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Review

The Lower Danube River–Danube Delta–North West Black Sea: A pivotal area of major interest for the past, present and future of its fish fauna — A short review

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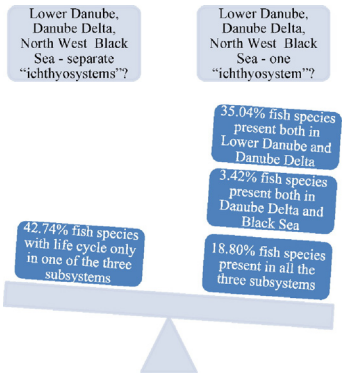
HIGHLIGHTS

- The Danube–Black Sea geo-ecosystem, is a matrix for an unique and diverse "ichthyosystem".
- Danube Delta has been identified as the pivotal element of this "ichthyosystem".
- Human impact decreases significantly the identified "ichthyosystem" resilience.

GRAPHICAL ABSTRACT



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ABSTRACT

The complex Danube–Black Sea geoecosystem, created by a unique combination of integrated biotopes and biocoenoses related forces and counter-forces in time and space, forms a rich "ichthyosystem". The equilibrium among the fish species captured in the Danube Delta reveals its structural and functional roles in the connectivity of the Danube and Black Sea. The key role of the delta is evidenced by the fact that 57.26% of the Lower Danube–Danube Delta–North West Black Sea fish species use two or three of the subsystems in terms of habitats. Therefore, this convergence area can be considered to be a dynamic and rich "ichthyosystem", with three subsystems. All three evolved interdependently, which permits their flexibility and adaptation in an interdependent way. The habitat heterogeneity, native economic and conservation priority fish species of the Lower Danube–Danube Delta–North Western Black Sea have decreased significantly, and there are no indications that this trend will be halted soon. The Danube "sub-ichtyosystem" seems to be more directly affected than the others. The Lower Danube–Danube Delta–North Western Black Sea "ichthyosystem" exhibits a significant level of flexibility, resilience and adaptation over geological time, but has become much more sensitive to environmental perturbations due to the last century of human impact. This "ichthyosystem" is affected by non-native fish species. The study area represents an interdependent ecological net, without which the specific "ichthyosystem" formed over geological time will disappear. The studied ecological net fish fauna is an accurate indicator of various

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human pressures. The Lower Danube–Danube Delta–North West Black Sea geoecosystem, in which the Danube Delta provides the pivotal habitat element, is the matrix for a unique "ichthyosystem." However, human impacts decrease its resilience and can induce its extinction.

Contents

1. Introduction

Large rivers, deltas and estuaries, wetlands where the sea converges with sources of freshwater (Tigris and Euphrates, Jordan, Indus, Nile, Volga, Huang He, Yangtze, Ganges, Brahmaputra, Amazon, Rangoon, Mekong, Niger, Rhine, Rhone, Tiber, Danube, etc.), have been inhabited by humans for more than five millennia and have played a major role in some of the most important human culture and civilization centres throughout human history. All of these significant societies emerged in wetland areas because they were appropriate for subsistence and the exchange of goods, and they also offered attractive resources for large human communities (Kappelman et al., 2014; Li et al., 2014; Williams et al., 2014; Mark and Macklin, 2015). In the early 20th century, wetlands also had an "ecological" value (Pritchard, 2004; Cameron and Matless, 2011; Ayres, 2012) and well-focused image (McDermont, 1976; Howarth, 1999; Hurd, 2001; O'Connor, 2004).

What are the key elements that attracted and fascinated humans for ages in these areas? Among others, an important trait is their rich natural diversity in services and products, such as fish (MEA, 2005; De Groot et al., 2006; Buckton et al., 2009; Costanza et al., 2014).

The Ramsar Convention (1971) concept for the conservation and wise use of wetlands and their resources is applied here. The primary reasons for the natural richness of wetlands, including fish communities, are their high primary and secondary productivities and their high production of biomass (Parikh and Datye, 2003; Durisch-Kaiser et al., 2011). The high number of habitats and biocoenosis diversity, including fish, is primarily the result of sea level fluctuations and the seasonal dynamics of the rivers and deltas. Productivity increases significantly when large rivers flow into the sea and provide a large biomass of nutrient-rich organisms. These complex areas are nodes in these large ecological networks, and their internal structures and functions are interconnected and depend on these networks (Erwin, 2009; Paolo et al., 2011; Rebelo et al., 2013). Consequently these wetland types represent some of the most productive natural areas on the planet, with several wildlife species. Fish are among most ecologically and economically important group of wildlife species (Brinson et al., 1981; Mitsch et al., 1994; Mitsch and Gosselink, 2000).

Fish are a valuable food resource for humans and wildlife and play a major role in ecosystem function. For one milliard of people, fish are the primary protein source, and for a much higher number of people, fish makes up a significant portion of their diet. These data are primarily for marine species: two-thirds of which depend on coastal wetlands for at least one stage in their life cycle (Doody, 2001). Productivity in these areas is, for example, "the engine" of the USA fishing fleet: the value of salmon, shrimp and crab was 13 million USD in 1991 (FAO, 2014). The fish are exploited at recreative, subsistence and industrial levels all around the world. For example, in Danube Delta, there are 26 commercial fish species. In the Okavango wetlands, there are 19 commercial species; in the Kafue River wetlands, there are five out of 67 fish species that make up most of the catches; in the Mississipi River wetlands, 12 fish species are commercially harvested; and so on (Nyimbili, 2006; Gomoiu et al., 2009; Tripp et al., 2012; Cowan et al., 2014).

In this context, a large regional geographic scale overview including time scale elements of the Lower Danube–Danube Delta–North West Black Sea ecological network ichthyofauna is needed for water managers and fish experts. Such a review is challenging given the high variability in the way in which data have been collected by different authors and the lack of reliable data in several cases.

This study aims to identify and highlight potential connections among the Lower Danube–Danube Delta–North West Black Sea ichthyofauna and to reveal some of the causes underlying the formation of a specific fauna of fish as well as the factors that threaten it.

2. Results and discussion

2.1. The Danube–Danube Delta–Black Sea spatial and temporal background

Understanding fish biology and dynamics requires study of ecosystem history as well as the spatial and temporal factors that underlie ecosystem structure and function.

The second largest European waterway, the Danube River, is one of the most natural, historical, cultural and economically important rivers. The oldest human traces date back to 180.000 BC at the upper end-term of the Danube–Black Sea geosystem. The length of this river is 2826 km, and its basin drains into 19 countries from the Black Forest to the Black Sea. The Danube River drainage basin extends up to 801,093 km^2 and represents 35% of the Black Sea catchment area, bringing approximately 50% of its tributaries water flow, which is approximately 827 km^3 of water every year. The major Danube tributaries from upstream to downstream are the following: Inn (515 km long, 26,128 km^2 watershed), Morava (354 km, 27,267 km^2), Váh (378 km, 19,660 km^2), Drava (719 km, 40,087 km^2), Tisa (965 km, 156,087 km^2), Sava (945 km, 95,793 km^2), Velika Morava (493 km, 38,000 km^2), Olt (615 km, 24,439 km^2), Siret (599 km, 46,289 km^2) and Prut (953 km, 28,568 km^2). The lower end-term of this geosystem is the Black Sea, one of the largest "closed" seas in the world, situated