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Review of riverine fish species, ecological impacts, and human interventions

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Abstract
Fish play a crucial role in maintaining the health and stability of riverine ecosystems, acting as both indicators of environmental quality and integral components of the aquatic food web. This review aims to provide a comprehensive synthesis of existing research on riverine fish, focusing on their ecological roles, responses to anthropogenic impacts, and various aspects of their biology and ecology. Key topics covered include the influence of human activities such as pollution, habitat alteration, and climate change on fish populations and river ecosystems. The review also examines significant research findings on fish landings, which provide insights into the trends and pressures faced by these populations over time. Additionally, it explores the dynamics of ecological changes within river systems, including shifts in fish communities and their implications for ecosystem function. Aging biology, including growth patterns and longevity of riverine fish, is discussed to understand the life history strategies of these species. The review also addresses the issues of biodiversity and taxonomy, highlighting the diversity of fish species in river systems and the challenges in classifying and conserving them. By integrating findings from a broad range of studies, this review offers an extensive overview of the current state of riverine fish populations and underscores their significance in assessing and managing riverine ecosystems.

Keywords: River system, human activities, age and growth

Introduction
Riverine ecosystems are among the most dynamic and ecologically significant environments on Earth, supporting a rich array of biodiversity and providing essential services to human societies. These systems are crucial for the health of aquatic and terrestrial environments, acting as nurseries for various species, sources of freshwater, and habitats for diverse flora and fauna (Chakraborty *et al*., 1989; Singh *et al*., 1998) [18, 63]. Fish, as integral components of riverine ecosystems, play a pivotal role in maintaining ecological balance and serve as critical indicators of environmental health (Bagenal, 1978; Jhingran, 1992) [10, 40]. They contribute to nutrient cycling, energy flow, and community structure, and shifts in fish populations can reflect broader changes in water quality, habitat availability, and ecosystem health (Froese and Pauly, 2005; Karr *et al*., 2006) [31, 44]. However, human activities such as industrialization, urbanization, agriculture, and dam construction have led to significant habitat degradation, pollution, and altered flow regimes, causing declines in fish populations and changes in species composition (Harris, 1995; Koehn, 2004) [35, 46]. Understanding these impacts is essential for effective management and conservation. Fishery assessments and landings data are crucial for tracking population trends, fishery health, and the effects of human activities, with studies from rivers like the Yamuna, Ganga, and Narmada providing valuable insights (Anon, 1962; 1976; 1991; 2001; 2002; 2003; 2008; 2010; Gupta and Tyagi, 1992) [2-9, 32]. This review synthesizes literature on riverine fish, focusing on fishery assessments, species changes, aging studies, biodiversity, and taxonomy, to offer a comprehensive overview of their ecological roles and the challenges facing riverine ecosystems (Berg, 1940; Dwivedi *et al*., 2004; Zhao, 1999) [11, 28, 70].

Fishery assessments and landings
Fishery assessments and landings are crucial for understanding the health and trends of riverine fish populations. Studies from rivers like the Yamuna and Ganga at Prayagraj (Anon, 1962; 1976; 1991; 2001; 2002; 2003; 2008; 2010) [2-9] and Patna (Bilgrami and Datta Munshi, 1985; Bilgrami *et al*., 1992; Jhingran, 1992; Kumar, 1996) [12, 13, 40, 48] have tracked significant trends in fish populations and fishery dynamics. Similar research in the Narmada River (Anon, 1962; Sasmal and Qureshi, 1999; Nath and Shrivastva, 1999) [2, 59, 52] has

contributed to this understanding. Changes in species composition and age distribution, impacted by pollution and other anthropogenic activities, are evident in studies such as Desai (1992a, b) [24, 25] on the Narmada River, Gupta (1993) [32] in Allahabad, and Sharma (2001) post-Pong Dam in the Beas River. Additional research across various reservoirs and rivers (Negi and Singh, 1998; Kumar, 2001; Vinod *et al*., 2003; Jha *et al*., 2004) [53, 49, 69, 38] provides further insights into these shifts.

Age and growth patterns

Research on aging biology and growth patterns, such as studies on *Cirrhinus mrigala* (Jhingran, 1959; Kamal, 1969; Hanumantharao, 1974) [39, 43, 34], Labeo rohita (Khan and Jhingran, 1975; Dwivedi and Nautiyal, 2010) [45, 27], and Tor putitora (Nautiyal, 1990) [51], has advanced our understanding of exploitation trends and population management. Freshwater biodiversity, including species like Cyprinus carpio, has shown rapid declines due to human impacts (Dwivedi *et al*., 2004; Karr *et al*., 2006; Sarkar, 2009) [28, 44, 58]. Taxonomic and genetic research on species such as Oreochromis niloticus (Günther, 1868; Jerdon and Evermann, 1896; Tanaka, 1921) [33, 37, 65] and hybridization studies (Alikunhi and Chaudhuri, 1959; Hulata, 1995) [1, 36] have enriched our knowledge of species diversity and adaptation. Additionally, studies on feeding habits, reproductive biology (Alikunhi, 1966; Schaperclaus, 1961; Vass and Van Oven, 1959) [1, 62, 68], population dynamics (Harris, 1995; McCormick *et al*., 2000; Van Sickle, 2000) [35, 50, 67], and the effects of invasive species like Nile tilapia (Koehn, 2004; Pinto *et al*., 2005; Schade *et al*., 2005) [46, 54, 60] are vital for effective fishery management. Lastly, research into the physico-chemical characteristics of rivers such as the Yamuna and Ganga (Chakraborty *et al*., 1989; Ray *et al*., 1976; Singh *et al*., 1998; Srivastava *et al*., 2003) [18, 57, 63, 64] provides insights into how environmental changes impact fish populations.

Conclusion

This review underscores the intricate nature of riverine ecosystems and the diverse ways in which human activities impact fish populations. Riverine systems, with their rich biodiversity and critical ecological functions, are profoundly affected by a range of anthropogenic pressures, including industrialization, urbanization, agriculture, and alterations to natural flow regimes through damming and water diversion. These activities have led to significant habitat degradation, changes in water quality, and shifts in species composition, which in turn affect fish populations.

The synthesis of research presented highlights several key findings: the importance of fishery assessments and landings data in tracking population trends; the impact of pollution and habitat alterations on species composition and age distribution; the insights gained from aging biology and growth studies for understanding exploitation trends; and the alarming declines in freshwater biodiversity. Additionally, advancements in taxonomy, genetic research, and studies on feeding and reproductive biology have deepened our understanding of species diversity and adaptation.

Despite the wealth of information available, significant challenges remain. The complexity of riverine ecosystems and the multiplicity of factors influencing fish populations necessitate ongoing and comprehensive research. Effective conservation and management strategies must be informed by continuous monitoring, integrating findings across various disciplines, and addressing the root causes of ecological changes. Strategies should include habitat restoration, pollution control, sustainable fisheries management, and policies aimed at mitigating the effects of climate change and human activities.

In summary, addressing the challenges facing riverine fish populations requires a holistic approach that combines scientific research with practical conservation efforts. By advancing our understanding of these ecosystems and their inhabitants, we can develop more effective strategies to preserve the ecological balance and ensure the sustainability of riverine fish species for future generations.

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