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Assessment of fish communities from biotic type 6 in Black Sea Basin in Bosnia and Herzegovina

Đug, S.[1], Gajević, M.[1], Vesnić, A.[1], Korjenić, E.[1], Mušović, A.[1], Šljuka, S.[1], Škrijelj, R.[1]*

[1]University of Sarajevo – Faculty of Science, Sarajevo, Bosnia and Herzegovina

**samirdjug@pmf.unsa.ba*

Abstract

Fish are very sensitive to changes in damming of rivers, fragmentation and destruction of habitats, and changes in physical and chemical parameters. Changes in species diversity are a signal indicating that a significant and, as a rule, long-term change in one or more factors has occurred in the aquatic ecosystem. This in long term could lead to reduction of diversity and significant changes in the structure and dynamics of aquatic ecosystems. Biomonitoring of ichthyofauna is a very important element in the ecological assessment of water quality since changes in the structure of the fish community reflect changes in the quality of water in freshwater systems. The grouping of fish into ecological guilds has greatly improved our understanding of the impact of anthropogenic activities on fish and their communities. Therefore, the fish guilds represent the basis for ecological assessment based on the preferences of each recorded species in relation to tolerance, habitats, nutrition, reproduction and migrations. The results of the analyses of the structure of fish communities at 166 sites in biotic type 6 in the waters from the Black Sea Basin in Bosnia and Herzegovina have shown that the greatest influence on the distribution of different fish species has water temperature, flow, dissolved oxygen, and pH value. Obtained results clearly indicate an inverse relationship between altitude and the level of fish biodiversity. Values of applied diversity indices stress that fish communities in a river system usually follow a pattern of increasing species richness and diversity from upstream to downstream.

Keywords: fish guilds, diversity indices, aquatic ecosystems

1. Introduction

Two main catchment areas in Bosnia and Herzegovina are Black Sea Basin and Adriatic Sea Basin (Figure 1). The Black Sea basin in Bosnia and Herzegovina includes watercourses situated in the Peripannonian lowlands and in the larger part of the mountain-valley part of Bosnia and Herzegovina. Here belong sub-basins of the rivers Sava (immediate basin), Glina, Korane, Una, Vrbasa, Ukrine, Bosnia and Drina and their tributaries. The Black Sea Basin in Bosnia and Herzegovina covers 38,223.5 km^2 (or 74.7%).

The Adriatic Sea basin encompasses the area of the Mediterranean part of the country and the high karst macroregion in the southern part of Bosnia and Herzegovina. Here belong sub-basins of the rivers: Neretva, Trebišnjica, Cetina and Krka and their tributaries. The area of the Adriatic Sea basin is 2,955.5 km^2, which represents about 25.3% of the total area of Bosnia and Herzegovina (Đug et al. 2020).

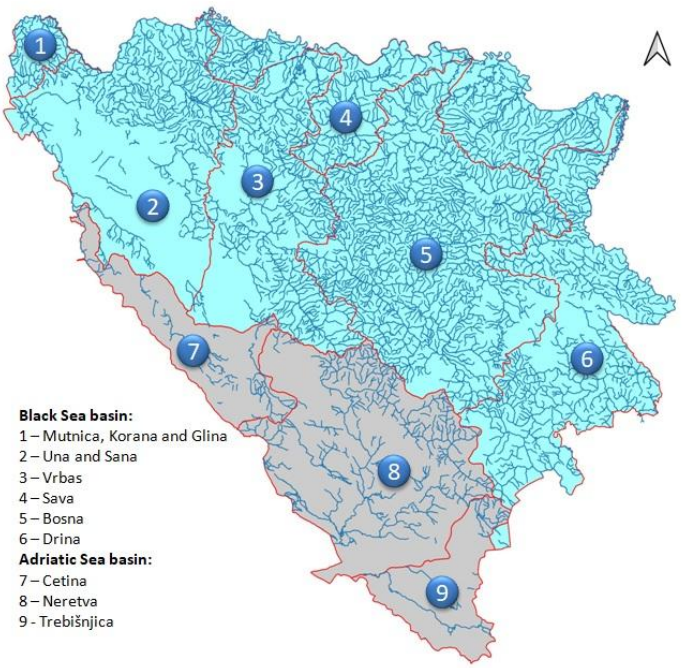

Figure 1. Main river basins in Bosnia and Herzegovina

All rivers and lakes in Bosnia and Herzegovina belong to the Dinarides ecoregion of the Western Balkans (Ecoregion 5). Taking into account the lithological composition of the substrate and climatic characteristics, which significantly

affects the distribution of aquatic flora and fauna, Ecoregion 5 was divided into three sub regions: Peripannonian sub region, Continental Dinarides and Sub-Mediterranean Dinarides (Figure 2). The Peripannonian sub region covers northern part of the country, where Pannonian climatic influences with a moderate continental climate. The area of this sub region is dominated by silicate rocks. The sub-region of the Continental Dinarides includes the central part of Bosnia and Herzegovina with a continental-mountainous climate, while the area of the Sub-Mediterranean Dinarides extends to the mountainous area of the Dinarides, where the influence of the Mediterranean climate is still felt. The area of the Continental and Sub-Mediterranean Dinarides is dominated by carbonate rocks. The sub region distribution is the basis for defining the biologically relevant characteristics of surface waters.

Biotic types of watercourses in Bosnia and Herzegovina were defined in accordance with the Decision on the characterization of surface and underground waters, reference conditions and parameters for water condition assessment and water monitoring (Službene novine Federacije BiH br. 01/14.).

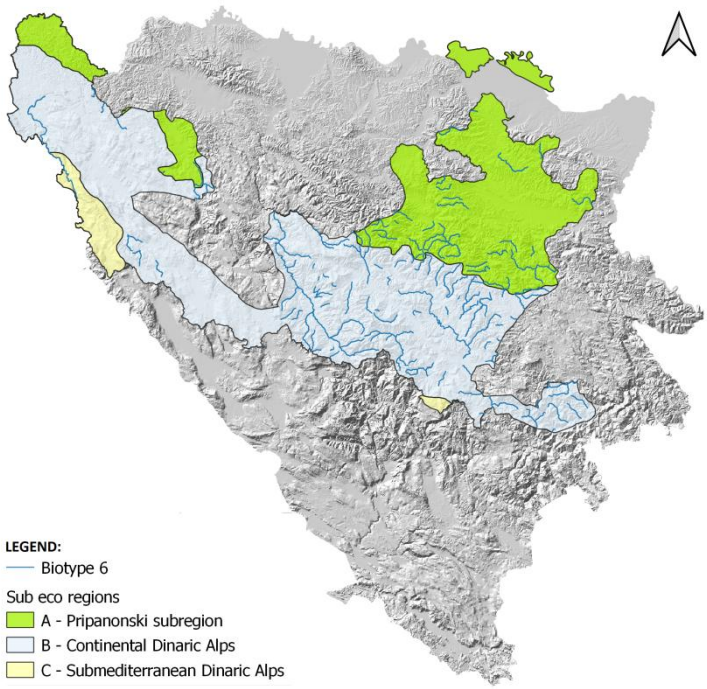

Figure 2. Biotype 6 in river Sava basin in The Federation of Bosnia and Herzegovina

Fish are very sensitive to changes in flow speed, damming of rivers, fragmentation and destruction of habitats, changes in water temperature and other physical and chemical parameters. Therefore, physical and chemical parameters determine the structure and size of fish populations in a certain watercourse. Changing conditions in the ecosystem result in changes in the structure and dynamics of fish populations. Changes in species diversity are a signal indicating that a significant and, as a rule, long-term change in one or more factors has occurred in the aquatic ecosystem. Rare and sensitive species are especially at risk. Since the changes in the structure of the fish community reflect changes in the quality of water in freshwater systems, biomonitoring of ichthyofauna is a very important element in the ecological assessment of water quality (Karr, 1987; Sallai & Mrakovčić, 2007). As extremely variable components of freshwater ecosystems, fish communities have been used in water biomonitoring for a long time (Karr & Chu, 1999). Fish are most often at the top of the food chain in aquatic ecosystems, which is particularly important from the perspective of bioaccumulation and biomagnification (Li et al., 2010).

In Bosnia and Herzegovina live 118 (sub) species of fish from 70 genera and 25 families. Of this number, 105 are autochthones and 13 allochtone fish species (Sofradžija, 2009). Today, due to a wide range of human activities, 200 species (38%) of freshwater fish from Europe are threatened (Kottelat, & Freyhof, 2007).

For biotic type 6, which includes small and medium-sized hill and mountain rivers with a dominance of large fractions in the bottom substrate, data were collected from 155 sampling sites in the Black Sea Basin. Analyses of ecological fish guilds and metrics was performed using historical data covering the period from 1967 to the present day.

2. Material and Methods

2.1. Field sampling

The Water Framework Directive (WFD) requires that standardized methods must be used in water quality monitoring, which will enable scientific quality and comparability. Considering the existence of very different fish sampling methods among European countries, and even within individual countries, the WFD requires harmonization and standardization of existing methods based on CEN (Comité Européen de Normalisation) standardization.

The method of sampling, identification and quantification is based on the European standard EN 14011:2003 (Water quality – Sampling of fish with electricity). This is the first of several European Standards that have been developed to evaluate the composition, abundance and diversity of fish in rivers, lakes and coastal waters. On the basis of Article 11 of the Law on Standardization of Bosnia and Herzegovina ("Official Gazette of BiH" 19/01), the Institute for Standardization of Bosnia and Herzegovina (BAS) accepted the standardization document "EN 14011" in the 'en' language as a Bosnian standardization document. This standardization document BAS EN 14011: 2004 (en) was accepted by the decision of the Institute for Standardization of Bosnia and Herzegovina 'OS-043/04', and it was published in the BAS Gazette '2004/3'.

2.2. Fish guilds

The term guild refers to species that have similar roles in the community. The grouping of fish into ecological guilds has greatly improved our understanding of the impact of anthropogenic activities on fish and their communities. Therefore, the fish guilds represent the basis for ecological assessment based on the preferences of each recorded species in relation to tolerance, habitats, nutrition, reproduction and migrations.

Tolerance indicates the sensitivity of the species to physical and chemical water degradation, not to habitat degradation, which is considered within the habitat guild. Assessment of species tolerance to anthropogenic pressure is very often used in ecological assessments. According to this assessment, an intolerant species will be present under suitable conditions but absent under disturbed conditions, while a tolerant species will dominate/persist.

The structure of habitat guild is based on three groups: rheophile (all life stages of freshwater species are related to lotic, i.e. flowing waters), eurytopic (all life stages can occur both in lentic, and in lotic waters) and limnophilic (all life stages are related lentic, i.e. standing waters).

Reproductive guilds are used to assess changes in the structure of fish communities, which are associated with changes in the availability of different habitat types for reproduction. Lithophilic guild (species that spawn on gravel) and phytophilic guild (species that spawn on vegetation) are used as a measure of the reproductive structure of fish communities, since with an increase in the level of degradation, the availability and suitability of specific niches or spawning substrates decreases, which has indirect negative impacts on the reproduction of species that need specific spawning grounds.

There are only a few species of fish in Europe that have specialized feeding habits, and they are mostly piscivores in the pre-adult and adult stages of development, which may represent a potential limitation for using a nutrition-based guild.

Migration guild is important since the absence of migratory species, where they once were, indicates a bottleneck at one or all stages of the life cycle, due to the presence of barriers to movement. Migratory species, therefore, enable assessment river system conditions in terms of connectivity (both longitudinal and lateral) for fish community functioning. The migratory behavior of fish in watercourses can be divided into two main types: potamodromous (migrate within freshwater only) and diadromous (migrate between freshwater and saltwater).

2.3. Diversity of fish communities

Assessment of biodiversity of fish communities in biotic type 6 have been carried out using: total number of species (S), total number of specimens (N), Margalef's index (d), Simpson index (1-D), Shannon-Wiener index (H'), and Pielou's evenness index (J).

Margalef's index (d) is a measure of species richness with emphasize on the number of individuals. This index is defined as: d = (S-1)/Log(N), where S = Number of different species in the sample, N = Total number of individual species in the sample.

Simpson's index (1-D) is a measure of dominance and therefore tends towards the abundance of the most common taxa. It is the probability that two randomly selected individuals from some infinitely large population will belong to different species. This index is usually expressed as the reciprocal of (DS=1−λ) higher values indicate higher diversity. It is less sensitive to rare species than the Shannon-Wiener index. This index ranges from 0 to 1.

Shannon-Wiener index (H') is the most commonly used of all diversity indices. Shannon-Wiener index values increase with increasing richness and evenness within a given community. The fact that this index includes both of these components of biodiversity can be considered both its advantage and its disadvantage. The advantage of this index is that it provides a simple synthetic summary, but its weakness is that it is more difficult to compare communities that differ widely in richness. The formula is: $H= -\Sigma[p_i*Log(p_i)]$, where p_i = proportion of individuals of i-th species in a whole community; and Log =

usually the natural logarithm, but the base of the logarithm is arbitrary (10 and 2 based logarithms are also used).

Pielou's evenness index (J) is a measure of how homogeneous a community or ecosystem is in terms of the abundance of its species. A community in which all species are equally common is considered even and has a high degree of evenness. Pilou's evenness (J) is a measure of how evenly individuals are distributed among different species. This index compares the actual diversity value (such as the Shannon-Wiener index, H') with the maximum possible diversity (when all species are equally represented, Hmax = ln s where s is the total number of species). For the Shannon-Wiener index, Pielou's evenness (J): J= =H'/ln S. It ranges between 0 and 1 and the greater the variation in abundance between different taxa within a community, the lower the value of J. Unfortunately, Pilou's J is highly dependent on sample size (since S – number of species depends on sampling method) and is also highly sensitive to rare taxa.

3. Results

The results of the analyses have shown that 30 fish species have been recorded within this biotype. Characteristical species for this biotype, represented by more than 10% in the total sample, are chub - *Squalius cephalus* (Linnaeus, 1758) (22.58%), schneider - *Alburnoides bipunctatus* (Bloch, 1782) (15.85%), and brown trout - *Salmo trutta* Linnaeus, 1758 (15.71%). The accompanying species, which are represented by 5-10% in the total sample, are the barbel - *Barbus meridionalis* Risso, 1827 (9.12%) and the Eurasian minnow - *Phoxinus phoxinus* (Linnaeus, 1758) (9.04%). Other important species are bullhead - *Cottus gobio* Linnaeus, 1758 (4.57%), grayling - *Thymallus thymallus* (Linnaeus 1758) (4.24%), common nase - *Chondrostoma nasus* (Linnaeus, 1758) (3.09%), gudgeon - *Gobio gobio* (Linnaeus, 1758) (2.91%).

Ecological fish groups – gilds in biotic type 6, have been analyzed on the basis of the ecological preferences of 12 fish species (three characteristic, two accompanying and seven other important species). The results of the analyses have shown that 41.6% of species are intolerant to physical and chemical habitat degradation and pollution, particularly schneider - *Alburnoides bipunctatus* (Bloch, 1782); bullhead - *Cottus gobio* Linnaeus, 1758; brown trout - *Salmo trutta* Linnaeus, 1758; and bitterling - *Rhodeus sericeus* (Pallas, 1776). The fish species from this biotic type are dominantly rheophile (83.3%) which all

life stages live in flowing waters. Here belong barbel - *Barbus meridionalis* Risso, 1827; schneider - *Alburnoides bipunctatus* (Bloch, 1782); Eurasian minnow - *Phoxinus phoxinus* (Linnaeus, 1758); chub - *Squalius cephalus* (Linnaeus, 1758); gudgeon - *Gobio gobio* (Linnaeus, 1758); bullhead - *Cottus gobio* Linnaeus, 1758; and brown trout - *Salmo trutta* Linnaeus, 1758. These species mainly spawn on gravel (75%). High percentage (41.6%) of these fish species are insectivore, which are fed by invertebrates/insects.

Table 1. Ecological fish groups – gilds in biotic type 6

Species	Tolerancy		Habitat		Reproduction		Nutrition		Migration	
	NoT	Tol	Bent	Rheo	Lith	Phyt	Ins	Omni	Dia	Pot
Characteristic species										
Squalius cephalus (Linnaeus, 1758)				X	X			X		X
Alburnoides bipunctatus (Bloch, 1782)	X			X	X		X			
Salmo trutta m. fario Linnaeus, 1758	X			X	X		X			
Accomapnying species										
Barbus meridionalis Risso, 1827			X	X	X		X			X
Phoxinus phoxinus (Linnaeus, 1758)				X	X					
Other important species										
Cottus gobio Linnaeus, 1758	X		X	X	X		X			
Thymallus thymallus (Linnaeus 1758)	X			X	X		X			X
Chondrostoma nasus (Linnaeus, 1758)			X	X	X					X
Gobio obtusirostris Valenciennes, 1842										
Gobio gobio (Linnaeus, 1758)			X	X						
Rhodeus sericeus (Pallas, 1776)	X									
Barbus barbus (Linnaeus, 1758)			X	X	X					X

The values of the metrics used to describe the biodiversity of fish communities in biotic type 6 are given in Table 2. The number of species in individual communities varied from one to 12 with an average of 4.5 species per investigated site. Margalef's and Simpson's index were 0 at sites where only one individual was found. The highest recorded value of Margalef's index was 2.173 with an arithmetic mean of 0.892. The highest value of the Simpson index was 0.9 with an average of 0.605. Shannon-Wiener index values calculated based on the composition of fish communities in watercourses, belonging to biotic type

6, ranged from 0.206 to 2.049. The average value of this index was 1.198. Evenness of fish communities ranged from 0.297 to a maximum of 1 with a fairly high average of 0.820.

Table 2. Values of the analyzed indices for biotic type 6

Index	min	max	average
Number of species (S)	1	12	4.539
Number of individuals (N)	1	1235	78.279
Margalef's index (d)	0.000	2.173	0.892
Pielou's evenness (J)	0.297	1.000	0.820
Shannon-Wiener (H')	0.206	2.049	1.198
Simpson's index (λ) (1- λ)	0.000	0.900	0.605

4. Discussion

A major advantage of the guild approach is to make ecological assessment of water ecosystems more objective by grouping fish species with similar ecological preferences into groups (Benoit et al. 2021). The results of the analysis of ecological fish guilds in this biotic type have shown the dominance of species that are sensitive to physical-chemical water degradation (intolerant species), and not to habitat degradation, which was considered within the habitat guild. An intolerant species is present under suitable conditions but absent under disturbed conditions. Significant percentage (41.6%) of these species at investigated sites of biotic type 6 indicates high environmental quality of these aquatic habitats. Intolerant species clearly indicate undisturbed habitat with clean water and high oxygen content. Rheophilic species that spend all their life stages in running waters and benthic species (they prefer to live on or near the bottom, where they get food, and usually do not go to the surface for feeding) are dominant in this biotic type. Habitat guilds are important for the assessment of the structure of fish communities in natural and degraded aquatic ecosystems (Smith et al. 2017). Reproductive guilds are used to assess changes in the structure of fish communities, which is also related to changes in the availability of different types of habitats. In terms of reproduction, the species that belong to the lithophilic guild (species that spawn on gravel or rocky bottoms) dominate in biotic type 6. Analysis of the trophic guild shows the dominance of insectivorous species. In the adult stage of these species, a high percentage of invertebrates/insects is present in their nutrition.

This research has shown that physico-chemical attributes play a key role in the distribution of fish in watercourses belonging to biotic type 6, and therefore any significant change in habitat conditions could represent potential threat to the freshwater fish fauna. Water temperature, flow, dissolved oxygen, and pH have the greatest influence on the distribution of different fish species. A similar pattern was observed by Gorman & Karr (1978), Stalnaker (1979), Bovee (1982) and Baltz et al. (1987) who attributed variation in fish assemblage structure to various factors such as river depth, water velocity, water temperature, type of substrate and water quality. The importance of habitat variables was also confirmed by Shrestha et al. (2009) who propose regular monitoring of the mentioned parameters of water quality in order to maintain the aquatic habitat favorable for the fish's existence.

A biocenosis has high species diversity when a large number of equally abundant species are present. On the other hand, if the biocenosis is composed of only a few species, or if only a few species are abundant, the species diversity is low. High species diversity indicates a highly complex community since greater species diversity allows for a wider range of interspecies interactions. Therefore, the concept of species diversity is defined in different ways, and several indices have been developed that enable its calculation (Magurran, 2004; Schannon, & Weaver1949).

Most of the investigated watercourses belonging to biotic type 6 are located above 700 m of altitude. According to Tripe (1998) and Reves-Gavilan et al. (1996) the results of investigations of various aquatic ecosystems have shown an inverse relationship between altitude and the level of fish biodiversity. The higher the altitude, the lower the uniformity and abundance of fish species. According to Nautiyal (2001), fish communities are poorer in the upper reaches due to the high water velocity of the current. Values of Shannon-Wiener index (H') (average = 1.198) which is measure of the relationship between number of species and number of individuals confirm this statement. In addition, the same author also suggested that the abundance and distribution of fish species is greatly influenced by the altitudinal and longitudinal zonation of any particular river system. FAO (1985), Bayley & Li (1994) and Grando (2000) also documented that fish communities in a river system usually follow a pattern of increasing species richness and diversity from upstream to downstream. Relative high value of Pielou's evenness (J) (0.820) in biotic type 6 indicates small variation in abundance between different taxa within a community.

5. Conclusions

Changes in species diversity are a signal indicating that a significant and, as a rule, long-term change in one or more factors has occurred in the aquatic ecosystem. The grouping of fish into ecological guilds has greatly improved our understanding of the impact of anthropogenic activities on fish and their communities. Therefore, the fish guilds represent the basis for ecological assessment based on the preferences of each recorded species in relation to tolerance, habitats, nutrition, reproduction and migrations. The results of the analyses of the structure of fish communities at 166 sites in biotic type 6 in the waters from the Black Sea Basin have shown dominance of species that are sensitive to physical-chemical water degradation which play a key role in the distribution of fish in watercourses belonging to biotic type 6. The greatest influence on the distribution of different fish species has water temperature, flow, dissolved oxygen, and pH value. The results of investigations aquatic ecosystems from biotic type 6 have shown an inverse relationship between altitude and the level of fish biodiversity. Values of applied diversity indices stress that fish communities in a river system usually follow a pattern of increasing species richness and diversity from upstream to downstream.

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