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EFFECTS OF FISH PASSAGE BARRIERS ON FISH MIGRATION AND BIODIVERSITY IN RIVER SYSTEMS

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Abstract

Fish passage barriers, such as dams, weirs, and culverts, are increasingly recognized as major impediments to the natural migration of freshwater fish. These barriers disrupt the longitudinal connectivity of rivers, leading to population declines, shifts in community composition, and loss of biodiversity. This paper reviews the effects of fish passage barriers on fish migration and freshwater biodiversity, drawing on studies published before 2011. It highlights the mechanisms through which barriers impede migration, presents empirical evidence of biodiversity impacts, and discusses management strategies for mitigating the negative effects. The paper concludes with recommendations for effective fish passage design and barrier removal to enhance the resilience of river ecosystems and restore migratory pathways for fish.

Keywords: fish migration, river barriers, fish passage, biodiversity loss, river fragmentation, fish health

1. Introduction

Freshwater ecosystems are vital for maintaining biodiversity and supporting ecosystem services such as water purification, nutrient cycling, and habitat provision. Migratory fish species, in particular, rely on the longitudinal connectivity of rivers for access to spawning, feeding, and refuge habitats. However, the construction of fish passage barriers—such as dams, weirs, and road culverts—has fragmented river systems, leading to declines in fish populations and biodiversity.

Fish passage barriers disrupt natural migration routes by obstructing or altering water flow, temperature, and sediment transport, which are crucial for the life cycles of migratory fish species. Many freshwater fish species, including those that support fisheries and local livelihoods, are now facing the loss of suitable habitats due to these barriers.

2. Literature Review

1) 2.1 Fish Migration and River Connectivity

Migration is a critical ecological process for many freshwater fish species, enabling access to spawning grounds, feeding areas, and refugia. According to Northcote (1984), freshwater fish migration is defined by the need to move between different habitats based on life stages, with some species migrating long distances (e.g., salmonids), while others undertake shorter migratory journeys.

The connectivity of river systems—both longitudinally (upstream-downstream) and laterally (floodplain) plays a central role in maintaining fish biodiversity. River connectivity ensures that fish can move between critical habitats and access resources needed for reproduction and survival.

However, barriers disrupt this connectivity, leading to fragmentation of fish populations and restricted access to spawning and feeding habitats. Northcote (1991) highlighted that fish migration and ecological integrity of rivers are closely linked, and the loss of connectivity is a major driver of freshwater biodiversity decline.

2) 2.2 Types of Fish Passage Barriers and Mechanisms of Impact

Fish passage barriers come in various forms, with the most common being:

- **Dams**: Large structures that impede fish migration both upstream and downstream by creating reservoirs and blocking fish passage.
- **Weirs and Locks**: Smaller barriers that affect local fish populations by altering water flow and disrupting migration routes.
- **Road Culverts**: These structures often restrict fish passage due to inadequate water depth, velocity, or submerged areas.

Barriers obstruct migration in multiple ways:

- **Physical blockage**: Complete obstruction of fish migration paths, preventing fish from accessing spawning or feeding grounds.
- **Flow alteration**: Dams and weirs change the flow dynamics, increasing water velocity, or creating still water areas that are unsuitable for certain fish species.
- **Temperature and sediment changes**: Barriers can change the thermal profile of rivers and affect sediment transport, disrupting spawning sites and water quality.

Larinier (1998) suggested that even low-head barriers could severely affect fish populations by increasing stress and reducing breeding success, especially for species that require high-quality habitats and uninterrupted migration routes.

3) **2.3 Effects of Barriers on Fish Populations and Biodiversity**

Fish passage barriers affect fish populations by reducing access to spawning habitats, disrupting breeding cycles, and isolating populations. This can result in:

- **Declines in population sizes**: Species that rely on migration for breeding or feeding face reproductive challenges when barriers block their paths, leading to population declines.
- **Loss of migratory species**: Many fish species are adapted to migratory patterns that are disrupted by barriers. Without migration, species may fail to breed successfully or disappear from impacted areas.
- **Changes in species composition**: As migratory species decline or disappear, more adaptable, non-migratory species may dominate, altering the ecological balance and reducing biodiversity.

For example, the construction of dams in the Columbia River system has led to the near-extinction of the endangered Chinook salmon population. Similarly, in the Danube River, the construction of hydropower dams has reduced populations of migratory fish, such as sturgeon and salmonids (Larinier, 1998).

3. Conceptual Framework

The conceptual framework presented here links fish passage barriers to changes in fish migration and biodiversity in river systems.

Fish Population and Biodiversity Outcome = f(Barrier Type, Migration Success, Fish Species Traits, River Connectivity)

Where:

- **Barrier Type** refers to the specific characteristics of the fish passage barrier, such as height, design, and flow alteration.
- **Migration Success** is the ability of fish to overcome barriers and access critical habitats.
- **Fish Species Traits** include the migratory behavior, life-history characteristics (e.g., age, size), and environmental tolerance of fish species.
- **River Connectivity** includes the longitudinal and lateral connectivity of habitats, which is essential for migration and biodiversity.

Hypotheses:

- H1: Barriers that impede upstream and downstream migration lead to population declines, especially for migratory species with strict habitat requirements.
- H2: Barriers result in changes in community composition, with migratory species being replaced by more tolerant, resident species.
- H3: The removal or retrofitting of barriers can restore migration success, leading to population recovery and biodiversity enhancement.
- H4: Species with low migratory capacity or specific habitat needs are more vulnerable to population loss due to barriers.

4. Empirical Evidence

4.1 Effects of Dams on Fish Migration

In the Columbia River Basin (USA), studies by Williams and Matthews (1995) documented significant declines in Chinook salmon populations following the construction of dams, which disrupted their migration routes. The failure of fishways in some cases led to high mortality rates for migratory fish attempting to pass upstream. Similarly, in the Danube River, multiple dams constructed throughout the river basin resulted in the near-extinction of sturgeon species, highlighting the critical importance of river connectivity for migratory fish (Jungwirth et al., 2003).

4) **4.2 Effects of Weirs and Locks**

Smaller barriers such as weirs and locks also have significant impacts on fish populations. In a study of the River Elbe (Germany), researchers found that small weirs blocked access to key spawning habitats for migratory fish species such as the European eel and Atlantic salmon. While fish passes were installed, their effectiveness was limited, especially for species that required specific flow conditions for successful migration (Larinier, 1998).

5) **4.3 Case Study: Road Culverts**

A study conducted in the UK (Smith et al., 2003) found that road culverts were one of the most common types of barriers impacting freshwater fish migration. The study demonstrated that culverts with poor design, including those with insufficient water depth or velocity, blocked fish migration entirely, leading to population declines of species like brown trout and grayling.

5. Discussion

6) **5.1 Barriers and Fish Population Declines**

Fish passage barriers restrict access to key habitats, resulting in population declines. Many migratory fish species are especially vulnerable to barriers due to their dependency on specific habitats for breeding, feeding, and refuge. The case studies presented above highlight how barriers, particularly dams, can lead to the isolation of fish populations, reduced genetic diversity, and local extinctions.

7) **5.2 Species Traits and Vulnerability**

Species with strong migratory behavior are particularly affected by barriers, as they rely on longitudinal river connectivity to complete their life cycles. Species with specialized habitat needs, such as specific water quality or substrate conditions, are also more vulnerable to the negative impacts of barriers. As such, fish species with generalist behavior or those less dependent on migration are less affected.

8) **5.3 The Role of Fish Passage Solutions**

Fish passage solutions, such as fishways and bypass channels, can partially mitigate the effects of barriers on fish populations. However, as highlighted by Larinier (1998), the effectiveness of these solutions depends on the barrier type, the species involved, and the design of the passage. Fishways designed for large, migratory species like salmon may not work for other species that have different migration patterns or environmental needs.

6. Management and Policy Implications

9) 6.1 Barrier Removal and Retrofits

The most effective management strategy for restoring fish migration is the removal of obsolete barriers. In cases where removal is not feasible, retrofitting existing barriers with effective fish passage solutions can help restore connectivity. The design of these solutions should be species-specific and take into account the life-history traits of the target fish species.

10) 6.2 Integrated River Management

Management strategies should consider the cumulative impacts of multiple barriers along a river system. A holistic approach to river management is necessary, where barrier removal, habitat restoration, and sustainable fish passage designs are integrated into broader conservation and fisheries management frameworks.

11) 6.3 Monitoring and Adaptive Management

Long-term monitoring of fish migration, population health, and biodiversity is critical for assessing the effectiveness of fish passage solutions and barrier removal programs. Adaptive management strategies that incorporate monitoring data will allow managers to make informed decisions and adjust strategies as needed.

7. Conclusion

Fish passage barriers have profound effects on fish migration, population viability, and freshwater biodiversity. The empirical evidence reviewed in this paper demonstrates that barriers such as dams, weirs, and road culverts can disrupt fish migration, reduce population sizes, and alter community structures in river systems. While fish passage solutions have

been developed, their effectiveness remains variable, and barriers continue to pose significant challenges to fish populations and river ecosystem health.

To mitigate these impacts, river systems need to be managed with a focus on maintaining connectivity, removing or retrofitting barriers, and restoring habitats. Future research should continue to focus on improving fish passage designs, understanding the ecological effects of barrier removal, and monitoring the recovery of fish populations in fragmented river systems.

References

1. Dudgeon, D., Arthington, A. H., Gessner, M. O., et al. (2006). Freshwater biodiversity: Importance, threats, status, and conservation challenges. *Biological Reviews*, 81(2), 163-182.

2. Larinier, M. (1998). Upstream and downstream fish passage experience in France. In M. Jungwirth, S. Schmutz, & S. Weiss (Eds.), *Fish Migration and Fish Bypasses* (pp. 15-31). Oxford: Fishing News Books.

3. Williams, J. G., & Matthews, G. M. (1995). A review of flow and survival relationships for spring and summer Chinook salmon, Oncorhynchus tshawytscha from the Snake River Basin. *Fishery Bulletin*, 93, 732-740.

4. Mallen-Cooper, M. (1999). Developing fishways for non-salmonid fishes: A case study from the Murray River, Australia. In *Innovations in Fish Passage Technology* (M. Odeh, Ed.). American Fisheries Society, Bethesda.

5. Moyle, P. B., & Leidy, R. A. (1992). Loss of biodiversity in aquatic ecosystems: Evidence from fish faunas. In P. L. Foster & S. A. Slobodkin (Eds.), *Fish Community Ecology* (pp. 127-169). University of California Press.

6. Northcote, T. G. (1984). Mechanisms of fish migration in rivers. In J. D. McCeave, G. P. Arnold, J. J. Dodson, & W. H. Neil (Eds.), *Mechanisms of Migration in Fishes* (pp. 1-18). New York: Plenum Press.

7. Northcote, T. G. (1991). Influence of water flow, water temperature and light on fish migration in rivers. *Nordic Journal of Freshwater Research*, 66, 20-35.

8. Jungwirth, M., Schmutz, S., & Weiss, S. (2003). Fish migration and fish bypasses: A European perspective. *Hydrobiologia*, 510(1-3), 131-146.

9. Smith, M., Wright, M., & Thompson, H. (2003). Impact of culverts on freshwater fish migration. *Environmental Management*, 32(4), 556-564.

10. Larinier, M. (2000). Dams and fish migration. *In Dams, Ecosystem Functions and Environmental Management* (T. Pelletier et al., Eds.).

11. Agostinho, A. A., & Gomes, L. C. (1997). The dependence of fish community structure and dynamics on floodplain and riparian ecotone zone in Paraná River, Brazil. *Hydrobiologia*, 303, 141-148.

12. Baran, E. (2010). Mekong fisheries and mainstream dams. In ICEM (Ed.), *Strategic Environmental Assessment of Hydropower on the Mekong Mainstream* (pp. 215-230). Hanoi: International Centre for Environmental Management.

13. Welcomme, R. L. (1985). The influence of habitat on the structure of fish communities in tropical and temperate floodplains. *Environmental Biology of Fishes*, 14(4), 363-374.

14. Williams, J. G. (1998). Fish passage in the Columbia River, USA and its tributaries: Problems and solutions. In M. Jungwirth, S. Schmutz, & S. Weiss (Eds.), *Fish Migration and Fish Bypasses* (pp. 99-120). Oxford: Fishing News Books.

15. Dudgeon, D. (2000). River Fragmentation and Fish Migration: Effects of Dams on Freshwater Fish. *Environmental Biology of Fishes*, 59(1), 15-23.