


# Novel Aspects in Freshwater Fauna Conservation

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Freshwater ecosystems, which include rivers, lakes, wetlands, springs, streams, and ponds, harbor a rich diversity of life, making them some of the most biologically productive environments on Earth. Even though they account only for approximately 1% of Earth's surface and 0.01% of the world's water, they make up approximately 10% of the world's biodiversity [1,2]. Just the estimated 25,000–40,000 different fish species residing in these ecosystems comprise 30–50% of all vertebrate diversity [3]. The rich freshwater fauna plays crucial roles in maintaining ecological balance and providing essential services to human societies, such as water purification and food resources. Unfortunately, many freshwater species are increasingly endangered due to a combination of anthropogenic pressures, necessitating urgent conservation efforts.

The endangerment of freshwater species is driven by several factors, primarily habitat loss and degradation due to anthropogenic activity. Urbanization, agriculture, and dam construction have altered natural water flows and polluted aquatic environments, leaving species with fewer viable habitats. Additionally, overexploitation, whether for food, sport, or the pet trade, has led to dramatic declines in certain species populations. Invasive species introduced by human activities further exacerbate the problem, often outcompeting native fauna for resources or introducing new diseases. Climate change is another impending threat, altering water temperatures and precipitation patterns, which in turn disrupts the delicate ecosystems that many species depend on.

The importance of conserving freshwater fauna extends beyond preserving biodiversity. These species are integral to the health of freshwater systems, contributing to nutrient cycling, maintaining water quality, and providing food for other animals, including humans. The loss of key species could have cascading effects, leading to the collapse of entire ecosystems. Moreover, freshwater systems often support human communities through the provision of clean water, food, and recreational opportunities, emphasizing the necessity of sustainable management.

Recent innovations in freshwater fauna conservation offer hope for reversing some of these negative trends. One promising area is the development of habitat restoration techniques that prioritize ecosystem-wide approaches rather than focusing on single species. Restoring wetlands, re-establishing natural water flows, and improving water quality have shown success in reviving degraded ecosystems. Genetic tools, such as environmental DNA (eDNA) monitoring, allow for more accurate detection of species presence and biodiversity assessments, which can guide more targeted conservation efforts. Public awareness campaigns to reduce pollution, minimize overexploitation, and halt the spread of invasive species will also be critical. Furthermore, addressing global climate change will play a key role in safeguarding the future of freshwater ecosystems. This Special Issue has collected five original research articles, each delving into a specific area of freshwater fauna conservation. The papers aim to provide a comprehensive overview of the existing threats to freshwater ecosystems, particularly concerning freshwater fauna, and to propose potential solutions to these challenges.



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The research conducted by Tarandek et al. [4] delves into the effects of habitat alterations on water quality and their impact on characteristics of a stone crayfish (*Austropotamobius torrentium*) population. Anthropogenic activities have been identified as a major cause of habitat degradation, resulting in reduced population densities and changes in age structures in the more disturbed areas. These findings emphasize the critical need for habitat preservation and restoration as integral elements of crayfish conservation strategies. While genetic analysis did not reveal significant genetic variance among the crayfish populations at the studied sites, ongoing habitat deterioration could pose potential risks to genetic diversity and the overall health of populations. Therefore, genetic monitoring and proactive conservation measures are of utmost importance. Successful conservation strategies should address the primary threats to freshwater ecosystems, including habitat degradation and pollution. Restoration initiatives should prioritize the improvement of habitat quality, pollution reduction, and mitigation of the impact of human activities. Furthermore, conservation programs should include genetic monitoring to ensure the long-term sustainability of crayfish populations. The insights gained from the Kustošak Stream case study offer valuable information that can guide broader conservation efforts for freshwater invertebrates. By comprehending the impact of habitat disruption and preserving genetic diversity, conservationists can develop targeted methods to safeguard these vulnerable species and their habitats.

Monitoring biodiversity and environmental changes is critical to understanding the status of freshwater species and ecosystems. Regular monitoring of key population dynamics and life-history parameters can provide early warnings of population declines, habitat degradation, or the emergence of invasive species, enabling quicker and more targeted conservation responses. Jakovljević et al. [5] investigated the population dynamics of the spirlin (*Alburnoides bipunctatus*), a small fish facing significant decline in Europe. The authors determined long-term population dynamics parameters and employed advanced AI analytical methods, UMAP, and decision tree algorithms, to analyze the influence of various environmental factors on the spirlin populations. Spirlin exhibited migratory patterns, moving upstream to higher altitudes during early summer and autumn. Despite the presumed vulnerability, the species showed a notable presence in altered habitats, which have been affected by pollution, climate change, and anthropogenic pressures. The study underscores the importance of maintaining environmental quality and managing anthropogenic impacts to support the conservation of spirlin. The insights into the species' adaptability and migratory behaviors provide valuable information for developing effective conservation strategies. These findings contribute to a broader understanding of how environmental factors and human activities influence the population dynamics of freshwater species, which is crucial for their conservation.

In addition, Barić et al. [6] investigated the morphological characteristics of European eels (*Anguilla anguilla*) to assess their population status in the Neretva River estuary in Croatia. The research revealed significant variations in the morphometric traits between different developmental stages of the eels. The study underscored the impact of environmental factors such as habitat conditions and fishing pressure on the morphological development of eels, which consequently influences their growth and overall population dynamics. The findings highlight the importance of using morphological indicators to monitor eel populations and develop conservation strategies to safeguard them from overfishing, habitat degradation, and other environmental changes. Overall, the study emphasizes the relevance of functional morphology in understanding and managing eel populations, contributing to broader conservation efforts for freshwater fauna.

Climate change is affecting freshwater systems by altering water temperatures, flows, and seasonal patterns. The study by Stojanović et al. [7] investigates the potential impact of climate change on two caddisfly species, *Helicopsyche bacescui* and *Thremma anomalum*, within the Balkans and neighboring regions. The researchers utilized species distribution models to predict how temperature and precipitation variations could influence these trichopteran species' distribution. Across all future climate change scenarios and models,

distinct responses to climate change and potential habitat shifts were observed, despite the similar ecological requirements of these two species. Predictions are that the species *H. bacescui* will potentially lose up to 68% of its range, while *T. anomalum* could expand its range by up to 72%. The study underlines the inadequacy of current protected areas (PAs) in the Balkans for conserving these freshwater species. It underscores the need for better management and expansion of PAs to include habitats critical for these and other freshwater invertebrates. The results advocate for integrating climate change projections into conservation planning to ensure the long-term survival of vulnerable species.

Engaging local communities in conservation efforts is crucial for long-term success. Indigenous and local knowledge about freshwater systems can complement scientific data, providing insights into species behavior, water flows, and environmental changes. Programs that involve communities in monitoring, habitat restoration, and sustainable water use can foster a sense of stewardship. Education campaigns that raise awareness about the importance of freshwater fauna, the impacts of pollution, and the need to prevent invasive species introductions can encourage more sustainable behaviors at a grassroots level. The study by Mercugliano et al. [8] delves precisely into this often-overlooked human dimension within conservation projects. The authors examined visitor perceptions of the conservation efforts for the native white-clawed crayfish (*Austropotamobius pallipes*) in a protected area, which has been severely affected by the invasive spiny-cheek crayfish (*Faxonius limosus*). These insights are crucial for effective conservation management and garnering public support. The research reveals that visitors' knowledge of crayfish characteristics significantly influences their attitudes toward conservation initiatives. Individuals with greater knowledge were more inclined to support investments in resources, eradication of invasive species, and educational training programs. The study highlights that enhancing visitor awareness and understanding can increase approval and backing for conservation initiatives. The authors emphasize the importance of addressing human impacts and fostering public awareness and involvement in protecting endangered freshwater species. Their findings highlight the necessity of incorporating social dimensions into conservation strategies to effectively manage and safeguard endangered species like the white-clawed crayfish. Understanding visitor awareness and attitudes is essential for developing more effective conservation strategies and educational programs.

In conclusion, while the challenges to freshwater fauna conservation are considerable, there are many potential solutions that can improve current efforts. By combining habitat restoration, innovative technologies, sustainable water management, and community involvement, we can create a more resilient future for freshwater ecosystems and the species that depend on them. Addressing global challenges such as climate change and pollution, and integrating conservation into broader policy frameworks will be essential for ensuring the long-term health of these vital ecosystems.

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