Navigating the depths: exploring the fascinating types of fish migration

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Abstract. Fish migration is a complex and multifaceted phenomenon that plays a crucial role in shaping aquatic ecosystems and supporting the livelihoods of millions of people worldwide. By understanding the various types of fish migration and their ecological significance, scientists, policymakers, and resource managers can develop effective strategies for conserving migratory fish populations, restoring habitat connectivity, and promoting sustainable fisheries management. As human activities continue to exert pressure on aquatic ecosystems, efforts to protect and preserve migratory fish species are essential for maintaining the health and resilience of freshwater and marine environments. This paper delves into the various types of fish migration, highlighting their significance in ecosystem dynamics, fisheries management, and conservation efforts.
Key Words: anadromous, catadromous, diadromous, oceanodromous, potamodromous.

Introduction. Fish migration is a remarkable phenomenon observed across aquatic ecosystems worldwide. Migration entails the seasonal movement of fish populations between different habitats for specific purposes such as breeding, feeding, or seeking favorable environmental conditions. The diversity of fish migration patterns reflects a range of ecological, physiological, and evolutionary adaptations. This paper delves into the various types of fish migration, highlighting their significance in ecosystem dynamics, fisheries management, and conservation efforts.

Anadromous migration. Anadromous fish species undertake migrations between freshwater and marine environments for spawning. These fish are born in freshwater habitats, migrate to the ocean to grow and mature, and return to freshwater rivers and streams to reproduce (Myers 1949). Examples of anadromous fish include: the Atlantic salmon - *Salmo salar* Linnaeus, 1758, the rainbow trout - *Oncorhynchus mykiss* (Walbaum, 1792), the American shad - *Alosa sapidissima* (Wilson, 1811), The Pontic shad - *Alosa immaculata* Bennett, 1835, and the beluga *Huso huso* (Linnaeus, 1758) (Figure 1). Anadromous migrations are often energetically demanding and involve navigating complex river systems and overcoming barriers such as dams and pollution (Ionescu & Petrescu-Mag 2022). The return of anadromous fish to their natal streams for spawning plays a vital role in nutrient cycling and ecosystem productivity.

The beluga sturgeon (*H. huso*) migration is a remarkable journey of endurance and survival, undertaken by one of the largest freshwater fish species on Earth. These ancient giants, with their elongated bodies and distinctive appearance, navigate the world's great rivers with unwavering determination each year. Driven by instinctual cues, beluga sturgeons embark on a perilous upstream odyssey to reach their ancestral spawning grounds. Facing formidable obstacles such as strong currents, natural barriers, and human-made impediments, these majestic fish traverse hundreds or even thousands of kilometers, crossing international borders and navigating through multiple river systems (Hont et al 2019). Upon reaching their spawning grounds, beluga sturgeons engage in elaborate courtship rituals before releasing their eggs and ensuring their

dispersal over a wide area. However, the journey of beluga sturgeon migration is fraught with challenges. Overfishing, habitat destruction, pollution, and illegal poaching for their valuable roe threaten the long-term survival of these iconic fish (Ionescu 2020). Conservation efforts, including habitat restoration, fishing regulation, and the establishment of protected areas, are crucial for safeguarding beluga sturgeon populations and preserving their critical role in freshwater ecosystems. The story of beluga sturgeon migration serves as a poignant reminder of the resilience, adaptability, and interconnectedness of life in our planet's rivers and lakes, underscoring the importance of collective action in ensuring the continued survival of these ancient giants for generations to come.

Figure 1. The beluga *Huso huso* (Linnaeus, 1758), an anadromous fish species (photo credit: Tudor Ionescu).

Catadromous migration. In contrast to anadromous species, catadromous fish migrate from freshwater habitats to the ocean to spawn. They spend most of their lives in freshwater rivers and lakes before migrating to coastal or marine environments for reproduction (Myers 1949). Examples of catadromous fish include: the European eel - *Anguilla anguilla* (Linnaeus, 1758) and the flathead grey mullet - *Mugil cephalus* Linnaeus, 1758 (Figure 2). Catadromous migrations are less well understood than anadromous migrations but are thought to serve similar ecological functions in nutrient transport and energy transfer between ecosystems.


Figure 2. The flathead grey mullet, *Mugil cephalus* Linnaeus, 1758 (Arrábida National Park, Portugal) a catadromous fish species (photo: Diego Delso, wikipedia.org).

The migration of the European eel (*A. anguilla*) is a fascinating and complex journey that spans thousands of kilometers across oceans and continents. Born in the Sargasso Sea, tiny eel larvae embark on an incredible transatlantic voyage, drifting on ocean currents for several years until they reach the freshwater rivers and estuaries of Europe. Here,

they undergo a remarkable metamorphosis, transforming from transparent larvae into pigmented glass eels. As they continue their migration inland, these glass eels face numerous obstacles, including dams, pollution, and habitat degradation (Piper et al 2020). Despite these challenges, eels display remarkable resilience, using their keen sense of smell and navigation abilities to overcome barriers and reach their ancestral spawning grounds. Once mature, adult eels undertake the arduous journey back to the Sargasso Sea to spawn, completing the cycle of life. However, the migration of European eels is under threat due to factors such as overfishing and habitat loss. Conservation efforts, including the regulation of eel fisheries, habitat restoration, and international cooperation, are essential for protecting this iconic species and preserving its migratory routes for future generations (Podda et al 2021). The story of the European eel migration serves as a poignant reminder of the interconnectedness of global ecosystems and the importance of collective action in safeguarding the natural world.

Potamodromous migration. Potamodromous fish undertake migrations within freshwater river systems, often moving between different habitats to fulfill specific life cycle requirements. These migrations may include movements between spawning, nursery, feeding, and overwintering areas within riverine environments (Myers 1949). Potamodromous migrations are common among many freshwater fish species, including: the common dace - *Leuciscus leuciscus* (Linnaeus, 1758) (Figure 3), and many cyprinid species (Sanz-Ronda et al 2021). The timing and extent of potamodromous migrations vary depending on factors such as water temperature, flow rates, and resource availability (Alò et al 2021).

Figure 3. Specimen of common dace *Leuciscus leuciscus* (Linnaeus, 1758) of 16 cm (potamodromous species), caught in the Lipetsk oblast, Russia (photo by Alexander Suvorov, Wikipedia.org).

The migration of the common dace (*L. leuciscus*) is a vital component of freshwater ecosystems, showcasing the species' remarkable adaptation to seasonal changes and their role in maintaining ecosystem health. Common dace typically inhabits rivers and streams across Europe and parts of Asia, where they undertake seasonal movements driven by factors such as temperature, water flow, and reproductive needs (Clough & Beaumont 1998). During the warmer months, dace often gather in deeper pools and slower-moving stretches of water, where they feed on aquatic insects, crustaceans, and plant matter. As temperatures drop and winter approaches, common dace migrate downstream to seek refuge in deeper, warmer waters, where they can conserve energy and survive harsh environmental conditions. Additionally, common dace may migrate upstream to spawn in the spring, seeking out shallow, gravel-bottomed areas where females deposit their eggs and males release sperm to fertilize them. This reproductive migration plays a crucial role in maintaining healthy fish populations and ensuring the survival of the species. However, the migration of common dace is increasingly threatened by human activities such as habitat destruction, pollution, and the construction of dams and other barriers.

Oceanodromous migration. Oceanodromous fish undertake migrations entirely within marine environments, moving between different oceanic regions for feeding, breeding, or overwintering (Myers 1949). These migrations may span vast distances and involve navigating ocean currents, temperature gradients, and seasonal changes in productivity. Oceanodromous migrations are characteristic of pelagic fish species such as: skipjack tuna - *Katsuwonus pelamis* (Linnaeus, 1758) (Figure 4), swordfish - *Xiphias gladius* Linnaeus, 1758, black marlin - *Istiompax indica* (Cuvier, 1832), and most species of sharks. Some species undertake extensive transoceanic migrations (Orlov et al 2020), while others exhibit more localized movements within coastal or offshore areas.

Figure 4. *Katsuwonus pelamis* (Linnaeus, 1758), an oceanodromous fish species (source: Hermawan et al 2023).

The migration of skipjack tuna (*K. pelamis*) is a remarkable journey that spans vast expanses of ocean, showcasing the species' adaptability and the interconnectedness of marine ecosystems. Skipjack tuna, known for their streamlined bodies and distinctive striping, are highly migratory fish found in tropical and subtropical waters worldwide. Their migrations are driven by a combination of factors, including temperature, food availability, and reproductive needs (Kiyofuji et al 2019). During the warmer months, skipjack tunas often travel long distances in search of food, following the movements of schools of smaller fish and other prey. These migrations can take them across entire ocean basins, from the Pacific to the Atlantic and Indian Oceans. As temperatures change and food sources become scarce, skipjack tuna may undertake seasonal movements to more favorable feeding grounds, sometimes congregating in large schools near the ocean's surface. Additionally, skipjack tunas are known to undertake extensive migrations for spawning purposes. They often gather in specific areas, such as offshore banks or seamounts, where they release their eggs and sperm into the water column. These spawning migrations are crucial for maintaining healthy skipjack tuna populations and ensuring the survival of the species. However, skipjack tuna migrations are increasingly threatened by overfishing and habitat destruction. Industrial fishing fleets target skipjack tuna for their valuable meat, which is widely used in canned tuna products and sushi. Conservation efforts aimed at sustainable fishing practices, habitat protection, and the establishment of marine protected areas are essential for preserving skipjack tuna populations and maintaining the health of ocean ecosystems.

Diadromous migration. Diadromous fish exhibit a combination of freshwater and marine migrations at different life stages. This category includes both anadromous and catadromous species, as well as species that migrate between freshwater and estuarine habitats (Myers 1949). Diadromous migrations are highly diverse and occur in a wide range of fish taxa, including salmons, eels, lampreys, and herrings. Diadromous fish play important roles in ecosystem functioning, nutrient cycling, and the economies of coastal and freshwater communities (Verhelst et al 2021).

Conclusions. Fish migration is a complex and multifaceted phenomenon that plays a crucial role in shaping aquatic ecosystems and supporting the livelihoods of millions of people worldwide. By understanding the various types of fish migration and their ecological significance, scientists, policymakers, and resource managers can develop effective strategies for conserving migratory fish populations, restoring habitat connectivity, and promoting sustainable fisheries management. As human activities continue to exert pressure on aquatic ecosystems, efforts to protect and preserve migratory fish species are essential for maintaining the health and resilience of freshwater and marine environments.

Conflict of interest. The authors declare that there is no conflict of interest.

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