Dec 11th, 11:40 AM - 12:40 PM

Upstream passage and attempt behaviour at a sloping weir by migrating adult river lamprey: are studded tiles effective in improving longitudinal connectivity?

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Enhancing the upstream passage of river lamprey at a microhydropower installation using horizontally-mounted studded tiles

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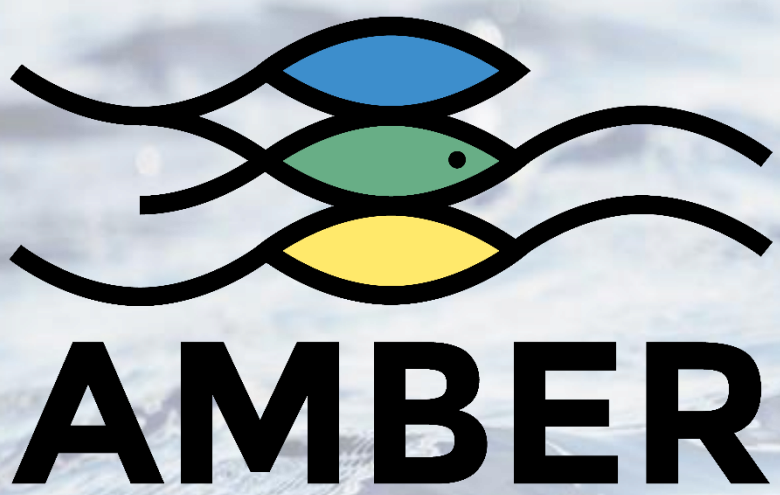
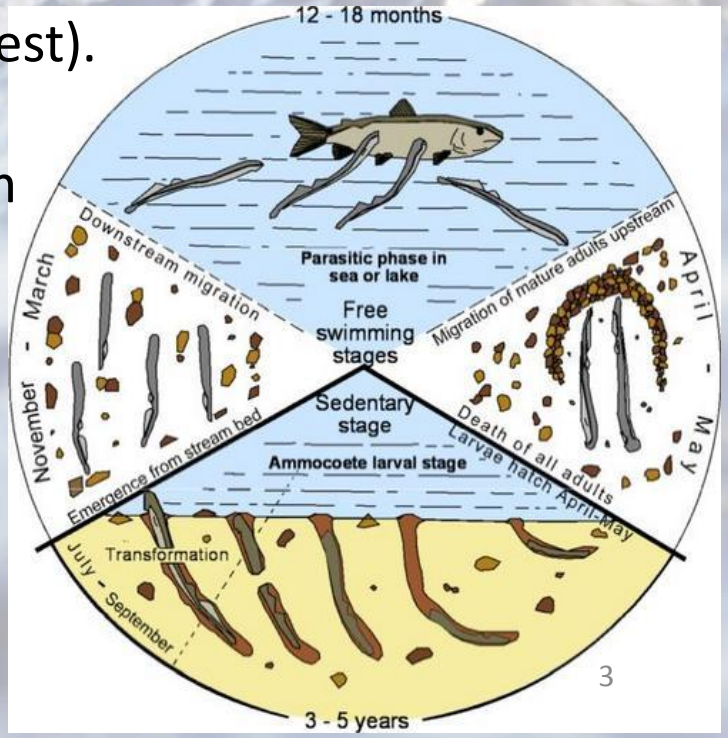


Adaptive Management of Barriers in European Rivers

A COLLABORATIVE PROJECT FOR GUIDANCE ON BARRIER LOCATION, REMOVAL AND MITIGATION IN EUROPE

Introduction

- River lamprey (*Lampetra fluviatilis*) - jawless fish with oral disc for parasitic adult life-stage.
- Migratory fish: spawn in freshwater, main growth in marine (/lacustrine (land-locked)) environment, return to river (anadromous).
- Habitats Directive species. In UK, SAC's for maintaining healthy populations.
- Exploit crevices, thigmotactic and positively rheotactic.
- Oral disc used to pass barriers (burst-attach-rest). Unlike fusiform morphotypes, anguilliformes often have poor swimming capacity - problem at barriers!



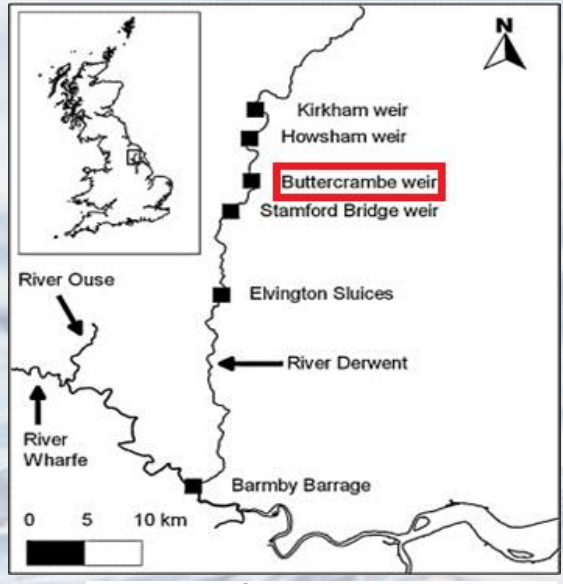
Introduction
In-river barriers

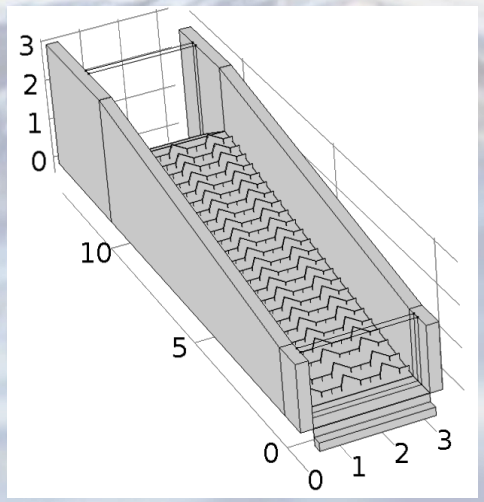
- Much of Europe's **drinking water , irrigation** and **flood control** relies on larger barriers.
- Hydropower: 80% of **renewable sources,** 10% of total in Europe. Expected boom.
- But… fragmentation of river habitat. Fishes unable to complete life-history stages. Migration and dispersal limited. Not new.
- Connectivity restoration through barrier removal, retro-fit fishways (technical and nature-like; with varying success (Bunt *et al*., 2012)) and modifications to obstacles (e.g. studded tiles, current 'design standard' for lamprey in UK).
- ***Aim: How effective are studded tiles in facilitating upstream passage of adult river lamprey?***

Bunt *et al*. 2012. *River Res. Applic*. 28: 457-478.

Study site

- River Derwent - SAC for river lamprey. Three barriers d/s. Humber catchment.
- Triangular 20 m wide weir (1973 for flow-gauging, now ultrasonic so obsolete), fish-friendly super-active baffle fishway (15% slope) and microhydropower near right bank.
- To facilitate river lamprey passage: modular, studded tiles (Tummers *et al*., 2016) placed on weir face, 1 m wide route.

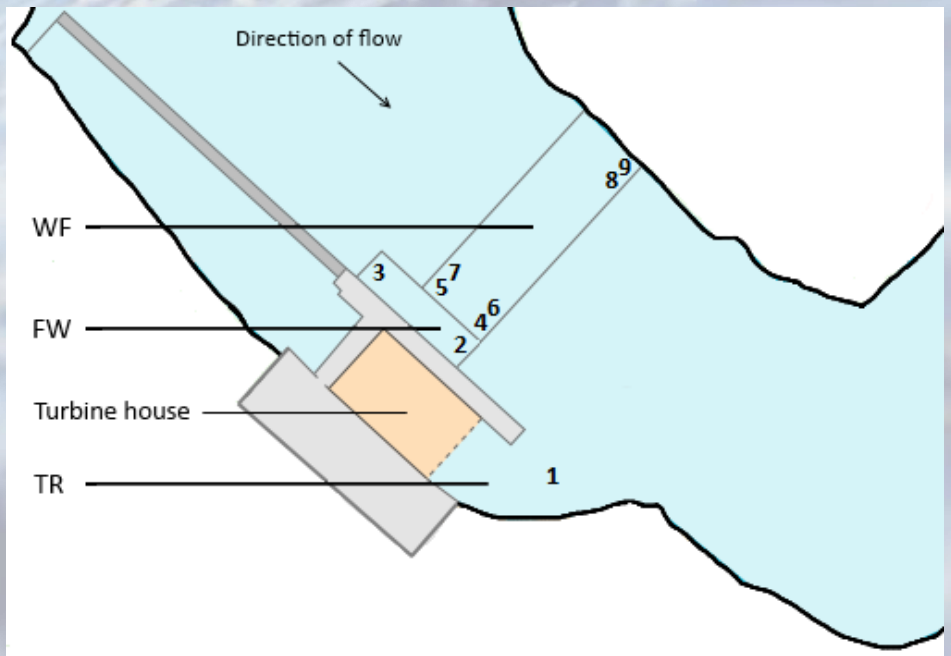




Tummers *et al*. 2016. *Ecol. Eng.* 91: 183-194.

PIT telemetry

- Lamprey sedated (MS-222). Length measured. 32 x 3.65 mm Passive Integrated Transponder (PIT) tag implanted (*n* = 395).
- HDX PIT system, 13 read-write cycles s^{-1}.
- Nine PIT antennas: 6 flatbed (weir face - control left bank, control right bank and tile route) and 3 swim-through (fishway, turbine tailrace).
- Date + time, antenna number and unique code logged as tag is detected. PIT system operational 08 Nov - 20 Dec 2017.



Results

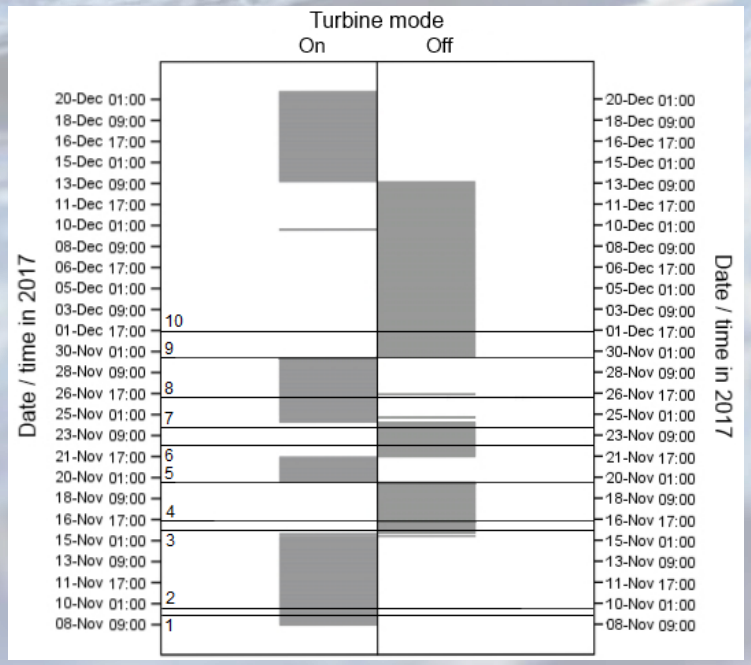
Route-specific detections, attraction/passage efficiencies and body length effect

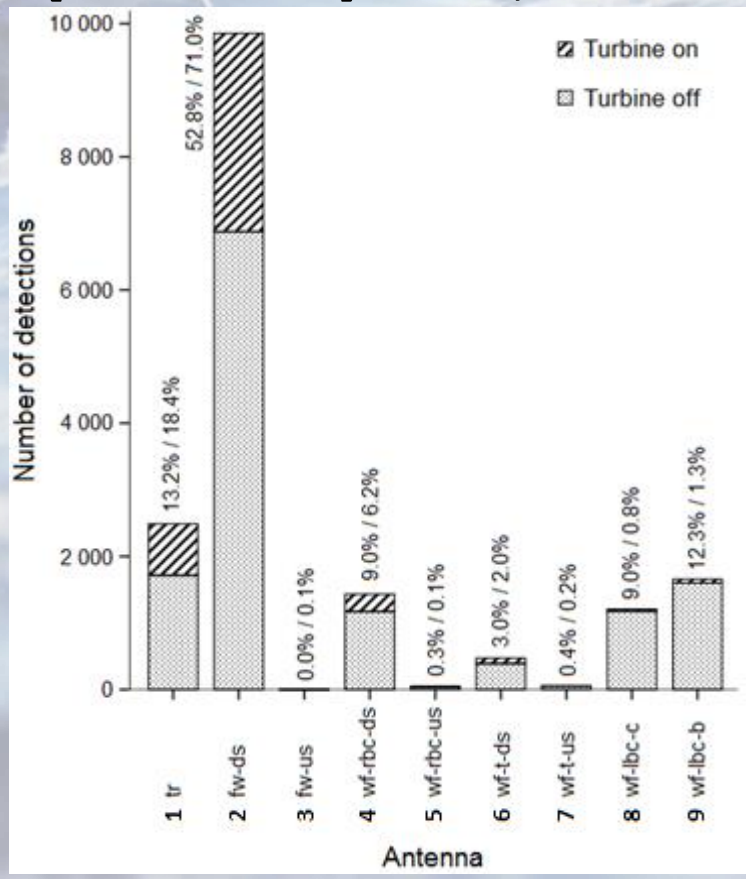
- Body length similar at tile (*n* = 44) and right-bank control route (*n* = 22) to all lamprey released (Mann-Whitney U: *U* = 7581, *p* = 0.165; *U* = 4041, *p* = 0.581).
- Undetected lamprey not significantly different in length from those detected (Independent samples t-test: *t*(393) = -1.376, *p* = 0.176).

Passage route and antenna identities (1-9)	No. of lamprey (efficiencies, AE and PE)		No. of first detections		Body length of lamprey detected (mm; mean ± SD)		Time taken to locate specific route (h; median [range])
	attraction (AE)	passage (PE)	downstream	upstream	downstream	upstream	downstream
Tailrace (1)	344 (87.1%)	n/a	156 (43.0%)	n/a	369.2 ± 21.4[a]	n/a	0.76 [0.07 - 571.43][a]
Fishway (2,3)	343 (86.8%)	5 (1.5%)	91 (25.1%)	0 (0.0%)	369.1 ± 21.6[a]	360.6 ± 13.2[b]	0.86 [0.08 - 561.72][a]
Weir face - control (right bank) route (4,5)	257 (65.1%)	22 (8.6%)	41 (11.3%)	0 (0.0%)	369.4 ± 22.1[a]	371.0 ± 21.2[a]	1.92 [0.77 - 564.35][b]
Weir face - treatment (tiled) route (6,7)	172 (43.5%)	44 (25.6%)	29 (8.0%)	2 (0.6%)	370.7 ± 20.4[a]	372.5 ± 24.2[a]	2.75 [1.03 - 577.20][c]
Weir face - control (left bank - channel-side) route (8)	229 (58.0%)	n/a	15 (4.1%)	n/a	369.4 ± 21.7[a]	n/a	2.33 [1.10 - 546.11][d]
Weir face - control (left bank - bankside) route (9)	248 (62.8%)	n/a	29 (8.0%)	n/a	370.1 ± 21.7[a]	n/a	2.38 [1.08 - 558.93][d]

Turbine operation effect

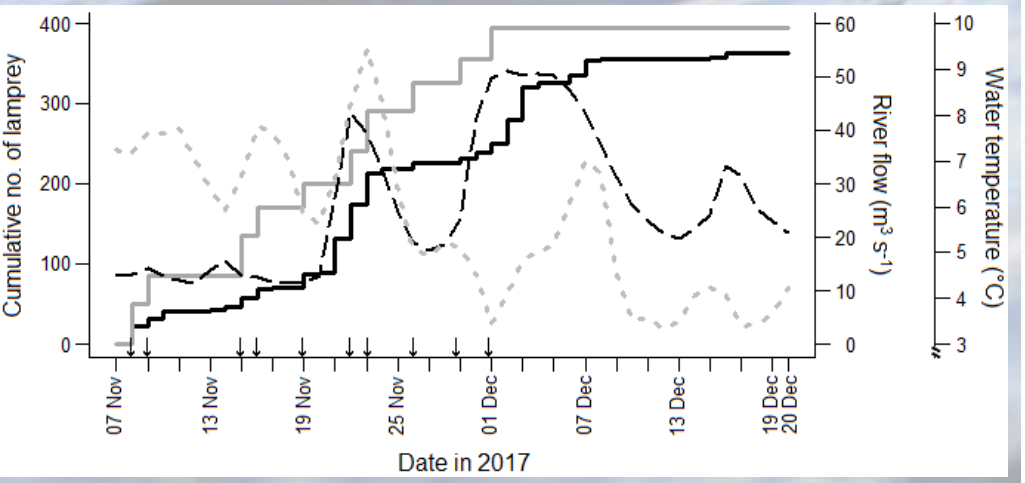
- Only *n* = 88/4190 detections (2.1% of total, turbine on) at two left-bank control antennas when turbine on *vs*. 2775/13029 (21.3%) at the same two antennas when turbine off.
- River flow lower when turbine on *vs*. off (median [range]: 18.7 [10.5 - 36.3] $m^3 s^{-1}$ against 36.2 [10.4 - 52.3] $m^3 s^{-1}$, $Z = -28.678$, $p < 0.001$).



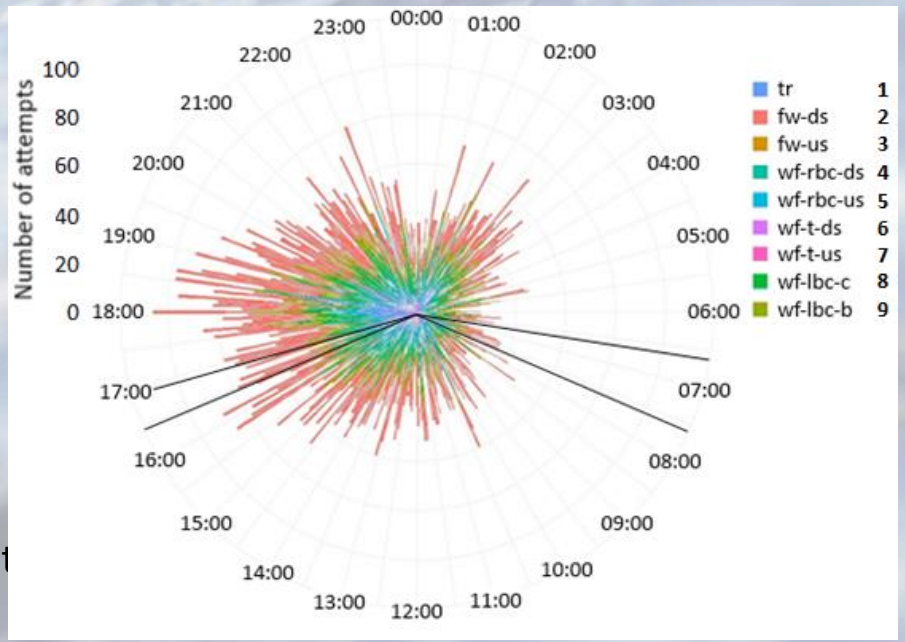


Environmental conditions and diel activity

- River flow but not water temperature effect on daily number of detections totalled for all antennas, excl. release days (ANOVA: $F_{1,43} = 13.706$, $p = 0.001$ and $F_{1,43} = 2.448$, $p = 0.125$).
- 16:00 - 20:00 most active time for lamprey, 22.4% of all attempts ($n = 3863/17219$).



River flow (m^3 s^{-1}; dashed black; inner right y-axis) and wat
temperature (°C; dotted grey; outer right y-axis).



Conclusion

- Studded tile: threefold PE increase *cf*. control (25.6% - 8.6%).
- Flow velocity tile route ↓, energy in water column ↓ (Larinier *et al*., 2002). Turbulence ↑, influenced by stud spacing, size and water flow. For Pacific lamprey: transition from attachment to resuming upstream swimming difficult under turbulent conditions; unable to re-attach, swept downstream (Keefer *et al*., 2011).
- Horizontally more effective than vertically aligned tiles (PE: 25.6% *cf*. 7.1%), but vertical in SAB fishway (Tummers *et al*., 2016) while horizontal on the weir face.
- SAB fishway ineffective (1.5% PE, 0.3% PE in earlier study).
- Should be > 90% efficient for effective population restoration (Lucas and Baras, 2001).
- Further research, *in situ*, needed.

Lucas, Baras. 2001. Blackwell Science, Oxford, 440 pp.
Larinier *et al*. 2002. *Bull. Fra. de la Pêc.* 364: 208-222.
Keefer *et al*. 2011. *Fish. Man. Ecol*. 18: 177-189.

Acknowledgements

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Durham University

Environment Agency

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Greg McCormick - MicroHEP hydropower
George Winn Darley, Shane Collier - Aldby Park Estate

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The AMBER project

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8 Universities Swansea (UK), Durham (UK), Highlands & Islands (UK), Southampton (UK), Cork (Ireland), Oviedo (Spain), Milan (Italy), DTU (Denmark).

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4 NGOs & SMEs WFMF (Netherlands), WWF (Switzerland), CNSS (France), AEMS (Spain)

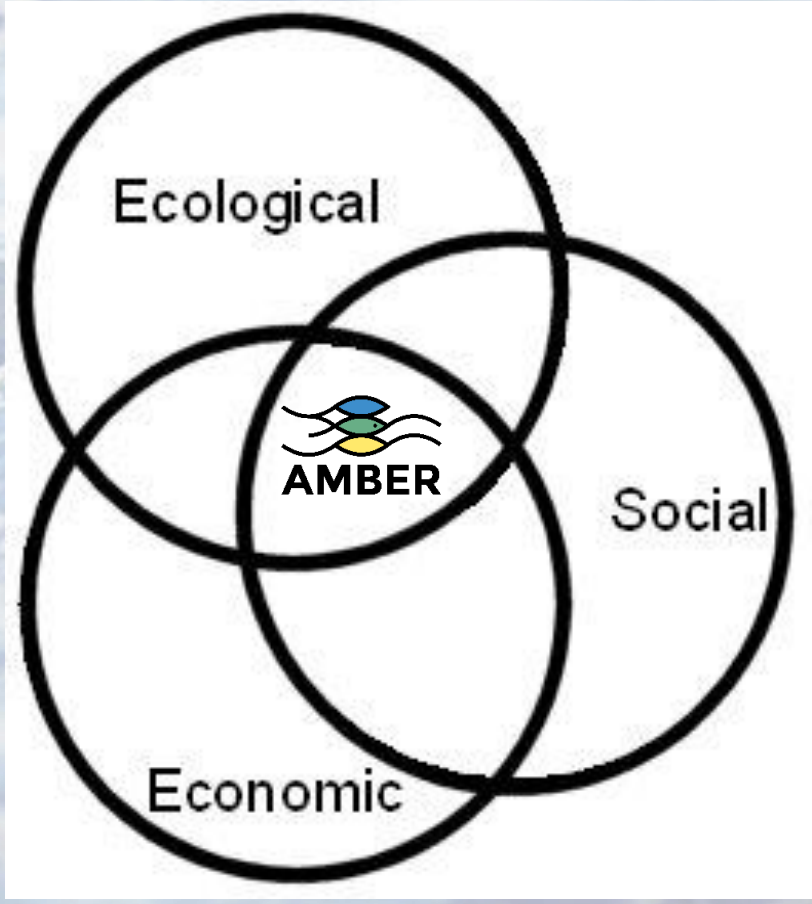
4 Government organizations IFI (Ireland), ERCE (Poland), SSIFI (Poland), Joint Research Centre (Italy)

The AMBER project

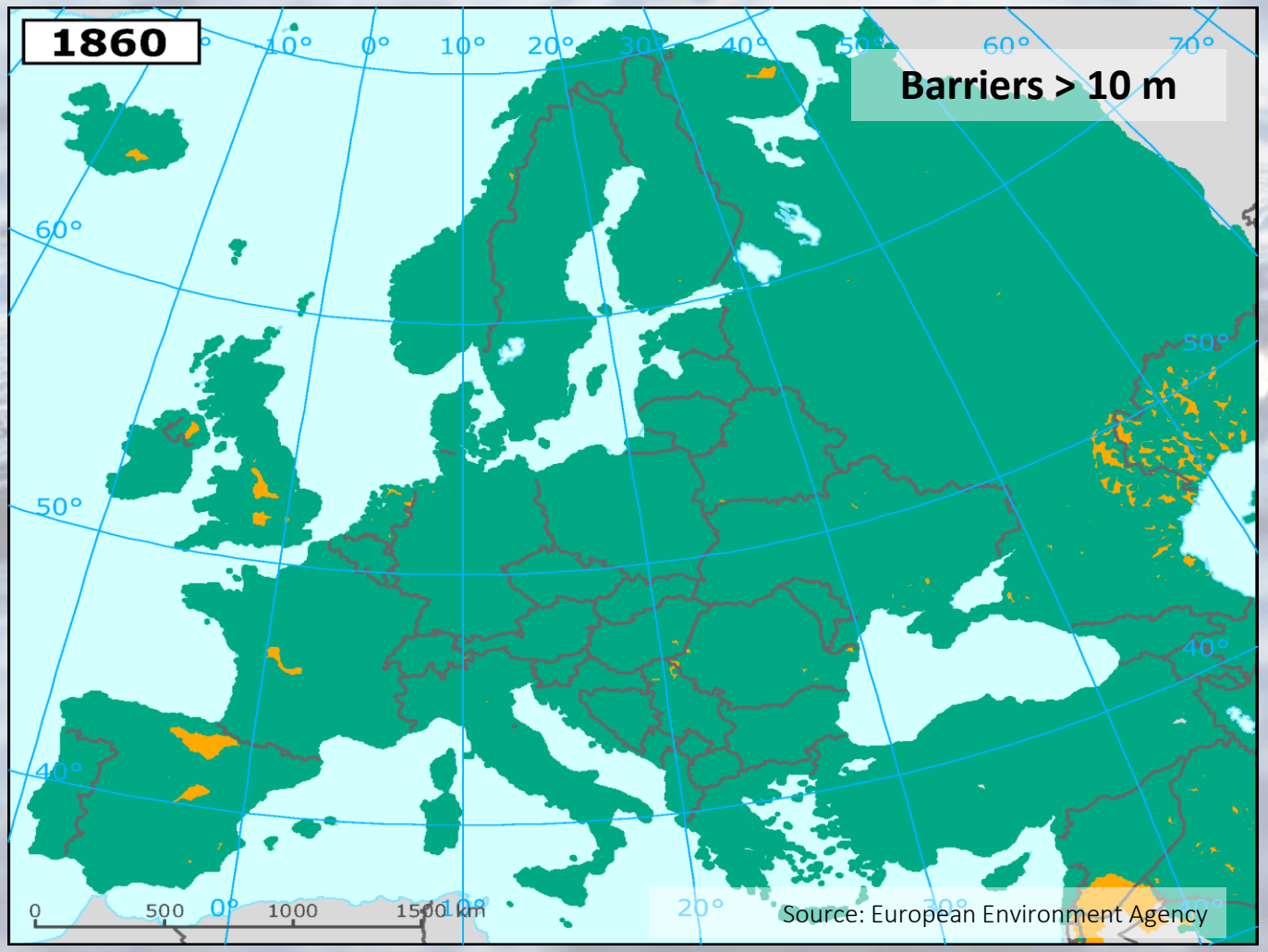
Aims:

- To develop more efficient methods of restoring stream connectivity.
- Requires a shift towards adaptive management, one that maximises benefits and minimises impacts through system monitoring.

(a) Removal
(b) Mitigation
(c) Construction of new dams



Loss of accessibility for migratory fish due to barriers in major European river basins



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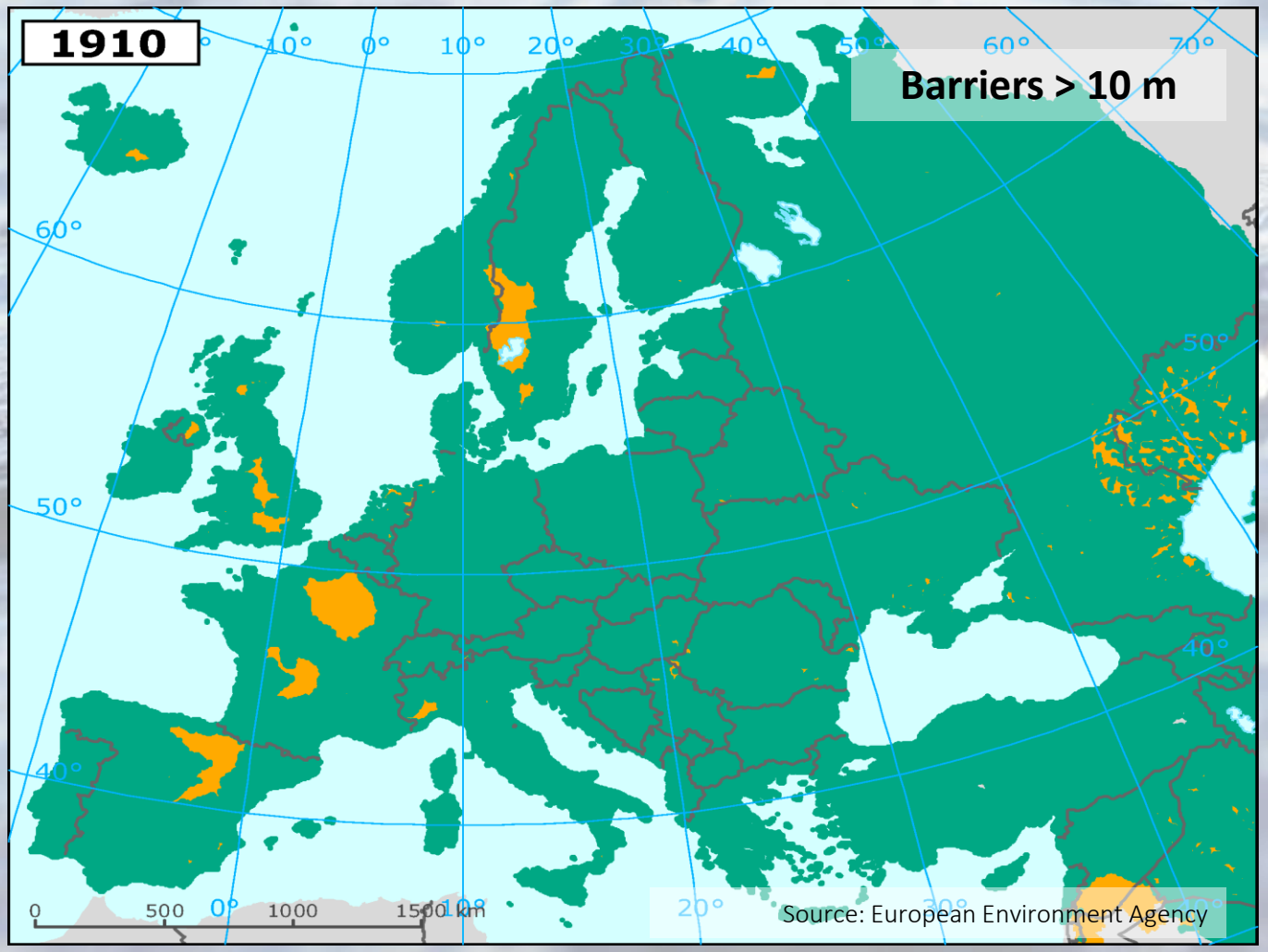

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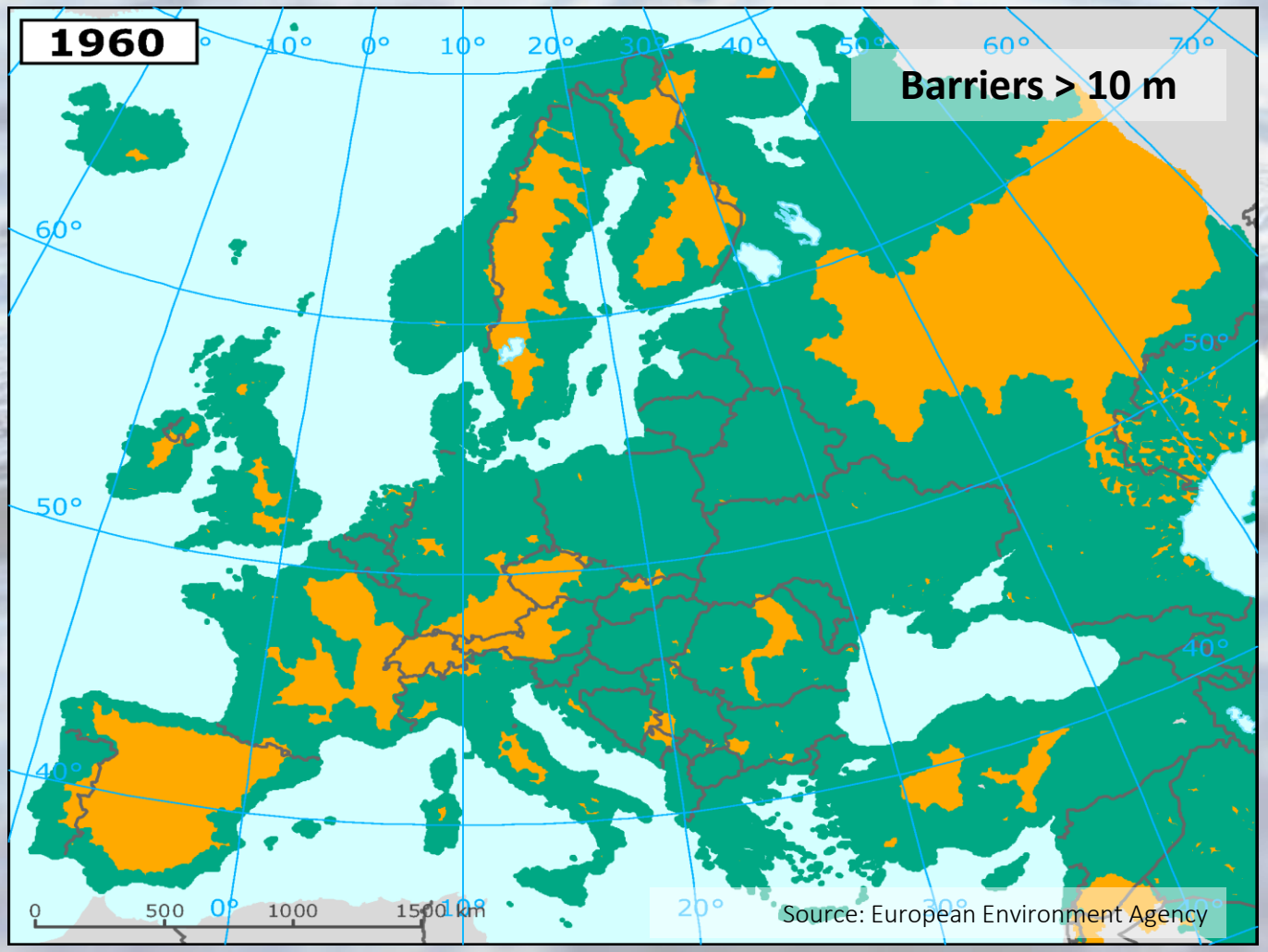

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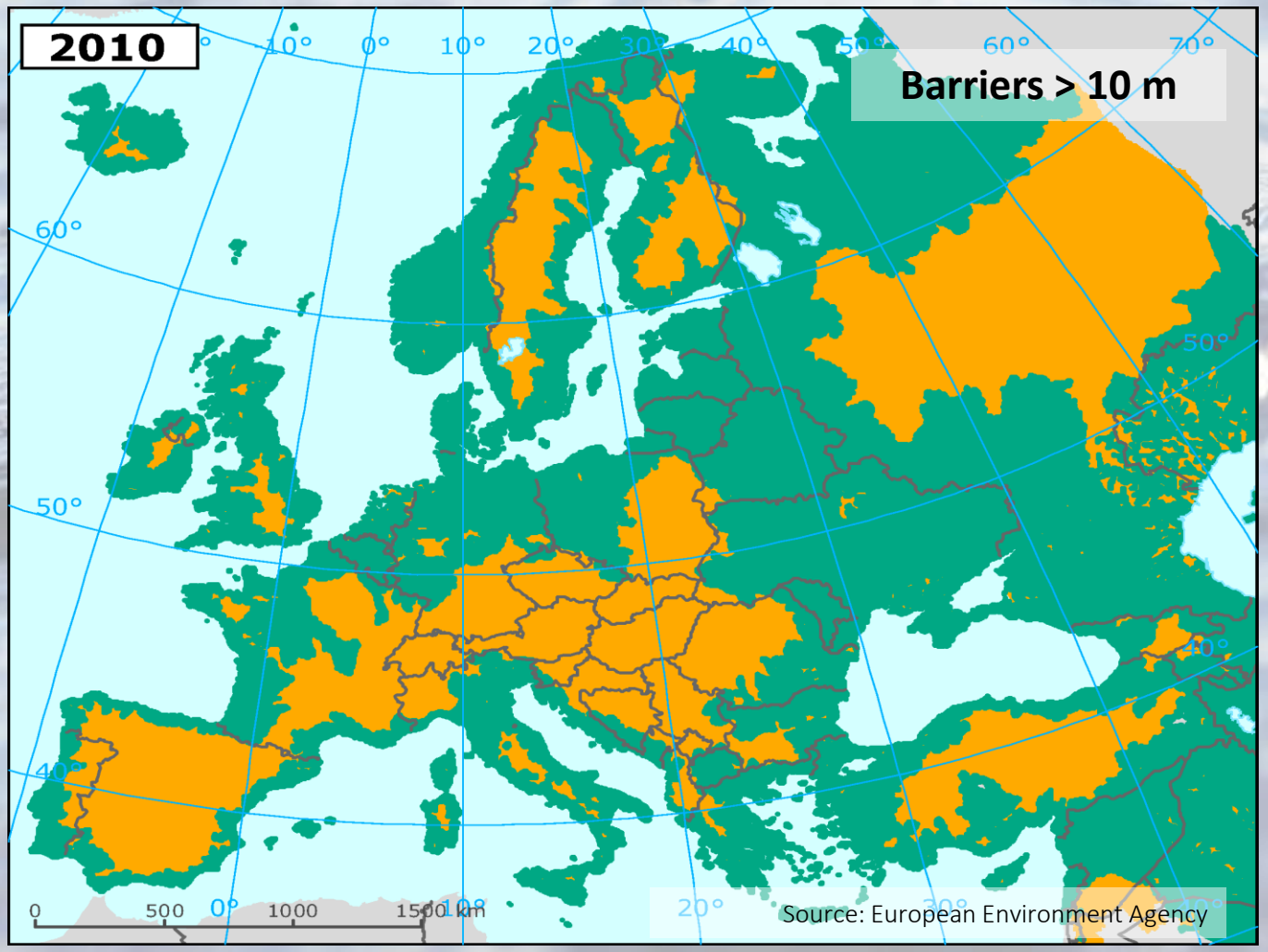

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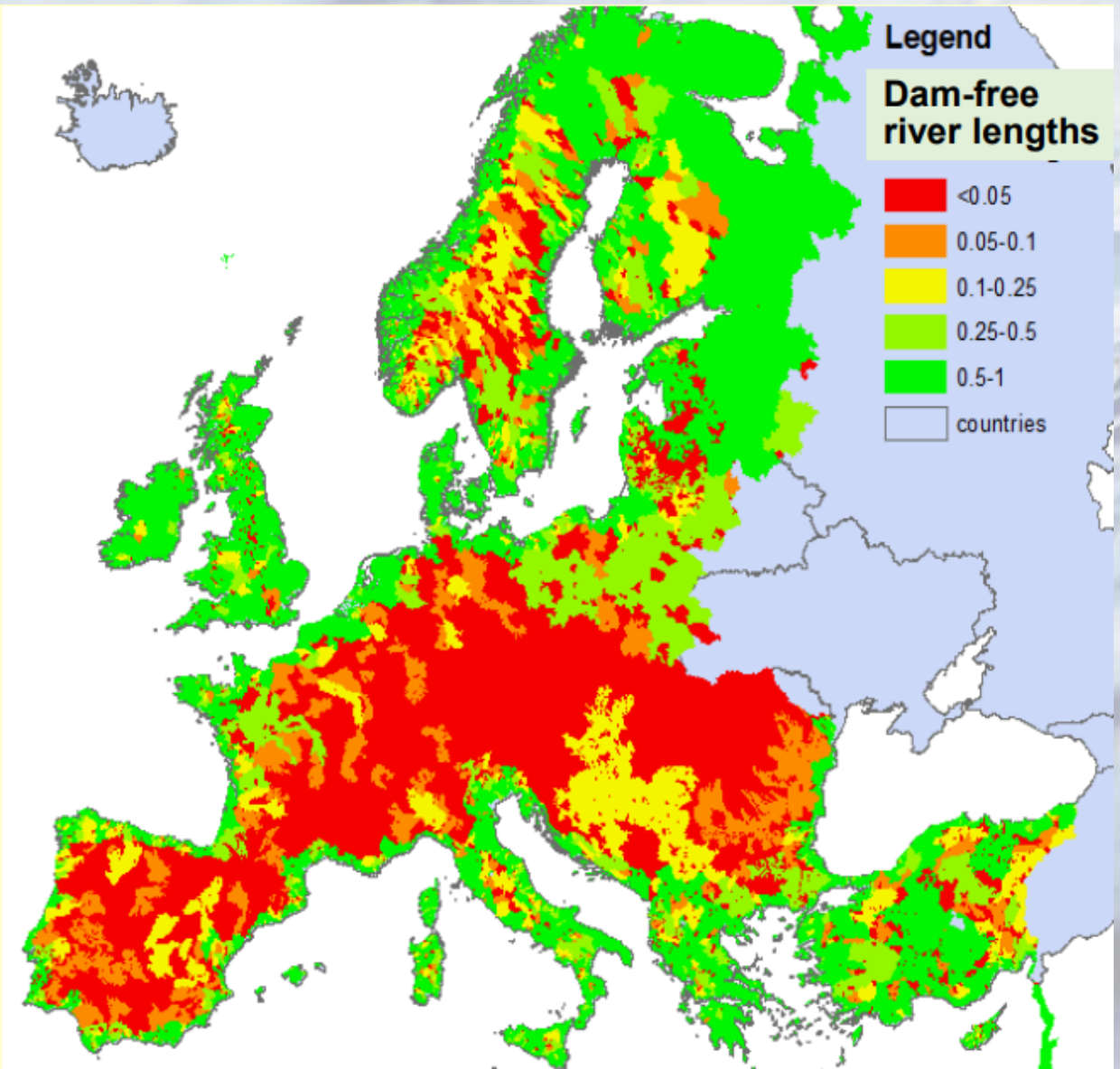

Despite EU legislation all major EU rivers remain poorly connected and inaccessible to migratory fish (Pistocchi *et al*. 2017).

Pistocchi *et al*. 2017. *Sci. Tot. Env*. 575: 1477-1488.

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River Connectivity Network

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