Fish ecology and diversity in the lower Vjosa river and its delta

Spase Shumka [1*], Nertila Muçollari [1], Paul Meulenbroek [2]

The lower Vjosa river and its delta support a diverse ichthyofauna comprising at least 34 fish species, of which 30 are native. Among these, eight species are endemic to the Balkan Peninsula. The family Cyprinidae is the most species-rich, represented by 12 species, followed by Mugilidae with five species. Both Salmonidae and Acipenseridae are represented by two species each, while ten other families are each represented by a single species. Four non-native species – *Pseudorasbora parva*, *Oncorhynchus mykiss*, *Carassius gibelio*, and *Gambusia holbrooki* – have been introduced into the Vjosa basin.

The lower river also supports several estuarine and marine-associated species, including the European eel (*Anguilla anguilla*), mullets, gilthead seabream (*Sparus aurata*), European seabass (*Dicentrarchus labrax*), flounder (*Platichthys flesus*), and soles (*Solea spp.*). Notably, *Atherina boyeri* and *Aphanius fasciatus* are numerically dominant, underscoring their ecological relevance in this transitional habitat.

Fish assemblages in the lower Vjosa and its delta are affected by multiple interacting stressors, including upstream damming, in-stream gravel extraction, pollution, land-use change, urban development, non-native species, and climate change. Understanding the cumulative and interactive effects of these pressures is essential for the development of effective conservation and river management strategies.

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Der Unterlauf der Vjosa und ihr Delta bieten Lebensraum für eine vielfältige Fischfauna von mindestens 34 Arten, wovon 29 heimisch sind und acht davon endemisch für die Balkanhalbinsel. Die artenreichste Familie sind die Karpfenfische (Cyprinidae) mit 12 Arten, gefolgt von den Meeräschen (Mugilidae) mit fünf Arten. Lachsfische (Salmonidae) und Acipenseridae sind jeweils mit zwei Arten vertreten, während zehn weitere Familien jeweils eine einzige Art aufweisen. Daneben wurden vier nicht heimische Arten ins Vjosa-Becken eingeführt: *Pseudorasbora parva*, *Oncorhynchus mykiss*, *Carassius gibelio* und *Gambusia holbrooki*.

Die Fischfauna des Unterlaufs umfasst mehrere Arten, die an Ästuare und das Meer gebunden sind, wie den Europäischen Aal (*Anguilla anguilla*), verschiedene Meeräschenarten (*Mugil cephalus*, *Liza ramada*, *Liza saliens* und *Chelon labrosus*), die Goldbrasse (*Sparus aurata*), den Wolfsbarsch (*Dicentrarchus labrax*), Plattfische (*Platichthys flesus*) und Seezungen (*Solea* spp.). Bemerkenswert ist die zahlenmäßige Dominanz von *Atherina boyeri* und *Aphanius fasciatus*, die auf ihre zentrale ökologische Rolle in diesem Übergangshabitat hinweist.

Die Fischgemeinschaften im unteren Vjosa-Fluss und seinem Delta sind komplexen und vielschichtigen Umweltbelastungen ausgesetzt. Dazu gehören anthropogene Eingriffe wie Staudämme flussaufwärts, Kiesabbau im Fluss und verschiedene Formen der Verschmutzung. Hinzu kommen Landnutzungsänderungen, städtische Entwicklung, die Einschleppung gebietsfremder Arten sowie der Klimawandel. Das Verständnis der kumulativen und synergistischen Auswirkungen dieser Stressoren ist entscheidend, um wirksame Strategien für den Schutz der Biodiversität und ein nachhaltiges Flussmanagement zu entwickeln.

Keywords: ichthyofauna, conservation, protected area, Balkan rivers, endemic species, delta ecosystem, habitat heterogeneity.

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[1] Faculty of Biotechnology and Food, Agricultural University of Tirana, Rruga Paisi Vodica 1025, Tirana, Albania
[2] Institute of Hydrobiology and Aquatic Ecosystem Management, BOKU University, Gregor Mendel Straße 33, 1180 Vienna, Austria
* Corresponding author: sprespa@gmail.com

Introduction

According to the Palearctic Habitat Classification (Devillers & Devillers-Terschuren, 1996), Albania encompasses two biogeographical regions: the Mediterranean and the Alpine. The majority of the country falls within the Mediterranean region, including the entire southern and northwestern areas. As a result of its geographic and ecological complexity, Albania is recognized as one of the countries with the highest freshwater fish diversity in Europe, hosting over 101 species, including marine euryhaline forms (Shumka et al. 2023). Furthermore, the ichthyofauna is distinguished by a large number of endemics, including 10 Balkan endemic species that only exist in the waters of Albania and one of the neighboring countries (Tab. 1).

Vjosa basin (Fig. 1) provides a unique opportunity to test biogeographical theories, as it is characterized by a young geology with distinctive geographical barriers and highly connected hydrographic networks (Bănărescu 2004; Oikonomou et al. 2014). The comparatively high fish diversity of the Vjosa river and the correspondingly particular conservation needs are confirmed by recent publications (Shumka et al. 2018a, 2023b; Meulenbroek et al. 2018, 2020; Hammerschmied 2019).

The fundamental goal of the Water Framework Directive (WFD 2000/60/EC) is to achieve good ecological status, which is assessed using biological quality elements (BQEs) that are sensitive to nutrient enrichment and hydromorphological pressures. (Lyche-Solheim et al. 2013; Dudley et al. 2013). As a sensitive component to changes in water condition and nutrient concentrations, fish are classified among the BQEs. As a result, countries undergoing European integration must incorporate fish into monitoring methods as a useful indication for evaluating the trophic status of aquatic ecosystems. Due to various human activities, freshwater environments and river systems in particular are among the most endangered ecosystems in the Mediterranean region (Weiss et al. 2018). The introduction and proliferation of alien species have one of the most detrimental effects on these ecosystems. However, overfishing, habitat destruction, pollution, hydrological and climate change frequently have a combined, synergistic effect on the impacts of alien and invasive fish species on the native fauna (Dudgeon et al. 2006; Buj et al. 2023). Alien species are recognized as a serious threat to the local ichthyofauna and are identified as such in Albania's Biodiversity Strategy and Action Plan (MoE 2015).

The native ichthyofauna of the 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 Balkan endemics (species restricted to the southern Balkans, specifically, to the Southeast Adriatic). The genera *Oxynoemacheilus, Cobitis* and *Pelasgus* include near endemic and endemic Balkan species. The alien fish that have been introduced within Albanian river basins from a number of continents, originating

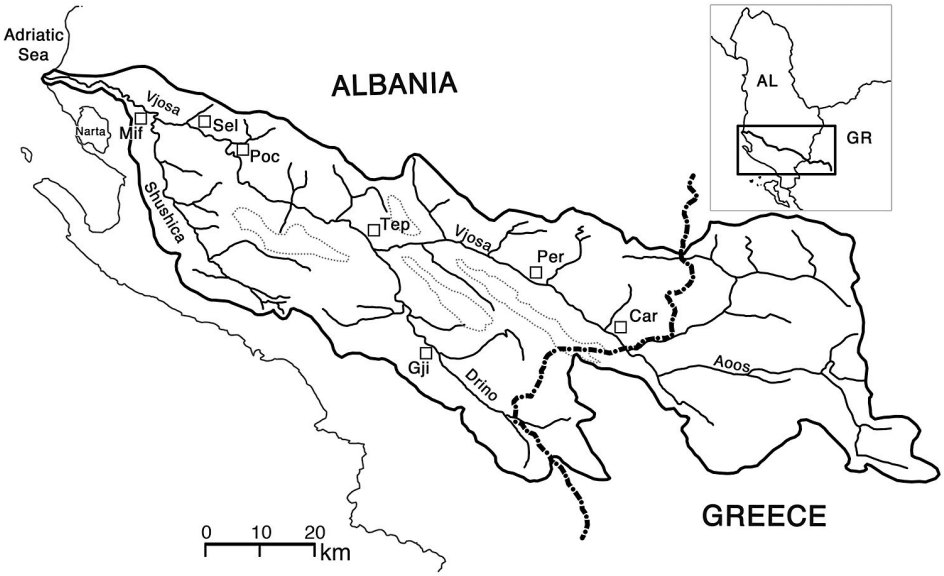

Fig. 1: Map of the study area showing the location of the Vjosa river (Source: VjoSusDev-APPEAR Project No. 251). | **Abb. 1:** Karte des Untersuchungsgebiets mit der Lage des Flusses Vjosa. (Quelle: VjoSusDev-APPEAR, Projektnummer 251)

from various biogeographic areas has also reached the Vjosa basin. These species have a broader range of ecological tolerances and occupy a spectrum of ecological niches (*Pseudorasbora parva, Gambusia holbrooki, Carassius gibelio*, etc.).

Because alien species differ in both establishment success and ecological impact, this study pays particular attention to interactions between the native Mediterranean killifish (*Aphanius fasciatus*) and the introduced mosquitofish (*Gambusia holbrooki*). Some introduced species may establish only small populations and exert minimal or no measurable impact on native communities (Buj et al. 2023). In contrast, other species can rapidly expand in abundance and distribution, exerting profound ecological pressures. These species, due to their high adaptability and dispersal capacity, often become invasive, significantly disrupting local ecosystems and threatening native biodiversity.

Introduced fish species can have both direct impacts on native fauna and indirect effects on ecosystem structure and function, often through resource competition or trophic interactions. Their successful establishment and spread are frequently facilitated by anthropogenic stressors such as water pollution, habitat degradation, and shifts in the composition of native fish communities. These changes can have significant ecological consequences, including alterations in community structure, declines in the abundance of native species – particularly those that are rare, endemic, or threatened – and, in extreme cases, local extinctions.

After Sovinc (2021) the Vjosa ecosystem offers numerous services to people, including biodiversity conservation, water purification, flood prevention, healthy fisheries, landscape, and culture. Increased fishing pressure and the use of non-friendly gears (which increases fishing pressure but also has destructive impacts) were among concerns for the fishers. A common local fishing technique known as "Bilançiera" is non-selective, and their very large quantity directly affects both the migration density and the rate of recruitment. It is a lift net fishing that consists in obliquely immersing a large circular sieve with loose mesh and rattan frame, which the fisherman maneuvers like a harrow. It is reserved to well-trained adult fishermen and are solely set up in a moderate water flow. Lift net fishing takes place preferably during moonless nights, but also during daylight right after heavy rain that has increased the turbidity of the water. Further to that the land-use changes, lack of wastewater treatment facilities along the Vjosa stretch, solid waste pollution, increased sedimentation rates and turbidity, intensive fishing within Adriatic coast and Mediterranean, etc., are likely to be the main factors impacting aquatic ecosystems and ultimately causing the apparent reductions in fish yields (Shumka et al. 2023b).

Changes in land-use and hydrological variation affect large areas over lengthy periods, so they are not amenable to accurate observation or recall by casual observers who work in restricted locales. The discrepancies between fishermen's perceptions and, in some cases, their own actual data and the true underlying environmental causes of changes highlight the need for more representative long-term monitoring data on key ecosystem attributes and the calibration of any interviews against actual monitoring data.

This study assesses the ecological characteristics and ichthyofaunal diversity of the lower Vjosa river and its delta, with particular emphasis on the distribution of native, endemic, and non-native fish species. It also evaluates major environmental pressures and outlines key conservation challenges and opportunities.

Materials and Methods

We used a fish database generated from the Vjosa sampled during the period of 2013–2024. The fish data was created as part of a newly established Vjosa Wild River National Park approach, supplemented by additional data from the authors. Further on a systematic review of the literature was 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 (Fig. 2). The data search was conducted in three comprehensive databases of scholarly publications – Web of Science, Google Scholar, and Scopus – between January 2000 and December 2024. A preliminary assessment was conducted of a subset of articles prior to 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. The comparative analyses and relative placement of 11 Albanian basins according to their fish population using Multi-Dimensional Scaling was based on Shumka et al. 2023a. The discussions with regard to interrelationship and competition among native Mediterranean killifish (*Aphanius fasciatus*) and introduced mosquito fish (*Gambussia holbrooki*) are based on recent data collected during the years 2023–2024.

Results and Discussions

33 fish species have been reported for the Vjosa as of 2018 (see Tab. 1), with 17 of them being freshwater species, 10 being saltwater species, four exhibiting anadromous activity, one species (*Anguilla anguilla*) being catadromous, and one species (*Atherina boyeri*) exhibiting amphidromous behavior. With nine out of 26 native species (27 percent) being endemic to the Balkans, the Vjosa exhibits a high degree of endemicity aside from records of four alien species. The majority of fish species in the Vjosa belong to the lithophilic spawning guild (15 species, 45 percent) followed by pelagophilic (nine species, 27 percent) and phytophilic (five species, 15 percent). Two species are categorized as being both lithophilic and phytophilic.

Tab. 1: Fish species recorded in the Vjosa river. Abbreviations: RL, Red List; N, native; A, alien; VU, Vulnerable; EN, Endangered; LR, Lower Risk; LC, Least Concern; CR, Critically Endangered; NT, Near Threatened; E, endemic; NE, near-endemic; EB, Balkan endemic; II, listed in Annex II (strictly protected fauna species); III, listed in Annex III (protected fauna species); rh, rheophilic; ind, indifferent; lim, limnophilic; pel, pelagophilic; lith, lithophilic; phy, phytophilic; ovo, ovoviviparous; omn, omnivorous; ins, insectivorous; herb, herbivorous; pisc, piscivorous; eur, euryhaline | **Tab. 1:** Im Fluss Vjosa nachgewiesene Fischarten. Abkürzungen: RL, Rote Liste; N, heimisch; A, gebietsfremd; VU, gefährdet (Vulnerable); EN, stark gefährdet (Endangered); LR, geringes Risiko (Lower Risk); LC, nicht gefährdet (Least Concern); CR, vom Aussterben bedroht (Critically Endangered); NT, potenziell gefährdet (Near Threatened); E, endemisch; NE, nahezu endemisch; EB, Balkan-Endemit; II, in Anhang II gelistet (streng geschützte Tierarten); III, in Anhang III gelistet (geschützte Tierarten); rh, rheophil; ind, indifferent; lim, limnophil; pel, pelagophil; lith, lithophil; phy, phytophil; ovo, ovovivipar; omn, omnivor; ins, insektivor; herb, herbivor; pisc, piscivor; eur, euryhalin

Species	Categories	Albanian RL	IUCN	Bern Convention	Categories	Species notations	Reophilic guild	Spawaning guild	Feeding guild	References
Acipenser naccarii	N	EN	CR	II	N		rh	lith	om	Poljakov et al. 1958; Rakaj 1995
Acipenser sturio	N	EN	CR	II	N		rh	lith	om	Poljakov et al. 1958; Rakaj 1995
Alburnoides aff. prespensis	N		EN		N	EB	rh	lith	om	Poljakov et al. 1958; Rakaj 1995; Stlerandova et al. 2016; Shumka et al. 2023
Alburnus scoranza	N		NT		N	EB	ind	lith-phy	ins	Rakaj 1995; Kottelat & Freyhoff 2007; Shumka et al. 2010; Barbieri et al. 2015
Alosa fallax	N		NT		N		rh	lith	pis	Poljakov et al. 1958; Rakaj 1995; Kottelat & Freyhoff 2007; Shumka et al. 2023
Anguilla anguilla	N		CR		N		ind	pel	om	Shumka et al. 2010; Moulenbroeck et al. 2020
Atherina boyeri	N		LC		N		lim	phyt	ins-her	Poljakov et al. 1958; Rakaj 1995; Kottelat & Freyhoff 2007; Shumka et al. 2023

Species	Categories	Albanian RL	IUCN	Bern Convention	Categories	Species notations	Reophilic guild	Spawaning guild	Feeding guild	References
Aphanius fasciatus	N	EN	LC	II	N		lim	phyt	pis	Poljakov et al. 1958; Rakaj 1995; Kottelat & Freyhoff 2007; Shumka et al. 2010
Barbus prespensis	N	LR	NT		N	EB	lim	phyt	ins-her	Crivelli 1996; Markova et al. 2010; Shumka et al. 2010; Kottelat & Freyhoff 2007
Carassius gibelio	A				A		ind	phyt	ins-her	Poljakov et al. 1958; Rakaj 1995
Chelon aurata	N				N		pel	pel	ins-her	Poljakov et al. 1958; Rakaj 1995; Kottelat & Freyhoff 2007; Shumka et al. 2010
Chelon labrosus			LC		N		pel	pel	ins-her	Poljakov et al. 1958; Rakaj 1995; Kottelat & Freyhoff 2007; Shumka et al. 2023
Chelon ramada	N				N		pel	pel	ins-her	Poljakov et al. 1958; Rakaj 1995; Kottelat & Freyhoff 2007; Shumka et al. 2023
Chelon saliens	N				N		pel	pel	ins-her	Rakaj 1995; Kottelat & Freyhoff 2007
Chondrostoma vardarensis	N	LR	NT	III	N	EB	rh	lith	herb	Crivelli 1996; Shumka et al. 2010; Kottelat & Freyhoff 2007; Gieger et al. 2014
Cobitis ohridana	N	LR	NT		N	EB	lim	phyt	ins	Crivelli 1996; Shumka et al. 2010; Kottelat & Freyhoff 2007; Sanda et al. 2010
Ctenopharyngodon idella	A		LC		A		lim	phyt	herb	Shumka et al. 2023
Dicentrarchus labrax	N		NT		N		pel	pel	pisc	Rakaj 1995; Shumka et al. 2010
Gambusia holbrooki	A		LC		A		lim	ovo	ins	Rakaj 1995; Kottelat & Freyhoff 2007; Shumka et al. 2008; Shumka et al. 2010
Gobio skadarensis	N	LR	NT		N	EB	ind	lith-phy	ins	Crivelli 1996; Shumka et al. 2010; Kottelat & Freyhoff 2007; Sanda et al. 2010
Gobius sp.	N				N		ind	lith-phy	ins	Shumka (non-published data)
Luciobarbus albanicus	N		LC		N	EB	lim	phyt	ins-her	Poljakov et al. 1958; Rakaj 1995; Crivelli 1996
Mugil cephalus	N		LC		N		pel	pel	ins-her	Poljakov et al. 1958; Rakaj 1995; Kottelat & Freyhoff 2007
Oncorhynchus mykiss	A				A		rh	lith	ins-pisc	Poljakov et al. 1958; Rakaj 1995; Kottelat & Freyhoff 2007; Shumka et al. 2010

Species	Categories	Albanian RL	IUCN	Bern Convention	Categories	Species notations	Reophilic guild	Spawaning guild	Feeding guild	References
Oxynoemacheilus pindus	N		NT		N	NE	rh	lith	ins	Kottelat & Freyhoff 2007; Shumka et al. 2010
Pachychilon pictum	N		NT	III	N	EB	lim	lith-phyto	omn	Poljakov et al. 1958; Rakaj 1995; Kottelat & Freyhoff 2007; Shumka et al. 2010
Pelasgus thesproticus	N		NT		N	NE	lim	phyt	ins-herb	Poljakov et al. 1958; Rakaj 1995; Kottelat & Freyhoff 2007
Petromyzon marinus	N	VU	LC	III	N		pel	lith	pisc	Poljakov et al. 1958; Rakaj 1995
Platichthys flessus	N	VU	LC		N		pel	pel	ins-herb	Rakaj 1995; Shumka et al. 2010
Pseudorasbora parva	A				A		ind	lith	omn	Rakaj 1995; Kottelat & Freyhoff 2007; Shumka et al. 2008; Shumka et al. 2010
Sparus aurata	N		LC		N		pel	pel	pisc	Rakaj 1995; Kottelat & Freyhoff 2007; Shumka et al. 2008
Squalius platyceps	N		LC		N	EB	ind	lith	omn	Kottelat & Freyhoff 2007; Shumka et al. 2023
Solea sp.	N				N		pel	lith	omn	Shumka unpublished data
Syngnathus abaster	N		LC		N		eur	ovo	omn	Shumka et al. 2023

The transitional habitats and fish of the lower river and delta of the Vjosa – a contrast between rare/endemic and introduced fish species

Aphanius fasciatus vs. *Gambusia holbrooki* – local records of potential alien invasive pressures on Mediterranean killifish. Aside from the fact that the relationship between these two species is not well studied, there is little literature data confirming the aggressive impacts of *Gambusia holbrooki* on the genus *Aphanius* and other related small-sized native fishes in other regions of Mediterranean (Pyke 2005; Kalogianni et al. 2014; Valdesalici et al. 2015). *A. fasciatus* spawns in the benthic submerged vegetation, with a spawning period from March to September, depending on the geographic position of the given population (Kottelat & Freyhof 2007). Populations in Italy spawn from March to June, in Greece from April to July and in Corsica from April to September (Leonardos & Sinis 1998; Marčić et al. 2015; Shumka et al. 2023b). Spawning takes place on the bottom and in submerged vegetation. The species is short-lived and maturity is reached within less than a year. Reproductive strategies of *Aphanius fasciatus* show the typical adaptations to the unstable and unpredictable environment of transitional waters, such as batch spawning and early sexual maturation (Leonardos & Sinis 1998). Our observational evidence shows that they reproduce in spring and/or early summer in the Vjosa delta complex (Shumka et al. 2023b).

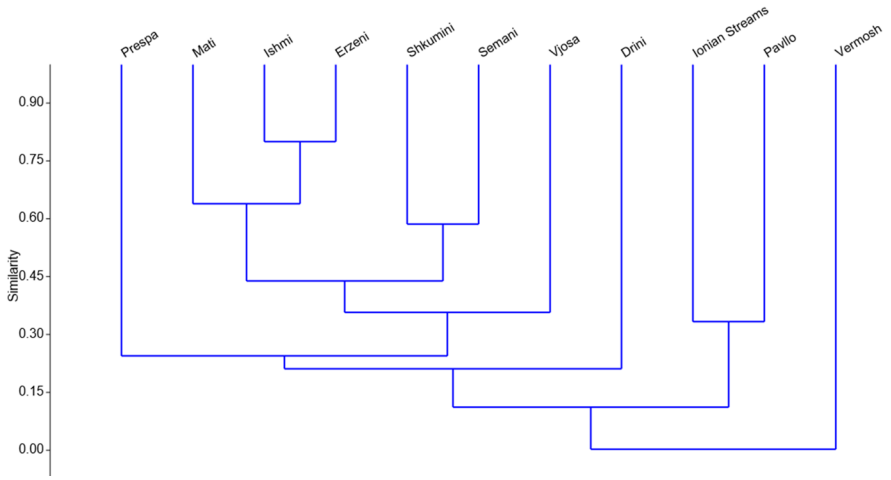

Fig. 2: Relative positioning of 11 Albanian river basins based on their fish assemblages using multidimensional scaling (MDS). (Source: Shumka et al. 2023a) | **Abb. 2:** Relative Anordnung von elf albanischen Einzugsgebieten anhand ihrer Fischgemeinschaften mittels multidimensionaler Skalierung (MDS). (Quelle: Shumka et al. 2023a)

The Mediterranean killifish (*Aphanius fasciatus*) is native to Albanian inland and coastal transitional waters. This small species (typically 4–6 cm total length) feeds mainly on zooplankton and may also consume eggs, larvae, and aquatic stages of mosquitoes and midges (Zogaris 2017; Shumka et al. 2023a). *A. fasciatus* is not a migratory fish, but in normal conditions it spreads beyond its resident areas. Our survey on the lower flow of the Vjosa, the Narta lagoon, and lowland drainage channels has shown that, at the wetlands complex, *Aphanius'* distributional pattern expands and contracts depending on meteorological conditions and seasonal drought effects on the local populations. According to Zogaris (2017), by late spring they are breeding and locally abundant at certain areas, but especially so in saline-brackish and saline waters where there is no competition with the alien mosquito fish (*Gambusia holbrooki*). The fish that have survived in refugia will be the population sources for future expansion events. Recent developments and interventions in the lower reaches of the Vjosa river may exacerbate the negative effects on *Aphanius fasciatus*, which appears to be primarily impacted by competition with *Gambusia holbrooki* rather than by salinity fluctuations alone. Structural modifications to watercourses and channels could prevent killifish from accessing long-standing aquatic refugia in the region. A similar threat has been documented by Zogaris (2017) in the Zakaki marsh of Cyprus, where *Aphanius* populations were displaced by the seasonally abundant mosquito fish. In the Vjosa-Narta wetland complex, *Aphanius* populations persist in slightly brackish to saline inland marshes and lagoon ecosystems, and appear capable of tolerating freshwater conditions as well. However, available data suggest that brackish environments may be more favorable for reproduction. Following the complex of communicating channels, the lagoon, etc., they show higher abundance in small brackish pools in salt marshes and disperse among pools during winter-spring flooding events, but generally they are not considered good dispersers. *Aphanius* forms dense concentrations when waters shrink in spring and summer, while they can survive in very crowded conditions and in very warm waters.

Position of the lower Vjosa river and its delta on the ichthyology map of Albania and Europe

In the map of global ecoregions (Abell et al. 2008), the Vjosa river is part of the 420-Southeast Adriatic Drainage. This freshwater ecoregion map is based on fish distributions and assemblage composition. However, the geomorphological complexity of the Vjosa basin and adjacent drainages makes precise delineation challenging. 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 (Shumka et al. 2023a).

Most of the above lakes and rivers belong to the catchment area of the Adriatic Sea and the southernmost areas to the slope of the Ionian Sea. Only a very small area in the northernmost part of Albania, in the Albanian Alps, is part of the Danube river basin. The area covered by this study corresponds to the Vjosa basin and, as stated above, lies at the Adriatic Basin. The river basins, delineated based on fish species richness and composition differences (Shumka et al. 2023a), are shown in Fig. 2. The data are derived from various published sources cited in Shumka et al. (2023a) as well as recent unpublished observations. The differences in geological settings and structures, and physicochemical characters of water in the different drainage basins enables different conditions for the development of fish communities within Adriatic watercourses. That has also enabled speciation processes (Economidis & Banarescu 1991). It is worth noting that basins differ because they have experienced distinct geological histories and environmental conditions. In the Vjosa, nine species (28%) are pelagophilic, five (16%) are phytophilic, and 15 (47%) are lithophilic. Taking feeding guilds into account, many species exhibit a variety of feeding tactics, making precise classification challenging. Following omnivorous feeding behavior (six species, 19%), the majority of fish species exhibit insectivorous (eight species, 25%) or insectivorous and herbivorous (eleven species, 34%) feeding behavior. As shown in Tab. 1, only two species (A*losa fallax* and *Petromyzon marinus*) are solely piscivorous during their adult life stage.

Diversity of habitats of the lower Vjosa river and its delta system 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 is changing (Stanford et al. 2005). After Schiemer et al. (2020), the fish fauna is an important indicator for the ecological integrity of large river systems, as a broad spectrum of habitat conditions is required to fulfil the habitat needs of different ecological guilds in the course of their life cycle. In the Vjosa case, this issue has been elaborated in detail by Meulenbroek et al. (2018). Hence, the following habitats have been identified within the main river channel

(littoral zones), shallow runs, downstream connected and disconnected sidearms, erosion pools within the active channel, with and without aquatic macrophytes, and water bodies within the floodplain fed by hillside streams with clear water and macrophytes. Such braided reaches with moderate floodplain development in the case of the Vjosa 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 (Schiemer et al. 2020). Very diverse and heterogeneous current and substrate patterns dominate the aquatic environment. The range of different morphological types within braided systems is very broad.

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 *Gobio skadarensis* and *Barbus prespensis*. The downstream connected side arms still reflected species found in the running waters, though the most abundant species were *Alburnus scoranza* and *Squalius platyceps*. *Pachychilon pictum* and *Alburnoides aff. perspensis* additionally characterize this habitat type. The disconnected river side-arms and small erosion pools were mostly inhabited by *Alburnus scoranza*, *Squalius platyceps*, *Cobitis ohridana*, and *Pseudorasbora parva* and some individuals of the non-native *Gambusia 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*, *Alburnoide aff. Perspensis*, and *Gambusia holbrooki* were dominant, while *Pachychilon pictum*, *Alburnus scoranza*, *Squalius platyceps, Cobitis ohridana*, and *Pseudorasbora parva* were also represented (Fig. 2).

How did events in the geological past and in human history affect the fish community in the lower Vjosa river and its delta system?

Although numerous advanced methods are available to determine the age of a region and reconstruct the geological events that have shaped it, such data for the Vjosa river basin remain limited. The high biodiversity of Balkan rivers is a consequence of the region's geologic and paleoclimatic history, as well as the geophysical variety of inland water bodies (Bănărescu et al. 2004). Hence, during the Pleistocene, glaciers were restricted to mountain summits. The lowland areas provided refugia for the continental freshwater fauna and flora (Skoulikidis et al. 2009).

The Vjosa river and its tributaries (two of its main arms: Drino and Shushica) can be categorized as gravel-dominated, laterally active, anabranch rivers with large sediment yields, where the supply of bed loads is greater than the channel's actual transit capacity. This is evident, especially in the middle section of the river, where large gravel plains that can reach 2,000 meters in width are present and are traversed by numerous lateral and parallel rovers, oxbows, and side channels. The quick desertion of the main river channel during catastrophic flood events and the creation of new, parallel river channels in old floodplains are two further characteristics of laterally active, anabranch gravel bars.

From an ichthyo-geographical perspective, there are two major divisions that are known in the Balkans: the Ponto-Caspian and the Western Balkan. These divisions are biogeographically

distinct because mountain boundaries form old barriers to fish dispersal. The Western Balkan rivers are dominated by relatively depauperate but endemic-rich assemblages that have experienced long periods of isolation (Skoulikidis et al. 2009).

The Adriatic and Ionian subdivisions were considered to comprise a single ichthyogeographic region (the Southern Adriatic–Ionian Division) (Economidis & Banasescu 1991). Further on, Bianco (1986) discussed the issue that the Adriatic and Ionian drainages host different fish faunas, and proposed their separation. The Adriatic subdivision, delineated to the north by the Drin and to the south by the Aoos, is rich in endemic fishes (for faunistic descriptions see Crivelli et al. 1997; Shumka et al. 2023a).

The Ichthyofauna of the lower Vjosa river and its delta

Recent studies indicate that the lower Vjosa fauna comprises 34 species from 10 orders and 14 families. Cyprinidae is the most species-rich family, followed by Mugilidae (Shumka et al. 2018b). Salmonidae and Acipenseridae are represented by 2 species each. The remaining ten families are represented by a single species (Tab. 1, Figs. 3 and 4).

The lower river reach is populated by other species as: European eel (*Anguilla anguilla*), species of the family Mugilidae (*Mugil cephalus*, *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.

At least five non-native species have been reported from the basin: *Pseudorasbora parva*, *Oncorhynchus mykiss*, *Carassius gibelio*, *Ctenopharyngodon idella*, and *Gambusia holbrooki*. They were all introduced over the past 100 years as a consequence of human activity (Skoulikidis et al. 2009).

Following the Albanian Red List (MoE 2013), three species are endangered (*Acipenser naccarii*, *Acipenser sturio*, and *Aphanius fasciatus*) and two vulnerable (*Petromyzon marinus* and *Platichthys flesus*). The IUCN considers three species to be critically endangered (*Acipenser naccarii*, *Acipenser sturio*, and *Anguilla anguilla*) and additionally *Gobio skadarensis* is categorized as endangered.

The Bern Convention lists three species in Annex II (strictly protected fauna species) (*Acipenser naccarii*, *Acipenser sturio*, and *Aphanius fasciatus*) and two in Annex III (*Alburnoides aff. prespensis*, *Chondrostoma vardarense*, *Pachychlion pictum*, and *Petromyzon marinus*) (Shumka et al., 2018; 2023a). There is a severe lack of knowledge concerning this river system compared to other systems in Europe, resulting in limited available data about these species and their population status. This means that more species than previously thought could be severely threatened.

To reach their spawning habitats or feeding grounds during different life stages, some fish exhibit migratory behavior. Some species undertake only short local movements to spawn (*Salmo faroides*), whereas other species travel up to 10,000 kilometers in order to reach their

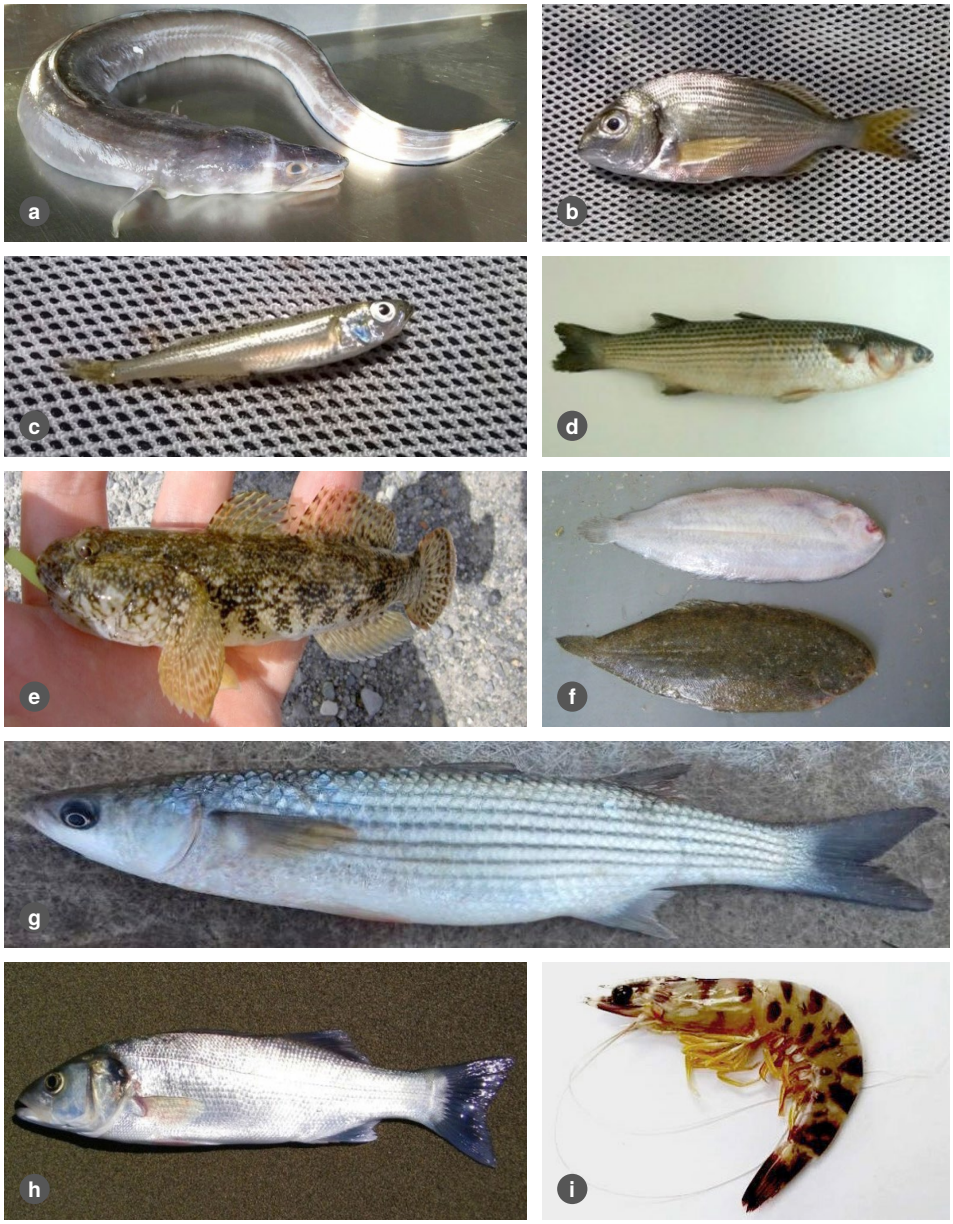

Fig. 3: Important fish species of the Vjosa delta and the lower reaches of the Vjosa river: (a) European eel (*A. anguilla*); (b) gilthead seabream (*S. aurata*); (c) sand smelt (*A. boyeri*); (d) thinlip grey mullet (*C. ramada*); (e) goby (*Gobius* sp.); (f) common sole (*S. vulgaris*); (g) flathead grey mullet (*M. cephalus*); (h) European seabass (*D. labrax*); (i) crustacean: caramote prawn (*M. kerathurus*) | **Abb. 3:** Wichtige Fischarten des Vjosa-Deltas und des Unterlaufs der Vjosa: (a) Europäischer Aal (*A. anguilla*); (b) Goldbrasse (*S. aurata*); (c) Mittelmeer-Ährenfisch (*A. boyeri*); (d) Dünnlippige Meeräsche (*C. ramada*); (e) Grundel (*Gobius* sp.); (f) Gewöhnliche Seezunge (*S. vulgaris*); (g) Dicklippige Meeräsche (*M. cephalus*); (h) Europäischer Wolfsbarsch (*D. labrax*); (i) Krebstier: Karamote-Garnele (*M. kerathurus*)

Fig. 4: Freshwater fish species occurring in the Vjosa river: (a) *G. skadarensis*; (b) *O. pindus*; (c) *A. cf. prespensis*; (d) *C. ohridana*; (e) *P. pictum*; (f) *B. prespensis*; (g) *A. anguilla*; (h) *S. faroides* | **Abb. 4:** Im Fluss Vjosa vorkommende Süßwasserfischarten: (a) *G. skadarensis*; (b) *O. pindus*; (c) *A. cf. prespensis*; (d) *C. ohridana*; (e) *P. pictum*; (f) *B. prespensis*; (g) *A. anguilla*; (h) *S. faroides*

spawning habitats (*Anguilla anguilla*) (Kottelat & Freyhof 2007). Concerning the native fish fauna of the Vjosa, migratory behavior has been described for*: Acipenser naccarii*, *Acipenser sturio*, *Anguilla anguilla*, *Alosa fallax*, *Atherina boyeri*, *Barbus prespensis*, *Chelon aurata*, *Chelon labrosus*, *Chelon ramada*, *Chelon saliens*, *Chondrostoma vardarense*, *Dicentrarchus labrax*, *Luciobarbus albanicus*, *Petromyzon marinus*, *Plathichthys flesus*, *Salmo farioides*, and *Squalius platyceps*, Thomson 1990; Bianco 1986; Kottelat & Freyhof 2007; Zupančič et al. 2010). These species are categorized by their average distance covered during migration in three groups, namely:

- **Sea-run species (Diadromous):** Showing a migration from saltwater to freshwater. (*Acipenser naccarii*, *Acipenser sturio*, and *Alosa fallax* are anadromous; *Chelon aurata*, *Chelon labrosus*, *Chelon saliens*, *Dicentrarchus labrax*, *Chelon ramada*, *Petromyzon marinus*, *Platichthys flesus*) and freshwater to salt water or catadromous (*Anguilla anguilla*).

- **Long-distance migratory species/Potamodromous:** Covering average annual migration distances of 20 kilometers or more (e.g *Barbus prespensis*, *Chondrostoma vardarense*, *Luciobarbus albanicus*, *Salmo faroides*, and *Onchorryhnchus mykiss*).

- **Short-distance migratory species:** Covering average annual migration distances of less than 20 kilometers (*Alburnoides prespensis*, *Alburnus scoranza*, *Carassius gibelio*, *Cobitis ohridana*, *Gambusia holbrooki*, *Gobio skadarensis*, *Oxynoemacheilus pindus*, *Pachychlion pictum*, *Pseudorasbora parva*, *Squalius platyceps*, *Pelasgus thesproticus*, *Atherina boyeri*, and *Aphanius fasciatus*).

Non-native fish species and threats to native Ichthyofauna

As stated above, there are five fish species that have been introduced into the Vjosa basin intentionally or accidentally. All alien species are not native at all to Albania: *Pseudorasbora parva*, *Oncorhynchus mykiss*, *Carassius gibelio*, *Chtenopharyngodon idella*, and *Gambusia holbrooki*.

Poljakov et al. (1958) provided the first information for Albania on the presence of only two introduced species, *Gambusia holbrooki* and *Cyprinus carpio*. Later, Rakaj (1995) reported the presence of a total of 20 non-native fish species for Albania. The ten-fold increase in the number of exotic species was due to the importing of species for aquaculture, especially East Asian cyprinids and several salmonids.

With the exception of *Lepomis gibbosus*, all remaining species found recently were included in Rakaj (1995), though two of the species mentioned by him and not found now are apparently incorrectly identified specimens of other introduced species: *Carassius carassius* and *Gambusia affinis*. Furthermore, *Misgurnus fossilis* and *Sabanejewia balcanica*, included in Rakaj (1995), are of uncertain status. Šanda et al. (2008) speculated that the record of *S. balcanica* in Rakaj (1995) could be due to misidentification of nontypical *Cobitis ohridana* specimens. The same could apply to *M. fossilis*. On the other hand, *M. fossilis* is well differentiated morphologically from *C. ohridana* (different number of barbels around mouth). Because many East Asian cyprinids were introduced to Albania, the presence of unintentionally transported East Asian *Misgurnus*, instead of *M. fossilis*, is also possible.

Several introduced species have become established in Albania, while the occurrence of *Oncorhynchus mykiss* probably results from escape from hatcheries, and that of *Hypophthalmichtys molitrix* from past introductions with no record of successful reproduction.

According to many local fishermen that were contacted, there are no recent records of most of the East Asian cyprinids *Hypophthalmichtys nobilis* (Richardson, 1845), *Ctenopharyngodon idella* (Valenciennes, 1844), *Megalobrama terminalis* (Richardson, 1846), *Parabramis pekinensis* (Basilewsky, 1855), nor of a few other species (*Thymallus thymallus* (Linnaeus, 1758), *Ameirus melas* (Rafinesque, 1820), *Coregonus sp*.) reported in Rakaj (1995). Introductions of the above-mentioned taxa were most probably unsuccessful.

The introduction of non-native species is recognized as a major threat to native freshwater fish, particularly when combined with other stressors such as hydropower development, unsustainable water management (in terms of both quantity and quality), pollution, and eutrophication – all of which contribute to the ongoing decline in native fish populations (Piria et al. 2017). Although non-native species were not commonly observed across most

surveyed areas in Albania in the present study, they are notably widespread in the country's four major lakes. These systems host established populations of several invasive species, including *Cyprinus carpio*, *Carassius auratus*, and *Pseudorasbora parva*, the latter of which appears to be particularly abundant. In Prespa lakes two other introduced species, *Tinca tinca* and *Lepomis gibbosus*, have become established; while around Lake Ohrid the rearing and accidental release of *Oncorhynchus mykiss* continues virtually unchecked. Following current knowledge for Albania there are 24 non-native fish species (Shumka et al. 2023a).

How can Vjosa National Park contribute to fish recovery and persistence?

The natural special character and unique landscape, biological diversity, and other associated values of the Vjosa river has led to protection of this area at different levels – it is protected under national legislation as a national park; it is included within its lower part in the candidate list of Emerald (ASCI sites) and potential Natura 2000 network sites; IBA (Important Bird Area), etc. However, despite the various layers of protection and abundant natural resources, this area, like many others, has not been immune to the negative consequences of anthropogenic activity (Schiemer et al. 2018). The fragile aquatic ecosystems of the Vjosa river, particularly in its lower reaches and delta, are subject to numerous pressures, with the most evident impacts observed in the native fish populations.

According to Sovinc (2021), the concept of protecting wild rivers and their tributaries is grounded in the strict preservation of the entire active riverbed, while permitting traditional land-use practices – such as agriculture and grazing – to continue, provided they are managed at a subsistence level rather than on an industrial scale. This approach also envisions the Vjosa river valley as a prime candidate for the development of green, cultural, and recreational tourism. Such a model aligns closely with fish conservation objectives, as the preservation of habitat heterogeneity is essential for the survival of native species and the completion of their life cycles (Shumka et al. 2018b).

Conclusions

The Vjosa river, as a dynamic fluvial system, exhibits a distinct longitudinal continuum encompassing steep-gradient headwaters, braided and meandering middle reaches, and deltaic formations at its terminus. This geomorphological diversity supports high fish species richness and provides an essential migration corridor. However, potential hydromorphological alterations – such as embankment, channel straightening, and reservoir construction – pose significant threats to the ecological integrity of the system. These interventions would directly affect the structure and function of the delta, as well as reduce groundwater aquifer recharge.

Given that aquatic and riparian fauna – particularly native fish species – are increasingly threatened across many Albanian river basins, the implementation of effective conservation strategies is of critical importance. The lowland sections and deltaic areas of the Vjosa are especially vulnerable due to shifts in agricultural practices, rapid infrastructure development, expanding tourism, and large-scale modifications occurring in the headwaters. Consequently, environmental decision-making in the region must be approached with heightened sensitivity, prioritizing biodiversity conservation and the principles of integrated river basin management.

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