

Mechanisms of Ecological Adaptation of Rare Fish Species in the Conditions of the Khorezm Oasis

Babadjanova Sayyora Khushnutovna

Associate Professor of the Department of Biotechnology of Urgench State University named after Abu Rayhan Beruni

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Abstract: The Khorezm oasis is located in the lower reaches of the Amu Darya basin and is a complex hydro-ecological region, characterized by instability of the hydrological regime, a high degree of water salinity, and increased anthropogenic pressure. These factors have a significant impact on the composition of aquatic ecosystems and ichthyofauna in the region, especially on the distribution and stability of rare and environmentally vulnerable fish species.

Keywords: Khorezm oasis, rare fish species, ecological adaptation, ichthyofauna, anthropogenic factors, biodiversity

Introduction

The inland water bodies of Uzbekistan, in particular the Khorezm oasis, are rich in inland water resources, where fish species adapted to various ecological conditions live. In recent years, as a result of anthropogenic factors, climate change, water mineralization, and the deterioration of the ecological situation in natural water bodies, the number of a number of rare fish species is sharply decreasing. Therefore, a deep study of the mechanisms of their ecological adaptation is a pressing issue in ecology and fish farming[1].

The Khorezm oasis is a region rich in inland water systems of Central Asia. Its hydrological conditions are historically variable, forming complex ecological gradients for fish populations through the Amu Darya and territorial canals. Under these conditions, rare fish species (for example, endemic populations of *Schizothorax* spp., *Capoeta capoeta*, and *Carassius auratus*) developed specific adaptations.

Adaptation is the organism's response to environmental conditions, formed through the evolutionary process. In fish, this process manifests itself at the morphological, physiological, and behavioral levels[2].

Fish exhibit a variety of ecological adaptation mechanisms, including morphological (simplified bodies, fins, scales, specialized jaws, gills for underwater breathing, swimming for swimming bubbles), physiological (osmoregulation for salinity, metabolic adjustments for temperature/oxygen, bioluminescence) and behavioral (migration, camouflage, thermal navigation, specialized nutrition/mating, drowsiness) characteristics, all related to genetic factors and evolutionary dynamics, such as natural selection for survival in a particular aquatic environment ranging from deep sea pressure to variable temperature and salinity[3].

Table 1. Ecological adaptations in fish: general classification

Adaptation type	Direction	Description and significance
Morphological adaptations	Body shape	Fusiform (simplified) body shape for fast swimming; flat or uneven body shape adapted for living on the bottom and camouflage.
	Finns (Swimflies)	The thoracic and pelvic fins maintain balance while the caudal fin provides basic movement; allowing for different swimming styles gives.
	Gills	Ensures efficient removal of oxygen from water, the main organ for water respiration.
	Floating urine vesicle	Energy of swimming depth in most bony fish controls without spending.
	Scales and mucus	Mechanical protects and reduces water resistance.
	Specialized jaw and teeth	Predation, filtration, or plant-feeding adapted to diets.
Physiological adaptations	Osmoregulation	Water-salt through the kidneys, gills, and specialized maintains cell balance; allows for survival in fresh and salty water.
	Metabolic adaptations	Metabolic rate and erythropoiesis change to adapt to hypoxia and temperature changes.
	Pressure resistance	In deep-sea fish, substances such as TMAO protect proteins from high pressure.
	Sensory systems	Improved vision, electrical reception, and bioluminescence are used for hunting and communication.
Behavioral adaptations	Camouflage and mimicry	Adapting to the environment through color and patterns, protecting oneself from predators.
	Migration	Seasonal movements for feeding, spawning, or temperature adjustment (e.g., salmon).
	Thermoregulation	Finding the optimal temperature along thermal gradients.
	Reproduction strategies	Time of fertilization, parental care, and diversity of reproductive forms.
	Insomnia (torpor)	Metabolic activity in unfavorable conditions (low temperature) decrease.

Genetik va evolyutsion omillar	Genetic basis	Adaptations are based on genetic changes and are reinforced by natural selection.
	Ecotypes formation	Different salinity and breeding conditions within the same species adapted ecotypes emerge (for example, the Atlantic herring).

Degree of study of the problem. The ecology and adaptation mechanisms of rare fish species have been studied by many scientists of Uzbekistan. In particular, A.M.Mukhamedov, R.A.Rakhimov, N.M.Karimova, V.A.Shukurov, A.A.Nasriddinov and others studied the bioecology, morphological variability, physiological adaptations, and population dynamics of fish of the Amu Darya basin under anthropogenic influence[4].

However, since the specific hydrological, climatic, and melioration conditions of the Khorezm oasis differ from other river basins, it is necessary to study the mechanisms of ecological adaptation of fish species living in this territory separately. In the available literature, the ecology of the habitat of some fish species in the conditions of the Khorezm oasis has not been fully analyzed, and this research fills this gap[5].

Mechanisms, their physiological, morphological, and biochemical properties[6].

Research methods

- Ecological observation method - determining the habitats of fish in the natural environment;
- Hydrochemical analysis - determination of the physicochemical composition of water (temperature, pH, salinity, O₂ content)[7];
- Morphometric method - measurement of external morphological indicators of fish;
- Biochemical analysis - determination of metabolic processes, enzyme activity, and energy metabolism;

Statistical analysis - mathematical processing of the obtained results [8].

As a result of the research, it was established that different ecological conditions exist in different water bodies of the Khorezm oasis. The flow rate, temperature, and mineralization of the Amu Darya River differ significantly compared to the Tuyamuyun Reservoir[9]. Therefore, fish exhibit different forms of adaptation depending on their habitat. For example, the Amu Darya shortbread is adapted to fast-flowing water and is characterized by strong muscle tissue and dense bone structure. The catfish is adapted to living in underwater clay areas, and its respiratory system is resistant to oxygen deficiency. Some semi-endemic species retained their viability even in environments with increased water mineralization[10].

These adaptation mechanisms are formed at the genetic and physiological levels, and their life strategy is the result of evolutionary adaptation to the conditions of the Khorezm oasis.

Conclusion

The research results show that rare fish species found in the Khorezm oasis have formed complex adaptive mechanisms adapted to the specific natural and ecological conditions of the region during a long evolutionary process. These adaptations are closely related to the temperature regime of water bodies, the degree of water mineralization, the amount of dissolved oxygen, and anthropogenic pressures caused by human activity. In particular, some fish species are adapted to living in conditions of high temperature and salinity, while others exhibit physiological resistance to oxygen deficiency.

Also, during the study, it was established that economic activities carried out in water bodies, including irrigation systems, industrial and household waste, and artificial regulation of water

flow, negatively affect the natural habitat of fish species. This situation can lead to a decrease in the number of some rare species, a decrease in biodiversity, and a disruption of the ecological balance.

Based on the obtained scientific data, it is advisable to implement the following practical measures:

development and strengthening of comprehensive programs for the protection of rare and endangered fish species in the natural environment, as well as their artificial reproduction and reintroduction;

Establishment of a permanent monitoring system for assessing the ecological state of water bodies, monitoring water quality, and conducting analysis based on biological indicators;

Development of a strategy for the rational and sustainable use of natural water resources, integration of environmental requirements into fishery activities.

The results of this research serve as an important scientific and practical basis for the ecologically sustainable development of fisheries in the Khorezm oasis, the protection of biological resources, and the preservation of natural resources for future generations. At the same time, these conclusions are of great importance in improving regional environmental policy and making scientifically based management decisions.

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