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Review Article

A REVIEW OF FISH DIVERSITY AND MANAGEMENT OF THE VJOSA BASIN: THE FIRST FREE FLOW RIVER PROTECTED AREA IN THE BALKANS

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ABSTRACT

Vjosa River, an ecologically important area and the last Europe free-flowing river, is an essential aquatic ecosystem for the Albanian ecological, social, and cultural aspects. Fish and other aquatic species are notable among livings composition found in this region. The river environment is unfortunately seriously threatened by the excessive use of its resources, and hence, the goal of this study was to examine the status of fish biodiversity and the demands of the ecosystem for management. The Vjosa river is home of at least 34 species of fishes inhabiting the river and delta system, of which 29 are native, including eight species endemic to the Balkans. With 12 species, *Cyprinidae* is by far the most specious family, followed by *Mugilidae* (five). *Salmonidae* and *Acipenseridae* are represented by 2 species each. The remaining ten families are represented by a single species. At least four species (*Pseudorasbora parva*, *Oncorhynchus mykiss*, *Carassius* spp., *Gambusia holbrooki*) were introduced into the Vjosa basin. The lower river reach is populated by other species as European eel (*Anguilla anguilla*), species of Family *Mugilidae* (*Mugil cephalus*, *Liza ramada*, *Liza salienes,* and *Chelon labrosus*), Seabream (*Sparus aurata*), Seabass (*Dicentrarchus labrax*), Flatfish (*Platichthys flesu*s, common sole (*Solea* spp.), etc., while the resident species associated with saline water include numerically prevalent with the two species *Atherina boyeri* and *Aphanius fasciatus* showing presence and significance.

Keywords: Species diversity, Abundance, Vjosa, Delta, Threatening.

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INTRODUCTION

River Vjosa or Aoos (in Greek) is a 270 km long, large river that has its origin in the Pindos Mountains in northern Greece close to the city of Vouvousa. Except for the first 10 km, this system is free flowing and not constrained by any longitudinal barriers. The river's source is located where the Aoos runs from southeast to northwest, 2159 m above sea level. The first 80 km are situated in Greece where the river course mainly leads through the Vikos–Aoos National Park and is characterized by a constrained riverbed and steep slope (Hammerschmied, 2019. From the Albanian border downstream, where the Sarandoporos a major tributary enters, the river is referred to as Vjosa. In the region of Permet, the river shows a narrow channel pattern, as sediment erosion exceeds sediment deposition, and it immerses into alluvial sediments. From this point on, the river's route is distinguished by broad, braided parts that alternate with restricted riverbeds and gorges whenever the river crosses significant geological barriers. 30–40 km upstream of the mouth, the slope of the river drops, and the appearance changes to a meandering form, before it enters the Adriatic Sea north of the town of Vlore and the Narta lagoon (Hauer, 2019; Schiemer *et al*., 2018; Hammerschmied, 2019).

With a catchment of 6700 km^2, the Vjosa has a mean annual discharge of 204 m^3/s. While the discharge during dry periods (Summer) drops down to levels of 40–50 m^3/s, annual flood events show a magnitude of >1000 m^3/s. This river shows a very active sediment regime with an estimated transport at the Pocem bridge of 5 million tons per year. The sediments mainly consisted of the substrate classes Psammal, Akal, and Mikrolithal (Griffiths et al., 1994; MoE, 2015; Hauer, 2019; Hammerschmied, 2019).

The native ichthyofauna of the River Vjosa reflects the rich geological past and geographic position of the basin, given the large number of *Near endemic* species (species almost entirely found within Vjosa territory and most of them are found in two lake systems shared with neighboring countries, i.e., Albania and Greece) and *Endemics Balkans* (Species restricted to the southern Balkans, specifically, to the Southeast Adriatic). There are species in the genera *Oxynoemacheilus*, *Cobitis,* and *Pelasgus*.

The alien fish that has been introduced here from a number of continents, originating from various biogeographic areas has also reached Vjosa basin (Smith and Darwal, 2006; Oikonomou et al, 2014; Leonardos and Sinis, 1998; Stierandová *et al*., 2016; Shumka *et al*., 2018a; Shumka *et al*., 2018b; Shumka, 2019; Meulenbroek *et al*., 2018; Shumka *et al*., 2020a; Shumka *et al*., 2020b; Shumka *et al*., 2020c; Meulenbroek *et al*., 2020; Pietrock *et al*., 2022; Shumka *et al*., 2023a; Shumka *et al*., 2023b). These species have a broader range of ecological tolerances and occupy a spectrum of ecological niches (*Pseudorasbora parva*, *Gambusia holbrooki*, *Carassius gibelio*, etc). Following the fact that not all alien species present an equal threat to the native ichthyofauna, nor is their influence equally present and strong in difference habitat types (ecological conditions); in this article, we considered the interrelationship and competitions among native Mediterranean Killifish (*Aphanius fasciatus*) and introduced Mosquito fish (*Gambusia holbrooki*). Certain species, following introduction, can have a small population size and may not necessarily have a negative impact on the native fauna (Buj *et al*., 2023). Following this, on the other hand, there are species that rapidly develop large populations, and they have an exceptionally large impact on the local ecosystems and native species, as they quickly and easily spread into new areas and new waters, making them invasive species. Introduced, alien fish species can have a direct impact on the native fauna, as well as an indirect effect on the ecosystem or competition for resources. Water pollution, habitat degradation, and changes in the makeup of native fish groups frequently contribute to the effective adaption and proliferation of non-native species. The effects of these impacts include altered fish community composition, decreased abundance of native fish species, particularly those that are uncommon, endemic, and threatened species, or even their total extinction.

METHODS

A systematic review of the literature has been conducted following the guidelines of Haddaway *et al*. (2015). The work was focused on

peer-reviewed studies, PhD and Master's theses, and scientific reports regarding Vjosa basin that were written in English and published online. The data search was conducted in three comprehensive databases of scholarly publications – Web of Science, Google Scholar, and Scopus between January 2000 and December 2022. The preliminary assessment has been conducted of a subset of articles before the main search to determine the search-string combination to utilize. All results were evaluated for relevancy and to avoid papers that were not related to our focus for each search string. Examples of the search-strings include water quality parameters, fish diversity, decline factors, management, conservation, livelihood profile, etc. Then, I found 59, 11, 8 peer-reviewed papers from Google Scholar, Web of Science, and Scopus, respectively. Finally, I was reviewed 33 papers. The step-by-step eligibility criteria were as follows: All studies must include information on the author(s), year of publication and titles, duplicates were removed; article titles and abstracts were screened to include only studies conducted in Vjosa Basin; and the criteria for subsequent inclusion were that the articles, when fully read, considered water quality parameters, fish diversity, driving forces of biodiversity decline, socioeconomic profile of engaged fishers, conservation and approach practices of the Vjosa Basin.

RESULTS AND DISCUSSION

Fishes River Vjosa on the Ichthyology Map of Albania

Albanian watersheds are defined as distinct river basins or isolated sub-basins, usually defined naturally by watershed boundaries. In Albania, there are several large, temporally independent river and lake systems. From north to south, they are arranged as follows: Drini (Ohrid-Drin-Skadar system including the Buna River), Mat, Ishëm, Erzen, Shkumbin, Seman (consisting of two major tributaries - Devoll and Osum), Vjosë (Aoos in Greece) river systems, several short rivers flowing from the Cika Mountains to the southernmost part of the Adriatic Sea and to the northernmost part of the Ionian Sea, the area around the Butrint lagoon (rivers Bistrica and Pavllo) and Lake Prespa (Fig. 1). The majority of the

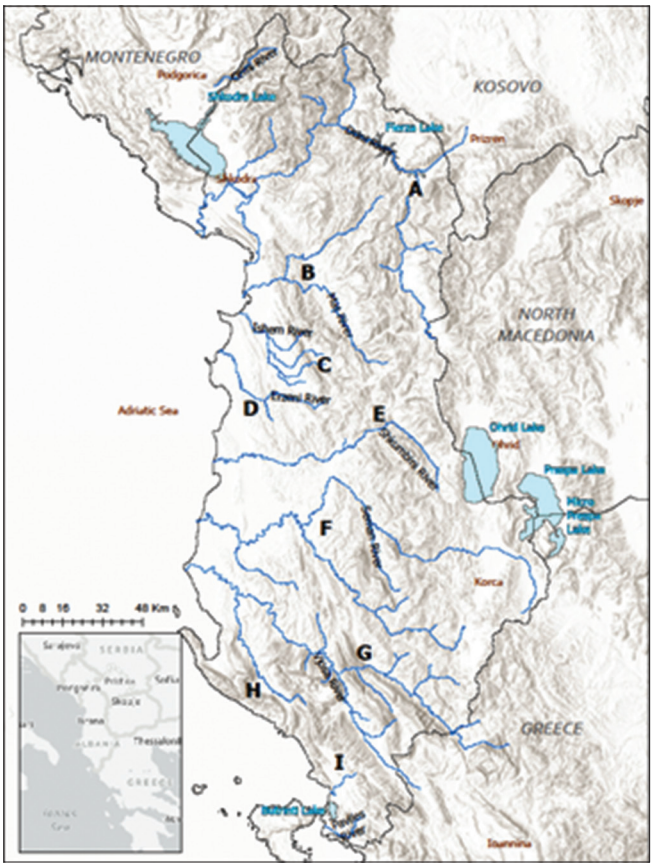

Fig 1: Albanian river basins

aforementioned lakes and rivers are part of the Adriatic Sea's catchment area, and the southernmost portions are part of the Ionian Sea's slope. Only a little portion of Albania's most northern region, located in the Albanian Alps, is a part of the Danube River basin. The Vjosa basin, which is located in the Adriatic Basin, corresponds to the area covered by this study.

The differences in geological settings and structures and physicochemical characters of water in the different drainage basins enable different conditions for the development of fish communities, within Adriatic watercourses. That has also enabled speciation processes. It is worth to mention fact that the waters belonging to different basins have been under the influence of different conditions and events.

Diversity of Habitats of the River Vjosa as a Basis for Development of Fish Communities

Following Schiemer (2000), the fluvial geomorphic processes provide the habitat diversity and the specific habitat conditions for characteristic species assemblages and result in high levels of habitat diversity. Within this context, the local species richness and differences between habitats and consequently, overall species richness of a river section are changing. In case of River Vjosa, this issue has been elaborated in detail by Meulenbroek *et al*. (2018). Accordingly, the following habitats were found within river stretches: The river's main channel (litoral zones), shallow runs, downstream connected side-arms, disconnected side-arms, erosion pools within the active channel without- and with aquatic macrophytes, and water bodies within the floodplain fed by hillside streams with clear water and macrophytes. Such braided reaches with moderate floodplain development represent highly unstable lotic to semi-lotic alluvial channels and the dominating coarse material of bed and banks is transported and deposited by fluvial action. The aquatic environment is dominated by current and substrate patterns that are extremely varied and heterogeneous. In braided systems, a wide variety of morphological characteristics can be found.

The clear spatial distribution patterns for the species (Meulenbroek *et al*., 2018), confirmed that sites within the main channel were dominated by *Barbus prespensis*, *Chondrostoma vardarense,* and *Gobio skadarensis. Anguilla anguilla* and *Squalius platyceps* were also commonly found. High numbers of *Oxynoemacheilus pindus* were caught in the shallow runs within the main channel accompanied mainly by *G. skadarensis* and *B. prespensis*. The downstream connected side arms still reflected species found in the running waters, though the most abundant species, were *Alburnus scoranza* and *S. platyceps*. *Pachychilon pictum* and *Alburnoides bipunctatus* additionally characterize this habitat type. The disconnected river side arms and small erosion pools were mostly inhabited by *A. scoranza*, *S. platyceps*, *Cobitis ohridana, P. parva,* and some individuals of the non-native *G. holbrooki*. In the larger erosion pools within the active channel with a generally high cover of macrophytes and clear water situations and in the waterbodies within the floodplain fed by hillside streams *Pelasgus thesproticus*, *Alburnoides,* and *G. holbrooki* were dominant, while *P. pictum*, *A. scoranza, S. platyceps, C. ohridana,* and *P. parva* are also represented.

Fish species River Vjosa

The very recent research and literature data focused to the freshwater of Albania and River Vjosa has confirmed that the current fish fauna consists of 34 species from 10 orders and 14 families (Bianco, 1986; Economidis and Banarescu, 1991; Crivelli et al., 1996; Devillers and Devilers-Terschuren, 1996; Banaresku, 2004; Dudgeon et al, 2006; Dudley et al., 2013; Šanda *et al*., 2008; Snoj *et al*., 2009; Markova *et al*., 2010; Shumka *et al*., 2023). Among them, 29 species are native to the River Vjosa basin: With 12 species, *Cyprinidae* are by far the most specious family, followed by *Mugilidae* (five). *Salmonidae* and *Acipenseridae* are represented by 2 species each. The remaining ten families are represented by a single species. At least five species (*P. parva*, *Oncorhynchus mykiss*, *C. gibelio*, *Ctenopharyngodon idella,* and *G. holbrooki)* were introduced into the Vjosa basin. The lower river reach is populated by other species as European eel (*A. anguilla*), species of Family *Mugilidae* (*Mugil cephalus*,

Table 1: Fish species present in River Vjosa

Species	Categories	Albanian RL	IUCN	Bern Conv	References
Acipenser naccarii Bonaparte, 1836	N	EN	CR	II	Poljakov *et al*. 1958; Rakaj, 1995
Acipenser sturio Linnaeus, 1758	N	EN	CR	II	Poljakov *et al*. 1958; Rakaj, 1995
Alburnoides aff. prespensis	N				Poljakov *et al*. 1958; Rakaj 1995; Stlerandova *et al*. 2016; Shumka *et al*. 2023
Alburnus scoranza Bonaparte, 1845	N		LC		Rakaj 1995; Kottelat and Freyhoff 2007; Shumka *et al*. 2010; Barbieri *et al*. 2015
Alosa fallax (La Cepède, 1803)	N				Poljakov *et al*. 1958; Rakaj 1995; Kottelat and Freyhoff 2007; Shumka *et al*. 2023
Anguilla anguilla (Linnaeus, 1758)	N		CR		Shumka *et al*. 2010; Moulenbroeck *et al*. 2020
Atherina boyeri Risso, 1810	N		LC		Poljakov *et al*. 1958; Rakaj 1995; Kottelat and Freyhoff 2007; Shumka *et al*. 2023
Aphanius fasciatus (Valenciennes, 1821)	N	EN		II	Poljakov *et al*. 1958; Rakaj 1995; Kottelat and Freyhoff 2007; Shumka *et al*. 2010
Barbus prespensis Karaman, 1924	N	LR	LC		Crivelli 1996; Markova *et al*. 2010; Shumka *et al*. 2010; Kottelat and Freyhoff 2007
Carassius gibelio (Bloch, 1782)	A				Poljakov *et al*. 1958; Rakaj 1995
Chelon aurata (Risso, 1810)	N				Poljakov *et al*. 1958; Rakaj 1995; Kottelat and Freyhoff 2007; Shumka *et al*. 2010
Chelon labrosus (Risso, 1810)			LC		Poljakov *et al*. 1958; Rakaj 1995; Kottelat and Freyhoff 2007; Shumka *et al*. 2023
Chelon ramada (Risso, 1827)	N				Poljakov *et al*. 1958; Rakaj 1995; Kottelat and Freyhoff 2007; Shumka *et al*. 2023
Chelon saliens (Risso, 1810)	N				Rakaj 1995; Kottelat and Freyhoff 2007
Chondrostoma vardarensis Karaman, 1924	N	LR	NT	III	Crivelli 1996; Shumka *et al*. 2010; Kottelat and Freyhoff 2007; Gieger *et al*. 2014
Cobitis ohridana Karaman, 1928	N	LR	LC		Crivelli *et al.* 1997; Shumka *et al.* 2023; Kottelat and Freyhoff 2007; Sanda *et al*. 2010
Ctenopharyngodon idella (Valenciennes, 1844)	A		LC		Shumka *et al*. 2023
Dicentrarchus labrax (Linnaeus, 1758)	N		LC		Rakaj 1995; Shumka *et al*. 2010
Gambusia holbrooki Girard, 1859	A		LC		Rakaj 1995; Kottelat and Freyhoff 2007; Shumka *et al*. 2008; Shumka *et al*. 2010
Gobio skadarensis Karaman, 1936	N	LR	EN		Crivelli 1996; Shumka *et al*. 2010; Kottelat and Freyhoff 2007; Sanda *et al*. 2010
Gobius spp.	N				Shumka (non-published data)
Luciobarbus albanicus (Steindachner, 1870)	N		LC		Poljakov *et al*. 1958; Rakaj 1995; Crivelli 1996
Mugil cephalus Linnaeus, 1758	N		LC		Poljakov *et al*. 1958; Rakaj 1995; Kottelat and Freyhoff 2007
Oncorhynchus mykiss (Walbaum, 1792)	A				Poljakov *et al*. 1958; Rakaj 1995; Kottelat and Freyhoff 2007; Shumka *et al*. 2010
Oxynoemacheilus pindus (Economidis, 2005)	N		VU		Kottelat and Freyhoff 2007; Shumka *et al*. 2010
Pachychilon pictum (Heckel et Kner, 1858)	N		LC	III	Poljakov *et al*. 1958; Rakaj 1995; Kottelat and Freyhoff 2007; Shumka *et al*. 2010
Pelasgus thesproticus (Stephanidis, 1939)	N		NT		Poljakov *et al*. 1958; Rakaj 1995; Kottelat and Freyhoff 2007
Petromyzon marinus Linnaeus, 1758	N	VU	LC	III	Poljakov *et al*., 1958; Rakaj 1995
Platichthys flessus (Linnaeus, 1758)	N	VU	LC		Rakaj 1995; Shumka *et al*. 2010
Pseudorasbora parva (Temm and Schlegel, 1846)	A				Rakaj 1995; Kottelat and Freyhoff 2007; Shumka *et al*. 2008; Shumka *et al*. 2010
Salmo farioides Karaman, 1938	N				Rakaj 1995; Kottelat and Freyhoff 2007; Shumka *et al*. 2008; Snoj *et al*. 2009
Squalius platyceps Zup., Mar, Nas and Bog, 2010	N				Kottelat and Freyhoff, 2007; Shumka *et al*. 2023
Solea spp.	N				Shumka unpublished data
Syngnathus abaster Risso, 1827	N				Shumka *et al*. 2023

Acronyms: N-native, A-alien, VU: Vulnerable, EN: Endangered, LR: Lower Risk, LC: Least concern, CR: Critically endangered, NT: Near threatened, II: Listed in Annex II (strictly protected fauna species), III: Listed in Annex III (Protected fauna species)

Chelon ramada, *Chelon salienes,* and *Chelon labrosus*), Seabream (*Sparus aurata*), Seabass (*Dincentrarchus labrax*), Flatfish (*Platichthys flesus*, common sole (*Solea* spp.), etc., while the resident species associated with saline water are numerically prevalent with the two species *Atherina boyeri* and *Aphanius fasciatus* showing presence and significance. The remaining four alien species, all introduced over the past 100 years as a consequence of human activity or unintentional one (Table 1).

According to the Albanian Red List (Moe, 2015), three species are endangered (*Acipenser naccarii*, *Acipenser sturio,* and *Asphanius fasciatus*) and two vulnerable (*Petromyzon marinus* and *Platychthis flesus*). IUCN considers three species to be critically endangered (*A. naccarii*, *A. sturio,* and *A. anguilla*) and in addition, *G. skadarensis* is categorized as endangered. The Bern convention lists three species in Annex II (strictly protected fauna species) (*A. naccarii*, *A. sturio,* and *A. fasciatus*) and two as in Annex III (*Alburnoides aff. Prespensis*, *C. vardarense*, *Pachychlion pictum,* and *P. marinus*) (Shumka *et al*., 2018). When compared to other systems in Europe, there is a severe dearth of understanding about these systems, which leaves little information about these species' population statuses available. This suggests that a greater number of species than previously believed may be seriously threatened.

Following Urban (2019) the majority of fish species in the Vjosa belong to the lithophilic spawning guild (15 species, 47%) followed by pelagophilic (nine species, 28%) and phytophilic (five species, 16%). Two species are categorized as being both lithophilic and phytophilic. Based on feeding guilds many species show indifferent feeding strategies and thus a clear categorization is difficult. Most fish species present show insectivorous (eight species, 25%) or insectivorous and herbivorous (11 species, 34%) feeding behavior, followed by omnivorous feeding behavior (six species, 19%). Only two species (*Alosa fallax* and *P. marinus*) are exclusively piscivorous in their adult life stage.

CONCLUSION

The free-flowing Vjosa River is home to rich fish diversity, while basin itself is shelter for numerous flora and fauna species. It is as typical dynamic systems create a distinct longitudinal sequence of steep gradient headwaters, braided and meandering channel types, and deltaic areas. This enables the existence of rich fish diversity and large migration corridor. The conservation strategies are crucial since many river basins in Albania's aquatic and riparian fauna, notably fish species, are currently in danger. Following this, there is a need for the reduction of human impacts to establish a "good" water status that goes in line with other conservation efforts including the establishment of protected area and enhancing integrated management practices.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

SS: Conceptualization; SS and NM: Methodology, SS and NM: Validation, NM: Formal analysis, SS and NM: Investigation, SS: Resources, SS: Writing-original draft preparation, SS: Writing-review and editing, SS and NM: Visualization. All authors have read and agreed to the published version of the manuscript.

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