-2026 up to mid-2028, highest priority barriers shall be removed or mitigated through fishway implementation. The REDIII allows MSs to exclude hydropower plants from RAAs. Hence, we encourage MSs to exclude hydropower plants in SEIs, as it is the safest way to conserve fishes migratory routes and habitats. Should MSs designate RAAs for hydropower development, hydropower plants and associated infrastructure projects such as storage and grid connectivity projects located in RAAs must comply with the mitigation rulebook of each MSs. New and refurbished barriers shall undergo Strategic Environmental Assessment or Environmental Impact Assessment procedures to ensure compliance with connectivity criteria under the HD. To achieve the environmental policy objectives set out for 2030, the impacts of renewable energy infrastructure shall be addressed before 2030 at the latest, preferably prioritising nature-like bypasses to prevent biodiversity loss induced by hydropower development. Similarly, best practice fishways should make high-priority barriers passable by 2030 at the latest, aligning with the EU BDS and obligations under the HD and NRR. The following timeline summarizes when it is advised to address which barrier in light of the above information.



6. Culverts

Culverts, i.e. pipes or tunnels to direct water under roads and other infrastructure, are often overlooked in Europe. However, these also restrict lateral fish migration significantly in the backwaters of swimways. Adapting culvert design to migratory species can contribute to the restoration of crucial lateral connectivity, making culvert retrofitting a key measure supporting migratory fish habitat restoration and the achievement of WFD, EU BDS, and NRR objectives. Culverts should maintain instream habitat continuity, in line with the natural stream gradient and stream width, while providing adequate water depth and velocity. Avoiding drops at inlets and outlets is crucial for non-jumping fauna. Last, natural substrates should be included throughout the culvert.

7. Fishway maintenance and monitoring

Maintenance should start already during the design phase, when a maintenance protocol aimed at the target species and a fishway design that allows safe access,

drainage, and debris prevention shall be established. Minimal maintenance should include a full inspection and servicing before every migration period, and monthly checks during the period. Fishway monitoring is crucial after the establishment of fishways in new settings or for fishways that could not be designed according to the prevalent state-of-the-art guidelines, to evaluate actual fishway performance. While hydrological monitoring confirms hydraulic suitability, ecological monitoring verifies actual fish passage. Lastly, monitoring the state of the fishway should be an ongoing part of the maintenance protocol. This ensures that the fishway works as intended. Fishway efficiency should be prioritised in monitoring to reveal delays and failed attempts to pass the barrier. Integrating maintenance and monitoring progress toward biodiversity and connectivity targets. Most importantly, it is key to ensure that swimways reopened for migration through fishway implementation do not deteriorate over time and fulfil their long-term objectives of continuous improvement of environmental quality as prescribed in the WFD, HD and NRR [33].

Recommendations

1. Prioritise connectivity solutions based on ecological gain, costs and local perception, as detailed in the connectivity priority list;
2. Where fishways are to be implemented or refurbished, to respect the seven key ecological principles for up- and -downstream passage;
3. Use the decision-tree and follow the suggested timeline ensuring legal requirements are fulfilled and swimways connectivity has been restored wherever possible by 2040.

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Recommended citation

Dragt, Tom, Cordier, Emma & Nagy, Szabolcs (2025). Fully functional fishways. Wetlands International Europe, Brussels, Belgium.

Acknowledgments

This brief was made possible thanks to the support and guidance of the Trans-European Swimways Network, and in particular Twan Stoffers (WUR), Matt Ford (IUCN SSC), Christian Wolter (IGB), Beate Striebel (WWF CEE). A special thank you to all for your time.

Disclaimer: Funded by CINEA. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of CINEA. CINEA cannot be held responsible for them.

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