Review Article

Reproductive Migration of Fish and Their Transit Through Azerbaijan Waters

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Abstract

The article summarizes the concept of fish reproductive migration, its main types, and the biological and ecological characteristics of migratory fish. The main goal of the study is to analyze the reproductive migration of migratory fish, especially species belonging to the sturgeon and salmonid families, distributed in Azerbaijani waters, the factors affecting the decline of their natural resources, and the importance of artificial enrichment measures. The article shows that migratory fish ensure population sustainability by moving between marine and river environments at different stages of their life cycle. The construction of hydrotechnical facilities, water pollution, illegal hunting, and degradation of natural spawning grounds in the Kura and Araz basins have sharply weakened the reproductive capabilities of these fish. Artificial reproduction programs are of strategic importance for the protection and restoration of valuable species, especially sturgeon and Caspian salmon, as their stocks are declining. The article discusses the role of fish breeding facilities operating in Azerbaijan, the importance of the practice of artificial insemination and the release of fry into natural water bodies, as well as the genetic, technological, and ecological problems that arise during this process. As a result, it is justified that artificial breeding alone is not enough for the restoration of migratory fish, and that it must be implemented in conjunction with the protection of basin ecosystems, the restoration of migration routes, and scientific monitoring.

Keywords: reproductive migration, migratory fish, sturgeons, salmonids, artificial insemination

1. Introduction

Fish migration is a significant biological event in terms of the circulation of substances in aquatic ecosystems, population dynamics, and the maintenance of biodiversity. As a result of migration, fish choose the most favorable environments for feeding, wintering, and reproduction. This process is especially clearly observed in migratory fish. These species spend different stages of their life cycle in marine and freshwater environments, reproducing primarily in rivers. Consequently, they serve as valuable indicators of the ecological condition of both marine and freshwater ecosystems.

The water bodies of Azerbaijan, primarily the Caspian Sea and the Kura and its tributaries, have historically been one of the habitats for valuable migratory fish. Sturgeons and salmonids are of great importance not only biologically, but also economically. However, in recent decades, increasing anthropogenic pressures, the construction of dams and reservoirs on rivers, deterioration of water quality, and illegal hunting have seriously affected the stocks of these species.

For this reason, artificial reproduction measures are widely used to protect and restore natural populations of migratory fish [1]. Artificial reproduction includes not only the acquisition of juvenile fish and their release into water bodies, but also complex measures such as the formation of mother fish flocks, the preservation of the gene pool, and ensuring adaptive management. Therefore, this review aims to evaluate reproductive

migration of migratory fishes occurring in Azerbaijani waters, with particular emphasis on sturgeons and salmonids, and to assess current artificial propagation strategies and future conservation priorities.

2. Reproductive Migration and Biological Characteristics of Migratory Fish

Migration is the regular and repetitive movement of organisms, including fish, from one habitat to another in order to meet certain biological needs. In fish, migration is often associated with feeding, reproduction, hibernation, and the provision of separate stages of ontogenesis. These movements act as a mechanism for adapting not only to spatial changes but also to factors such as temperature, salinity, flow rate, oxygen regime, and photoperiod.

Fish migration is classified according to various principles. Depending on the purpose, feeding, wintering, and breeding migrations are distinguished. Depending on the direction, horizontal and vertical migration are distinguished. In vertical migration, fish change places between water layers, while in horizontal migration, they cover large distances. Depending on the environments involved in the life cycle, marine, river, transient, and semi-transient migrations are noted.

Of particular importance is reproductive migration, during which sexually mature individuals move to areas most suitable for their embryonic and early postembryonic development for spawning. In such areas, the water is usually rich in oxygen, the flow is stable, the bottom is sandy and gravelly, and the temperature regime is favorable. Restricted access to natural breeding grounds has a direct negative impact on the population of migratory species.

In the scientific literature, two main groups of migratory fish are indicated: anadromous species feed in the sea and reproduce in rivers, and catadromous species, on the contrary, live in fresh waters and reproduce in the sea. In the Caspian basin, the most important from the point of view of economy and protection are anadromous, that is, fish that migrate from the sea to the river. Sturgeon and Caspian salmon, which are widespread in Azerbaijani waters, belong to this group.

Migratory fish are species that regularly move between bodies of water of different salinity to complete their life cycle. Their bodies have highly developed osmoregulation mechanisms. This feature allows them to regulate water-salt metabolism during the transition from the sea to the river or vice versa. Migration in migratory fish is not only a physiological phenomenon, but also a form of instinctive behavior.

The life cycle of these fish usually consists of several stages: ascending the river to spawn, initial development of the larvae that hatch from the eggs in the river, then the juveniles to the sea, intensive feeding and growth in the sea, and migration back to the river after reaching sexual maturity. Disruption of this sequence reduces the rate of population renewal and puts the species' survival at risk.

Migratory fish usually have high commercial value [2]. Sturgeons produce black caviar and high-quality meat, while salmonids are important both as a valuable food product and as a sport fishery. Therefore, intensive fishing in the past has put serious pressure on these species. Currently, many migratory fish species are listed as rare or endangered species.

There are two main approaches to protecting transient species: natural habitat restoration and artificial augmentation. The first approach requires maintaining the ecological flow of rivers, opening migration routes, and reducing pollution. The second approach is based on taking reproductive products from mother fish in a hatchery, raising juveniles through artificial insemination, and releasing them into natural reservoirs.

3. Reproductive Migration of Sturgeons and Salmonids in Azerbaijani Waters and Artificial Propagation Measures

The Caspian Sea is one of the basins where the world's most important sturgeon stocks are formed. According to official data, more than 100 fish species and subspecies live in the Caspian Sea, some of which are migratory and semi-migratory species; 6 species of sturgeon are noted to be widespread in this basin. This group has historically had high economic importance in Azerbaijani waters. The main feature of their breeding strategy is their migration to rivers after feeding at sea.

The main sturgeons found in Azerbaijani waters include sturgeon, longnose sturgeon, stellate sturgeon, and Russian sturgeon. The largest and slowest-maturing forms of these species are giant beluga-type sturgeons,

while smaller forms are regional and other species. Sturgeons are particularly vulnerable to anthropogenic impacts because they are long-lived, reach sexual maturity late, and have a low natural recovery rate.

The most important migration route of the Sturgeons was connected to the Kura River [3]. In the past, these fish would migrate upstream along the river to spawn in areas with flowing, oxygenated, and gravelly bottoms. However, hydrotechnical structures, especially the Mingachevir reservoir and other regulatory facilities, have restricted the migration route. As a result, most of the natural spawning grounds have become inaccessible, and the natural reproduction of sturgeon has weakened.

The second major threat to sturgeon is illegal and uncontrolled fishing. The species has been intensively exploited for many years due to the high market value of its caviar and sturgeon meat. For this reason, a moratorium on commercial fishing was introduced in 2011 to protect sturgeon in the Caspian Sea. Although the moratorium is a significant conservation measure, it is not sufficient on its own to fully restore the population; artificial reproduction and habitat restoration are essential in parallel.

Hatcheries operate in Azerbaijan to restore sturgeon stocks. State and international sources state that millions of sturgeon fry are released into the Caspian Sea every year. At the same time, FAO data indicate that the Khilli sturgeon hatchery, located in the lower reaches of the Kura River, is carrying out artificial propagation of Acipenser persicus, Acipenser stellatus, Acipenser nudiventris, and Huso huso. The maintenance of broodstock, the procurement of reproductive products, and the raising of fry in these facilities constitute a key part of the sturgeon conservation strategy.

The most important place among migratory salmonids in Azerbaijani waters belongs to the Caspian salmon or Kura salmon. This fish is an anadromous form that feeds in the sea and enters rivers to reproduce. According to official data, there are two types of salmon in the Caspian [4]. Caspian salmon and white salmon. However, the main object of research in terms of reproductive migration is the Caspian salmon.

The biological characteristic of Caspian salmon is that after hatching, the juveniles develop in freshwater for a certain period of time, then descend to the sea and grow intensively [5]. Various sources indicate that this species has formed local populations associated with the Kura, Samur, Yalama, and other rivers. Clean, cold, oxygen-rich, and gravelly bottom areas are essential for their reproduction.

Historical data indicate that Caspian salmon was an important hunting target until the mid-20th century. However, the stock has declined sharply due to dam construction, changes in water regime, pollution, and destruction of spawning grounds in the Kura and Araz rivers. Disruption of the migration route is one of the most critical factors for this species, as salmon need to reach upstream to reproduce.

Special breeding facilities have been established in Azerbaijan to restore salmonids. According to the Ministry of Ecology and Natural Resources, approximately 200,000 salmon fry are released into natural water bodies each year. FAO data from 2021 shows that Kura salmon are being bred at the Azerbaijan Experimental Marine hatchery, and tens of thousands of 50-gram fry are released into the Caspian Sea every year. This fact shows the real practical importance of artificial breeding in restoring salmonid stocks.

However, for salmonids, simply releasing fry is not enough. The survival rate of the released individuals, their adaptation to the sea, protection from predators, the food base, and the ecological state of the rivers directly affect the final result. Therefore, the protection of salmonids should be based on the basin approach, and ecological measures should be taken in the upper reaches of the rivers.

Artificial breeding of migratory fish is a system of complex biotechnical measures applied in conditions of natural population decline or disruption of natural reproduction [6]. This system includes the capture or retention of parent fish, assessment of their maturity status, collection of reproductive products, artificial insemination, incubation, rearing of larvae and fry, and subsequent release into natural water bodies of appropriate size.

The main goal of artificial augmentation is not to artificially increase the natural resource, but to support the population's self-renewal potential. Therefore, preserving genetic diversity in breeding programs, using mother fish of different ages and origins, controlling diseases, and selecting the release time according to ecological conditions are important conditions. Otherwise, while a short-term increase in numbers may be observed, long-term recovery may not be achieved.

In Azerbaijan, this sector is being developed through both state and private enterprises [2]. According to official and FAO data, specialized fish breeding facilities operate in the country to restore stocks of migratory and other valuable fish species. The FAO indicates that three main hatcheries operate in the country, of which the Khilli Sturgeon Plant specializes in sturgeon, and the Azerbaijan Experimental Marine Hatchery specializes in Kura salmon.

FAO figures for 2019 indicate that 0.342 million sturgeon, 0.168 million Caspian (Kura) salmon, and a total of 3.927 million valuable fish fry were released into natural basins. Information from the Ministry of Ecology and Natural Resources shows that 7-9 million sturgeon juveniles and approximately 200,000 salmon fry are released annually [7]. The difference in figures may be due to different years and reporting approaches, but both sources confirm that artificial augmentation occupies an important place in the country's politics.

One of the most important stages in the artificial reproduction process is the correct selection of the place and time for the release of the fry. The fry should be released at a stage where they can adapt to the water temperature, salinity, food base, and hydrodynamic regime. The normal formation of landing behavior after release, especially in transient species, strongly influences subsequent survival rates. Therefore, fish breeding measures should be accompanied by continuous monitoring and tagging programs.

Despite artificial enrichment measures, the stable recovery of migratory fish stocks is hampered by a number of problems. The first problem is the limited stock of parent fish [8]. As natural populations decline, it becomes more difficult for factories to obtain mature, productive individuals. This increases the risk of reusing individuals with the same genotype and can lead to a decrease in genetic diversity.

The second important problem is technological and veterinary in nature. During the incubation and initial rearing stages, slight deviations in temperature, oxygen, water chemistry, and sanitation lead to high losses. Sturgeons and salmonids are particularly vulnerable during the larval stage. The spread of diseases, poor feed quality, or failure to carry out timely prophylaxis weaken the quality of the breeding material.

The third problem is ecological. After the factory-raised fry are released into the natural basin, most of them face unfavorable environmental factors. Disturbance of ecological flow in rivers, pollution, transformation of beds, and weakening of the food base in the sea reduce their survival rate. If the natural habitat is not restored, the effect of artificial reproduction remains limited.

The fourth problem is that migration routes are closed [9]. Even if fish are caught in a factory and released into the sea, there must be passageways in rivers to allow them to return to their natural breeding grounds once they reach sexual maturity. Dams and hydroelectric dams interrupt these routes, so the natural cycle is not completed. In this case, the population becomes permanently dependent on the plant, which is not an ecologically desirable model.

The fifth problem is that management and monitoring are not sufficiently integrated. An effective program requires the marking of released juveniles, registration of returning producers, genetic analyses, and monitoring of river and marine habitat indicators. Without this information, it is not fully determined which method is more effective, and which species cause the most losses at which stage.

4. Conclusion

While artificially increasing migratory fish populations is an important conservation tool, it must be complemented by an ecosystem approach. The main priorities in this area are the protection of the parent fish gene pool, the ecological restoration of water bodies, the prevention of illegal fishing, the implementation of fish passage devices, and the strengthening of the scientific observation system.

The analysis shows that reproductive migration of fish is one of the main biological mechanisms of their population sustainability. In migratory fish, this process provides interaction between marine and river ecosystems and is directly related to reproduction, which is the most sensitive stage of the life cycle.

Among the migratory fish in Azerbaijani waters, sturgeons and salmonids occupy a special place. These species are of great importance both in terms of biodiversity and economic value. However, their stocks have been seriously reduced as a result of the loss of natural spawning grounds, the closure of migration routes, pollution, and illegal hunting.

In the current situation, artificial propagation is an important tool for the conservation and restoration of these species. Specialized fish breeding facilities operating in Azerbaijan ensure that sturgeon and salmon fry are raised and released into natural reservoirs [10]. However, the effectiveness of artificial propagation directly depends on the condition of the natural habitat.

Therefore, future measures to protect migratory fish should be comprehensive. Artificial breeding programs should be coordinated with the restoration of river ecosystems, the opening of migration routes, genetic monitoring, the application of modern biotechnological methods, and management at the basin level. Only in this case will it be possible to achieve long-term restoration of migratory fish stocks in Azerbaijani waters.

Author Contributions

Y. Seyidzade prepared the manuscript, conducted the literature review, and wrote the original draft. N. Guliyeva supervised the study, provided scientific guidance, and critically revised the manuscript. Vitaliy Bekh reviewed the manuscript and contributed to its improvement through editing and constructive comments. All authors have read and approved the final manuscript.

Conflict of Interest

The authors declare no conflicts of interest.

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