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Can’t do them all, so how should we prioritize barriers for removal?

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AMBER LET IT FLOW

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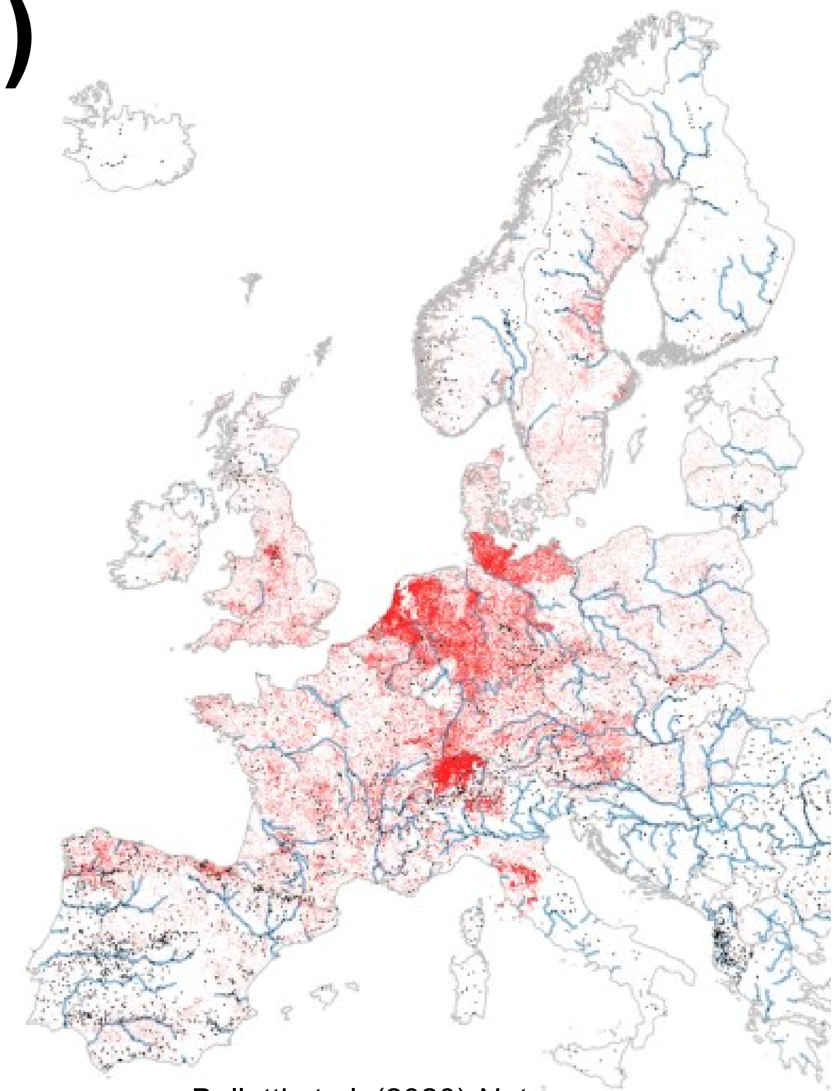
The Challenge (in Europe)

+1.2M barriers*

Goal of +25k of free-flowing rivers in the EU by 2030

Operational Definition: '*any built structure that interrupts or modifies the **flow of water**, the **transport of sediments**, or the **movement of organisms** and can cause **longitudinal discontinuity***'

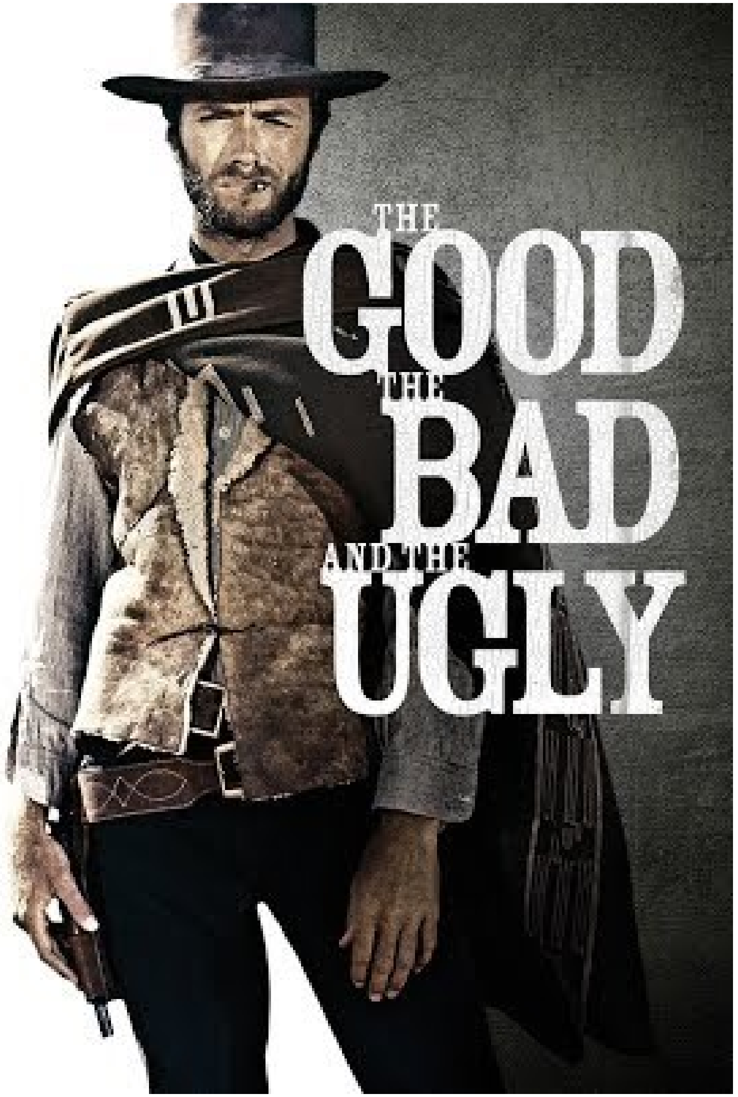
European Barrier Density



Belletti et al. (2020) *Nature*

0.74 barriers/km

Barriers



Know the enemy and know yourself

Barrier Typology: 6 main types

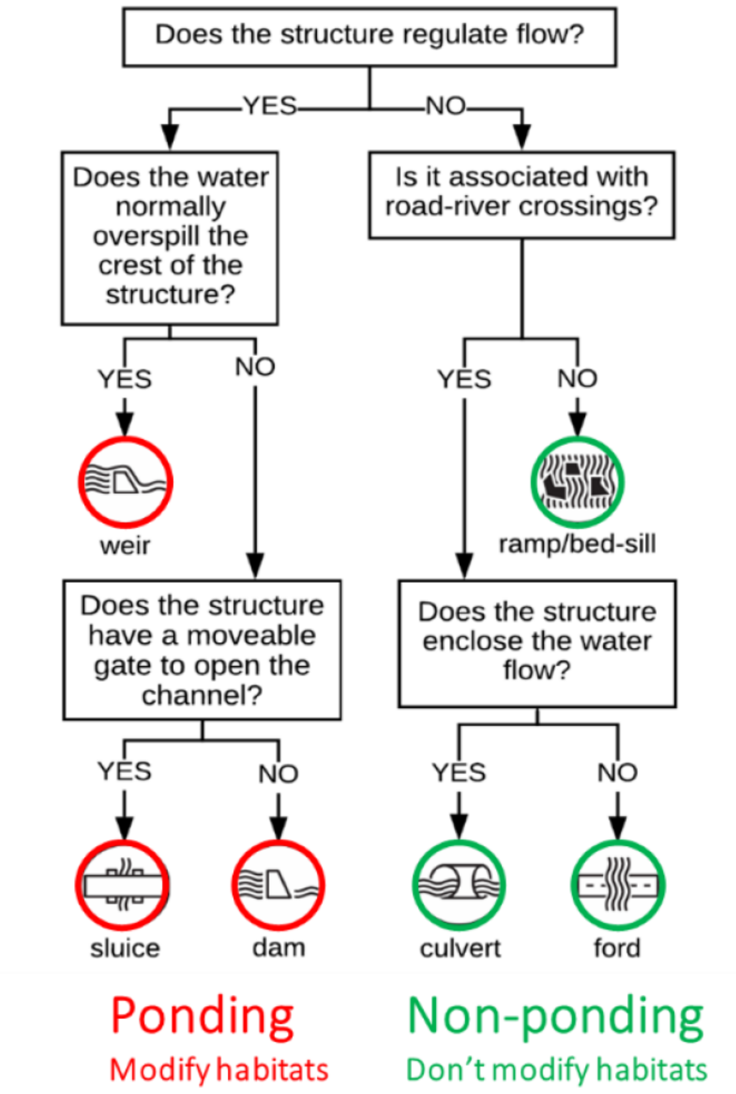
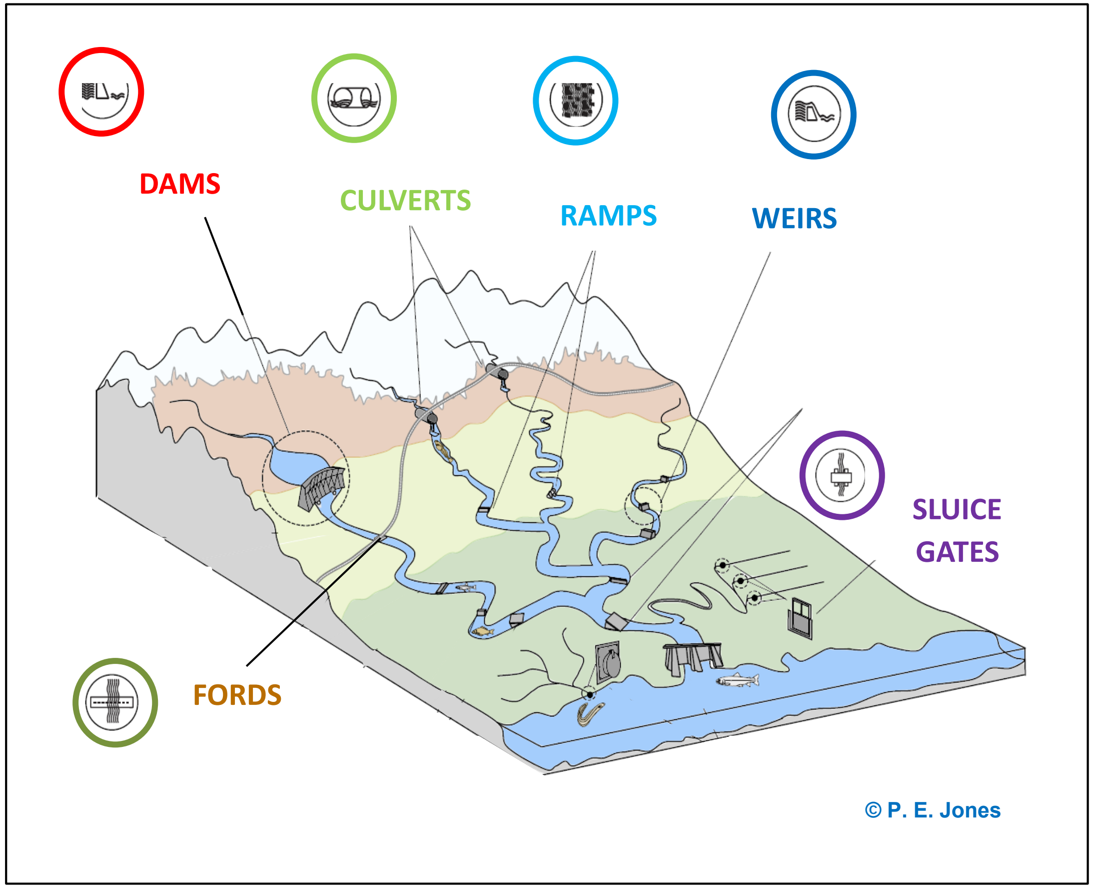


Figure 1. Classification of six main barrier types (Jones et al., 2020a).



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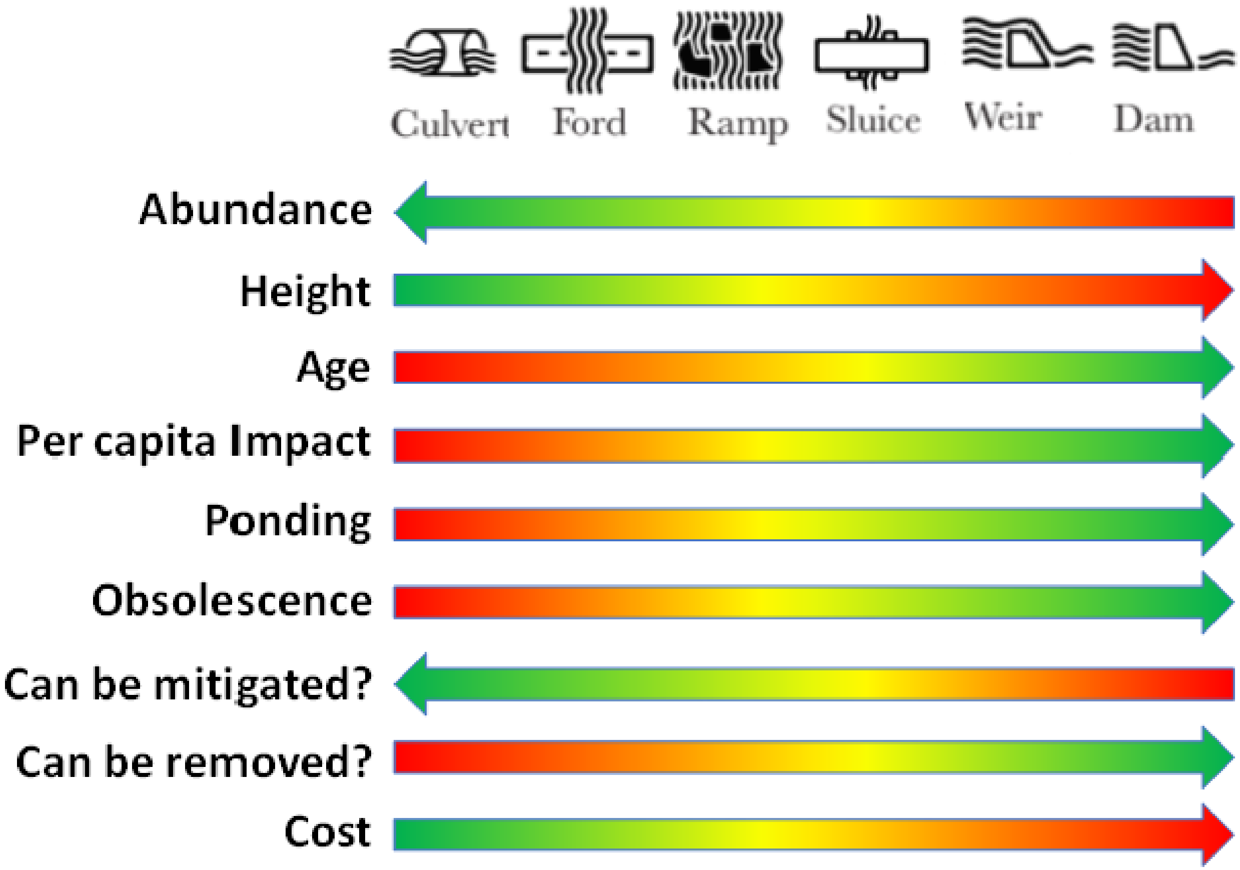
Barrier Typology: 6 main types



Arrow direction: increase in a given trait

Color: benefit or suitability of removal

Figure 2. Characteristics of different barrier types and how these can affect decisions about barrier removal. The direction of arrows represent an increase in a given trait and the color the benefit or suitability of removal (note these are only indicative).

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Why prioritize?

- Barrier removal/mitigation usually aims to maximize connectivity gains given available resources
- Resources usually (very) limited
- Essential to prioritize as benefits and costs will vary from barrier to barrier
- Barrier removal should usually fulfill 4 conditions:
  (1) Bring about a meaningful gain in connectivity
  (2) Be cost-effective
  (3) Not cause significant or lasting environmental damage
  (4) Ideally be obsolete structures

Barrier Prioritizing Methods

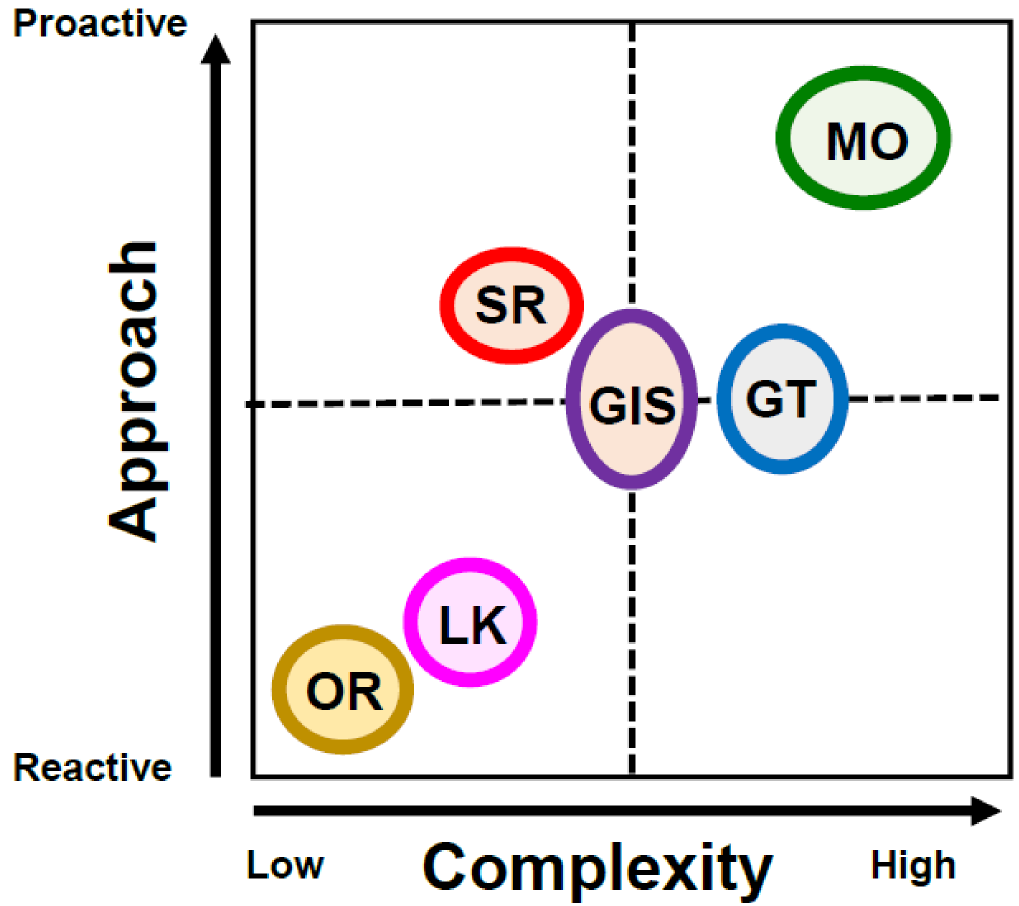

Figure 3. Classification of the main barrier prioritization methods according to their complexity and type of approach. OR - opportunistic response; LK - local knowledge & expert opinion; SR - scoring and ranking; GIS - GIS scenario analysis; GT - graph theory; MO - mathematical optimization.

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At least:

- 23 habitat connectivity metrics
- 13 flow alteration metrics

for assessing baseline conditions and predicting response of barrier removal that can potentially feed into:

- 6 prioritization methods

OR – Opportunistic Response

Informal Method

- Passive strategy requiring little or no strategic planning
- Easy to implement – usually in response to dam owner request
- Can potentially remove lots of barriers
- Can be very inefficient
- Assumes every removal bring some benefit

Example: American Rivers responding to dam owners' safety concerns

LK – Local Knowledge & Expert Opinion

Informal Method

- Most widely used informal method
- Easy to implement
- Flexibility in combining envir., econ., and social criteria
- Captures domain knowledge from multiple disciplines
- Can have good stakeholder involvement (beyond experts)
- Highly subjective and prone to bias
- Low repeatability (agency culture)
- Unmanageable at large spatial scales

Example: The vast majority of small-scale projects initiated by local environmental groups

SR – Scoring & Ranking

Formal Method

- Most popular formal method
- Usually considers habitat quantity & quality, improved fish passage, and cost
- Scores often computed as benefit-cost ratios: habitat gain ÷ cost
- Prescriptive – barriers ranked from highest to lowest score
- Simple and easy to communicate
- Flexible – new data can be added and barriers re-ranked
- Usually ignores barrier spatial structure (downstream barriers)
- Decision made independently, leading to very inefficient solutions

Example: Washington Department of Fish and Wildlife 2009 prioritization manual

GIS – GIS Scenario Analysis

Formal Method

- Spatial data layers used as filters to simulate "what if" scenarios
- Simple connectivity metrics used to help rank scenarios
- Visually appealing, easy to communicate
- Easy to scale up and handle multiple data layers
- Requires a GIS platform and expertise
- Choice of attributes to consider can be highly subjective
- Low repeatability and transparency
- Descriptive approach – provides no guidance (on its own) of how to cost-efficiently mitigate barriers

Example: Northeast Aquatic Connectivity, Chesapeake Fish Passage Prioritization, and Southeast Aquatic Connectivity Assessment Project online analysis tools

GT – Graph Theory

Formal Method

- Takes a holistic view of river connectivity
- Captures river dendritic structure and barrier spatial relationships
- Accounts for interactive effects of barrier mitigation
- Can be tailored to different fish life-history / dispersal patterns
- Descriptive approach – provides no guidance (on its own) of how to cost-efficiently mitigate barriers
- Only useful for "what-if" type analyses focused on river connectivity enhancement

Example: Dendritic Connectivity Index (DCI)

MO – Mathematical Optimization

Formal Method

- Like GT, accounts for spatial structure and interactive effects of barrier mitigation
- Unlike GT, is prescriptive – produces optimal or near optimal solution that make the best possible use of limited resources
- Objective and systematic
- Able to balance multiple, competing goals and uncertainty
- Priorities heavily dependent on accurate cost data and budget
- Ignores site specific factors and ease of implementation issues
- Normally requires a high-level of mathematical expertise

Example: OptiPass Windows app, RIP Excel app, Fishwerks online platform, California Fish Passage Forum FishPASS service

Summary of Characteristics

Table 1. Characteristics of the six main types of barrier prioritization methods benchmarked by trait (L = Low; M = moderate; H = High)

Trait	Prioritization method					
	OR	LK	SR	GIS	GT	MO
Factor uncertainty	L	L	L	L	L	H
Difficulty	L	L	M	M	M	H
Flexibility	L	M	H	M	M	H
Optimal solution	L	L	L	M	M	H
Multiple objectives	L	L	L	M	M	H
Transparency	H	L	L	M	M	H
Repeatability	L	L	H	M	M	H
Multiple barriers	L	L	L	M	M	H
Stakeholder	M	H	M	L	L	L
Examples	American Rivers (2021)	Fox et al. (2016) Sneddon et al. (2017)	Roni et al. (2002) WDFW (2000)	Barrios (2011) Martin and Apse (2011)	Cote et al. (2009) Segurado et al. (2013)	O'Hanley and Tomberlin (2005) Kuby et al. (2005)

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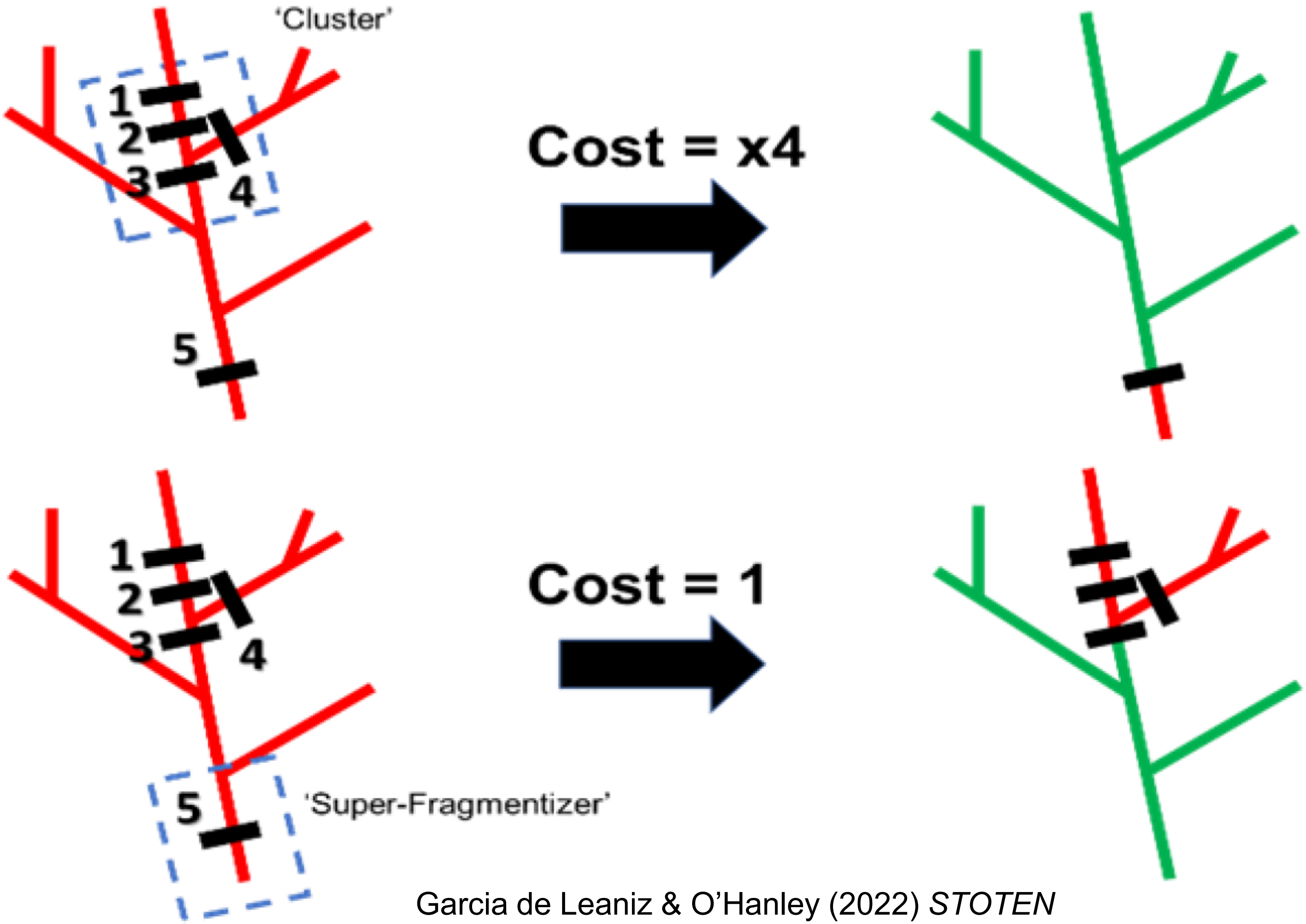
Some Key Operational Challenges

1. Mitigation sometimes out of scope – many funding programmes only support removal, not mitigation
2. Natural barriers often ignored – overestimation of the benefits of barrier mitigation, especially in headwaters
3. Uncertainty:
   - Number of barriers is typically underestimated
   - Location of (known) barriers not always known precisely
   - River networks generally inaccurate
4. Climate change and extreme weather may necessitate future-proofing barrier removal plans or even opting for a do-nothing option

Additional Considerations

5. The value of identifying ‘Fragmentizers’
6. The value of identifying ‘Low Hanging Fruit’ and capitalising on opportunities

Identifying ‘fragmentizers’



Barriers are NOT randomly distributed, they are usually **clustered**

“Fragmentizers” can be identified and targeted…

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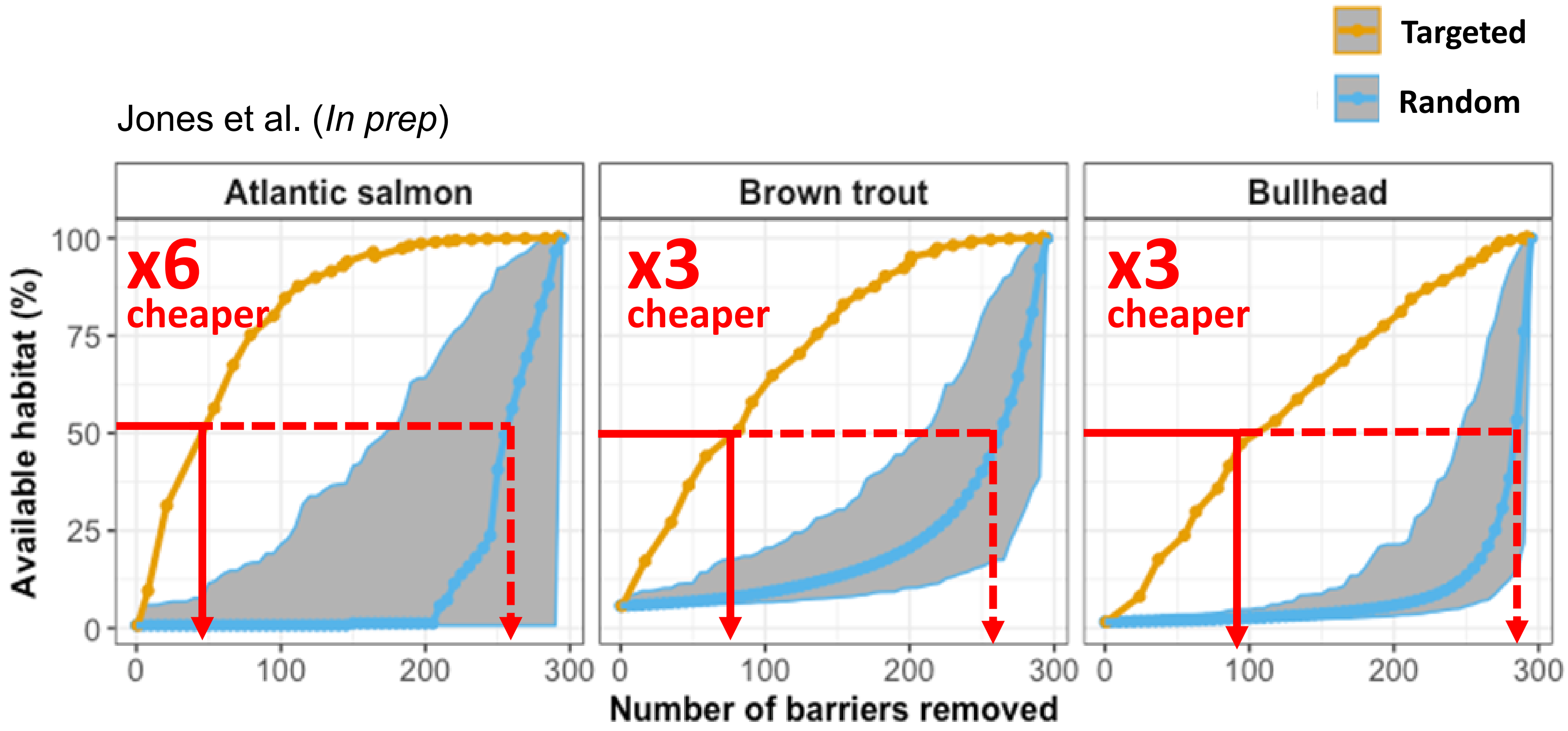
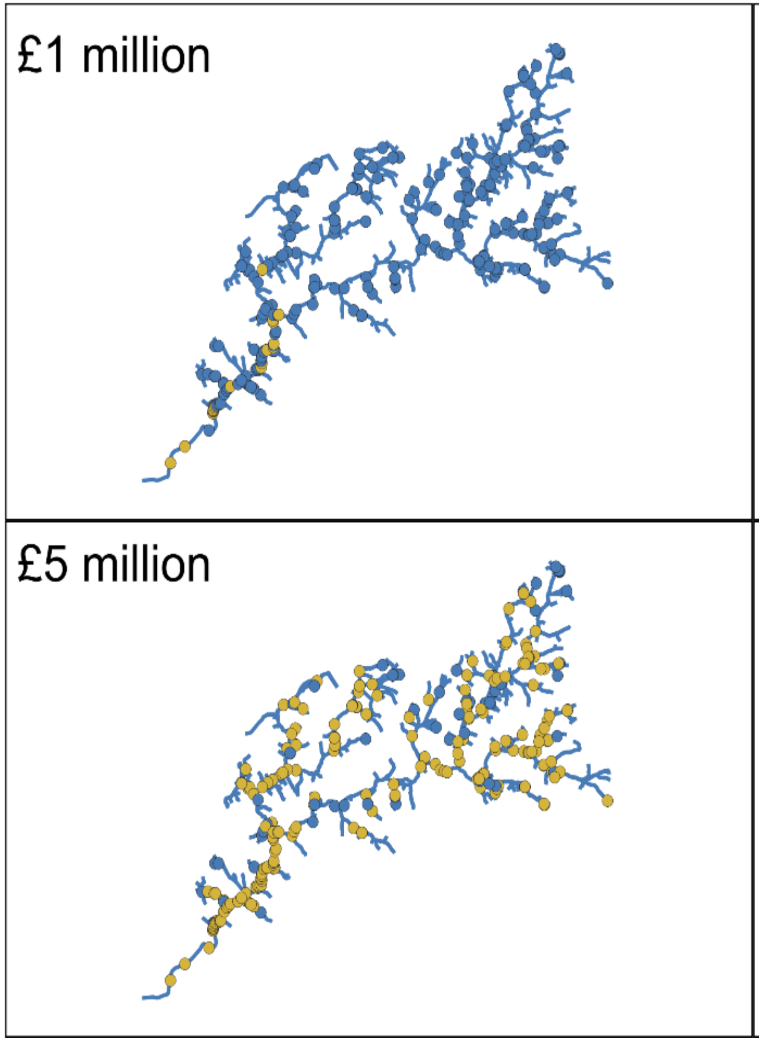
A Real-World Example: The River Afan

Jones et al. (*In prep*)

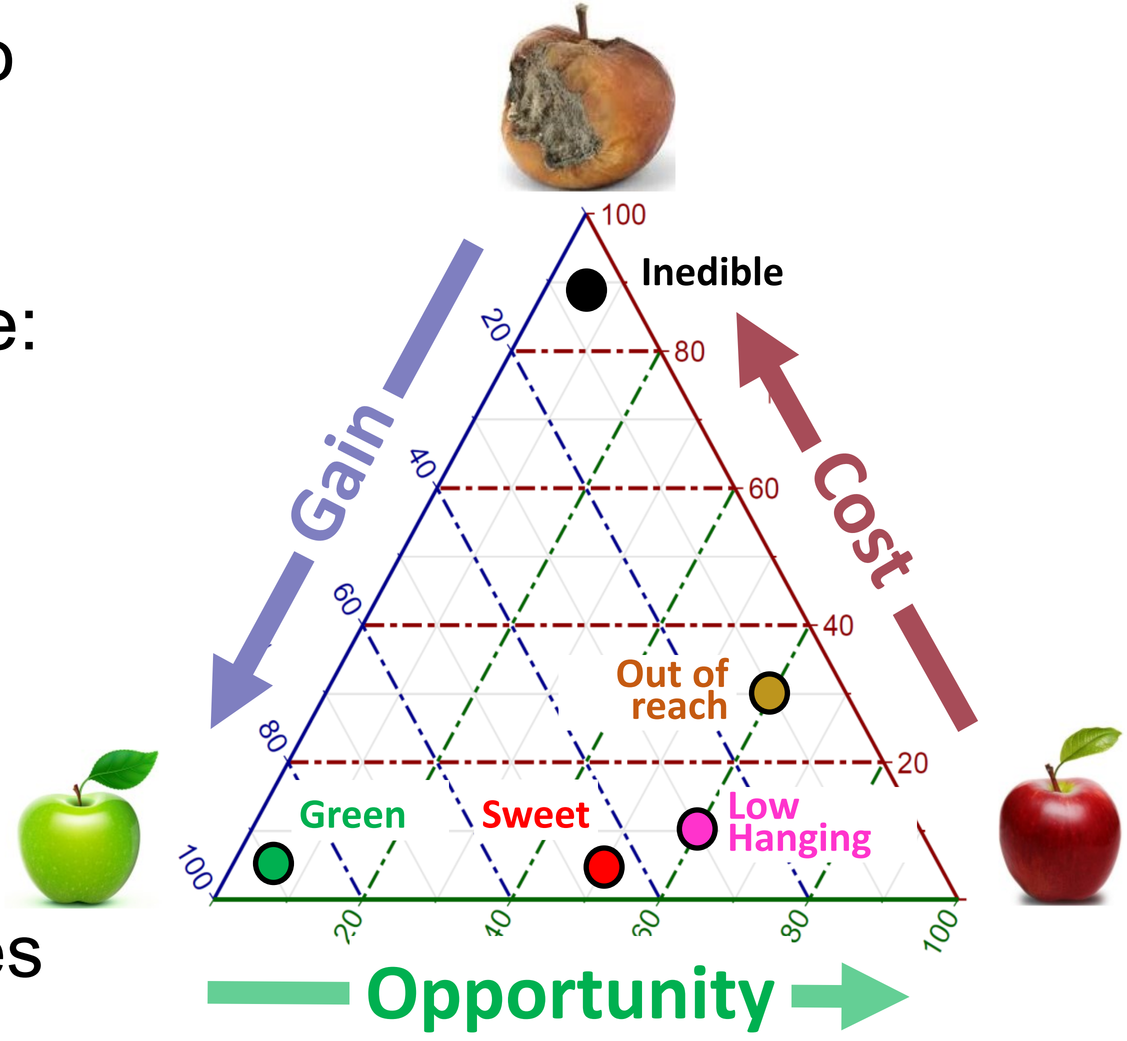




A targeted (optimized) approach is cheaper and yields significant benefits from the very 1st removal

Identifying the Low Hanging Fruit

- Barrier removal can be mapped onto three axes – **opportunity**, **cost** and **gain**
- Opportunities may develop over time:
  - As infrastructure ages and requires repair or removal
  - As support for barrier removal grows
- A snowball effect can occur at catchment scale – acting on some initial barriers may open opportunities for acting on others



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Thank you!
Any Questions?