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The structure of fish community in the river Mirna

Struktura ribje združbe v reki Mirni

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Abstract: Natural perturbations and human pressure increasingly affect the river ecosystems and their biological communities. Fish species are a good indicator of the river status and one of the factors for the assessment of ecological condition by the Water Framework Directive (Directive 2000/60/EC). River Mirna, one of the larger right tributaries of the river Sava, is a good example of anthropogenic pressure on the running water ecosystem. Fish community species structure was analyzed at selected eight sampling sites located over the 28 km length of the river. Abiotic conditions were determined by measuring the physical, chemical and hydro-morphological parameters and the influence of measured parameters on present fish community was analyzed. It has been determined, that the river Mirna is loaded with organic matter and physically changed by regulations, river beds canalizing and bank stabilization. Fish were sampled with standard electro-fishing method to determine species diversity, biomass of the specimens and their size. 29 fish species from seven families (26 native and 3 allochthonous species) were recorded along with one type of the Danubian brook lamprey (*Eudontomyzon vladykovi*). Only two species, *Telestes souffia* and *Cottus gobio*, were present at all eight sampling sites. The largest number of specimens (890) and the largest biomass (5697 g) per 100 m^2 was recorded at the sampling site located after the town as a result of the flow of purified water from the water treatment plant and a large number of invertebrates, which are an important food source. The minimum number of specimens per 100 m^2 (86) and the minimum biomass of fish per 100 m^2 (457 g) was measured at the relatively natural part of the channel. The most common causes for this are low temperatures, less food and a fast, turbulent flow. The study confirms that the changes in abiotic factors induced by anthropogenic activities significantly influence the structure of fish species community.

Keywords: running waters, loading, anthropogenic pressure, fish community, fish biodiversity

Izvleček: Naravne motnje in naraščajoči vplivi človeka vedno močneje vplivajo na rečne ekosisteme in njihove življenjske združbe. Ribje vrste so dober pokazatelj stanja reke in eden od elementov za oceno ekološkega stanja po okvirni vodni direktivi (Direktiva 2000/60/ES). Reka Mirna, eden večjih desnih pritokov reke Save, je dober primer antropogenega vpliva na ekosisteme tekoče vode. Vrstno strukturo ribje združbe smo analizirali na izbranih osmih vzorčnih mestih na dolžini 28 km reke. Z meritvami fizikalnih, kemijskih in hidromorfoloških parametrov smo ugotavljali abiotske razmere in analizirali vplive merjenih parametrov na prisotno združbo rib. Ugotovili smo, da je reka Mirna obremenjena z organskimi snovmi in fizično spremenjena z regulacijami, kanaliziranjem struge in utrjevanjem brežin. Ribe smo vzorčili z elektroagregatom, določili vrstno pestrost, biomaso osebkov in njihovo velikost. Evidentirali smo 29 vrst rib iz sedmih družin (26 avtohtonih in 3 alohtone vrste) in eno vrsto donavskega potočnega piškurja (*Eudontomyzon vladykovi*). Le dve vrsti, *Cottus gobio* in *Telestes souffia*, sta bili zastopani na vseh osmih vzorčnih mestih. Največje število osebkov na 100 m^2 je bilo na vzorčnem mestu za naseljem (890), z največjo ocenjeno biomaso na 100 m^2 (5697 g), kar je posledica dotoka očiščenih vod iz čistilne naprave naselja in večje število nevretenčarjev, ki so pomemben vir hrane. Najmanjše število osebkov na 100 m^2 (86) in najmanjšo biomaso rib na 100 m^2 (457 g) smo ugotovili na izvirnem delu struge. Najpogostejši vzroki za takšno stanje so nizka temperatura, manj hrane in hiter, turbulenten tok. Potrdili smo, da spremembe abiotskih dejavnikov, ki jih sprožijo antropogene aktivnosti, signifikantno vplivajo na vrstno strukturo ribje združbe.

Ključne besede: tekoče vode, obremenjevanje, antropogeni vplivi, združba rib, diverziteta ribjih vrst

Introduction

Aquatic ecosystems are complex systems of living and non-living components, which are governed by homeostatic mechanisms. Human activities reduce the flexibility of homeostatic processes consequently affecting the stability of the natural ecosystem (Tarman 1992). These changes impair the ecological conditions in the river ecosystem. The altered water quality and sediment structure impact the communities of aquatic organisms, including fish.

Fish are good bioindicators of the quality status of a river system. They respond to natural and anthropogenic-induced changes, and are one of the biological elements which help evaluate the ecological status of surface waters according to the Water Framework Directive (Directive 2000/60/EC).

Fish communities in aquatic ecosystems are being affected by several hydro-morphological, physical and chemical factors that vary spatially among different habitats and on a time scale among different seasons and hours within the day itself (Jackson et al. 2001). Specific conditions thus greatly influence the fish community in both the abundance of individual species as well as in the length and biomass of individual specimens (Cattanéo et al. 2002).

The Mirna River flows through the Mirna valley in central Dolenjska region (Slovenia) and has been regulated in several locations due to frequent flooding in the past. Its catchment area is settlements, agricultural land and major industrial plants. The effects of pollution are occasionally acute and result in fish mortality. The structure of fish community of the Mirna River and the effect of human activities on the fish are poorly known.

Materials and Methods

The analyzed location

Research was conducted on the 28.30 km long section of the Mirna River. Eight sampling sites were determined, which contrasted according to different effects of the catchment area. The first two sampling sites (Zagrad and Mirna1) were representative – on these sections no significant anthropogenic influences are present. The third site (Mirna 2) represents a regulated section of the Mirna River and the fourth site (Mirna 3) is located just after the wastewater treatment plant in the city. Three sampling sites (Puščava, Pijavica and Gabrje) were hydrologically diverse and had a different periphyton community and rate of bank regulation. The eighth sampling site (Zapuže) is located 2.6 km before the outflow to the Sava River, where the Mirna River is slow flowing and meandering (Fig. 1).

Research was conducted in August and September. Measurements of physical and chemical parameters (temperature, conductivity, pH level) were performed on a 100 meter section of the riverbed using EUTECH PCD 650 and HACH HQD equipment. The width and depth of the riv-

Figure 1: The Mirna River basin from its source to its mouth with marked sampling sites (scale 1: 121856; Interactive Atlas of the environment, 2006).
Slika 1: Porečje reke Mirne od izvira do izliva z označenimi vzorčnimi mesti (merilo 1: 121856; Interaktivni Atlas okolja, 2006).

erbed were measured and the fish harvesting area was calculated per 100 m^2. Different flow types, shoreline vegetation proportion, shading-regulation of the banks and catchment area were estimated at each sampling site. The AQEM method (2002) (Urbanič and Toman 2003) was used for the quantification of the categories of inorganic substrate.

Fish sampling

Fish were sampled using a standardized electro-fishing method (EN 14011, CEN 2003) with two back-mounted electro aggregates with the power of 0.6 to 1.5 kW. The stunned fish were collected with a net and transferred to vessel containing water and narcotics (5 mL ethyleneglycolmonophenyl ether per 10 L of water). The species of each stunned fish was determined and the weight and total body length were measured. The analyzed fish were returned to the river. To estimate the size of fish populations at each sampling site the procedure was repeated twice.

Statistical analysis

The fish population of the Mirna River was compared among different sampling sites according to species diversity, number of fish per 100 m^2 and biomass (g per 100 m^2).

Species diversity at individual sampling sites were confirmed by Margalef index of species diversity (R_1) and the Shannon-Wiener diversity index (H'), which was calculated using the program Ecological Methodology (Krebs 1999). The value of the Bray-Curtis similarity index (S_{BC}) for each sampling site was calculated with the PAST (http://folk.uio.no/ohammer/past) program and a dendrogram depicting the similarities among sampling sites was prepared.

Results

Analysis of the hydro-morphological, physical and chemical parameters

Hydro-morphological conditions changed longitudinally from the first to the eighth sampling site. The channel expands increasing the water flow. Substrate at the first two sites can be grouped to the category of macro- and mesolital but in the central and lower part acal and psamal prevail. At the last sampling site (Zapuže) the substrate is again grouped in the category of macro- and mesolital. At all analyzed sites slow flow predominates. The riverbed is natural at most of the sampling sites with the exception of Mirna 2, where the river is regulated. At the Pijavica sampling site the embankment is fortified with large stones. The total riparian part of the river is sporadically planted with trees.

Differences in water temperature, pH level and conductivity were minimal among sampling sites and within the expected values for this type of river (Tab. 1).

Table 1: Water temperature (T [°C]), pH and conductivity (G [µS/cm]) at each sampling site.
Tabela 1: Temperatura vode (T [ºC]), pH in elektroprevodnost (G [µS/cm]) na posameznih vzorčnih mestih.

Sampling site	T [ºC]	pH level	G [µS/cm]
Zagrad	16,7	8,4	561
Mirna 1	15,8	8,5	455
Mirna 2	18,0	6,9	551
Mirna 3	16,7	8,3	571
Puščava	20,9	8,3	494
Pijavica	21,8	8,5	502
Gabrje	19,0	8,5	505
Zapuže	19,3	8,7	483

Fish population analysis

29 species of fish from seven families along with one type of the Danubian brook lamprey (*Eudontomyzon vladykovi*), (larvae and adults were present) were determined. The majority of fish species (26) were indigenous only three (3) types of allochthonous (*Oncorhynchus mykiss*, *Carassius gibelio* and *Lepomis gibbosus*) were found (Tab. 2). The biggest diversity of fish species was recorded at Puščava sampling site (24 species) (moderate flow), and the poorest diversity at the first sampling sites (only 6 species). This has further been confirmed by the calculated value of the Margalef index of species diversity (Fig. 2A) and Shannon – Wiener diversity index (Fig. 2B) which were greatest for the sampling site Puščava (R_1 = 7.251 and H' = 3.182) and lowest for the sampling site Zagrad (R_1 = 1.917 and H' = 0.458). The comparison of fish communities according to Bray – Curtis similarity index revealed greatest similarity between the sampling site Pijavica and Gabrje (0.769) (Fig. 3), which shared 14 species. Only two species (*Telestes souffia* and *Cottus gobio*) were present at all eight sampling sites (Tab. 2).

The number of fish at each sampling site was estimated as the number of individuals per 100 m^2. The highest number of fish (890) was recorded at the Mirna 3 sampling site, and the lowest number of specimens (86) at the Zagrad site (the natural riverbed) (Fig. 4A). At all sampling sites individuals from the *Alburnoides bipunctatus*, *Cottus gobio* and *Telestes souffia* species prevailed. The biomass of fish at individual sampling sites is presented in g per 100 m^2. The highest biomass was measured at Mirna 3 site (5697 g/100 m^2) (located after the treatment plant in the city), the lowest at Zagrad (457 g/100 m^2) and Mirna 2 (708 g/100 m^2) sites, located at the start of the river (Fig. 4B).

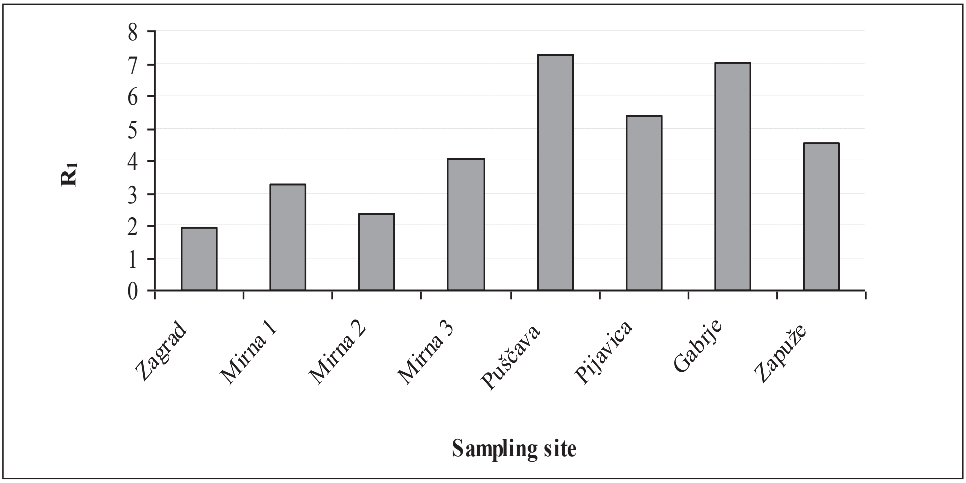
Discussion

Fish communities are suitable bioindicators of the quality of aquatic ecosystems (Feyrer and Healey 2003), since they are affected by various abiotic and anthropogenic factors. Among the abiotic factors, hydro-morphological, physical and chemical factors are extremely important (Jackson et al. 2001). The key anthropogenic factors influencing aquatic ecosystems are river engineering interventions, the type and degree of pollution and the introduction of non-native fish species (Trontelj 2005). All of these elements affects the conditions in aquatic ecosystems and consequently alter the fish communities (Giller and Malmqvist 1998).

Throughout the hydro-morphologically, physically and chemically diverse flow of the Mirna River 29 species of fish were determined. Great species diversity was recorded at sites with a calm, meandring flow (such as Puščava), and only a few fish species were caught at the start of the river (Zagrad). This can be explained by the habitat heterogeneity at the Puščava site where different substrates, meanders and riverbank vegetation were found. Similar conclusions have been reported by Grossman et al. (1998). In contrast, the Zagrad site is characterized by highly homogeneous and fast water flow, high riverbank shading rate (90–100%), which resulted in the lowest fish species diversity.

Low species diversity was also recorded at the regulated channel (Mirna 2). Povž and Sket (1990), Cattanéo et al. (2002), Dekar and Magoulick (2007) observed that river regulation negatively affects the diversity of micro habitats leading to reduced species diversity. Fish are considerably more vulnerable to predators (eg. fish-eating birds) in regulated rivers, because there is no convenient hiding place available (Jackson et al. 2001). Therefore, if hydrological conditions permit the fish will move to other parts of the riverbed with suitable hiding places and spawning (Povž and Sket 1990). The largest number of specimens (890) and the largest biomass (5697 g) per 100 m^2

A



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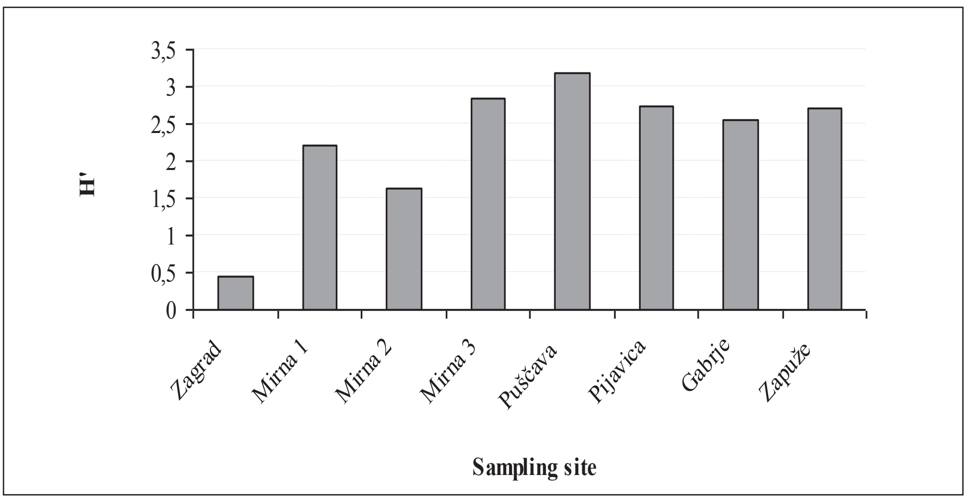

Figure 2: Margalef index (R_1) (A) and Shannon – Wiener index (H') (B) at each sampling site.
Slika 2: Margalefov indeks vrstnega bogastva (R_1) (A) in Shannon – Wienerjev diverzitetni indeks (H') (B) na posameznih vzorčnih mestih.

Table 2: List of fish species found in the Mirna River at each sampling site.
Tabela 2: Seznam ribjih vrst najdenih v reki Mirni na posameznih vzorčnih mestih.

Family	Species	Sampling site							
		SS 1	**SS 2**	**SS 3**	**SS 4**	**SS 5**	**SS 6**	**SS 7**	**SS 8**
Salmonidae	*Salmo trutta m. fario* (L., 1758)	+	+	+	+	+		+	+
	Oncorhynchus mykiss (Walbaum, 1792)							++	
Cyprinidae	*Carassius carassius* (L., 1758)					+			
	C. gibelio (Bloch, 1782)					++			
	Cyprinus carpio (L., 1758)					+			
	Barbus barbus (L., 1758)					+	+	+	+
	B. balcanicus (Kotlík et al., 2002)		+	+	+	+	+	+	+
	Gobio gobio (L., 1758)				+	+	+	+	+
	Romanogobio vladykovi (Fang, 1943)							+	+
	R. kessleri (Dybowski, 1862)					+	+	+	+
	R. uranoscopus (Agassiz, 1828)								+
	Squalius cephalus (L., 1758)	+	+		+	+	+	+	+
	Rutilus rutilus (L., 1758)		+			+		+	
	R. virgo (Heckel, 1852)					+		+	+
	Telestes souffia (Risso, 1826)	+	+	+	+	+	+	+	+
	Chondrostoma nasus (L., 1758)				+	+		+	
	Vimba vimba (L., 1758)					+			
	Abramis brama (L., 1758)				+		+		
	Alburnoides bipunctatus (Bloch, 1782)		+	+	+	+	+	+	+
	Alburnus alburnus (L., 1758)					+	+	+	
	Rhodeus amarus (Bloch, 1782)				+	+	+	+	
	Phoxinus phoxinus (L., 1758)		+	+	+		+		
Cobitidae	*Cobitis elongatoides* (Bacescu et Maier, 1969)				+	+	+		
	C. elongata (Heckel et Kner, 1858)					+	+	+	+
	Sabanejewia balcanica (Karaman, 1922)					+	+	+	+
Balitoridae	*Barbatula barbatula* (L., 1758)	+		+	+	+	+	+	+
Centrarchidae	*Lepomis gibbosus* (L., 1758)							++	
Percidae	*Perca fluviatilis* (L., 1758)		+		+	+	+	+	
Cottidae	*Cottus gobio* (L., 1758)	+	+	+	+	+	+	+	+
Petromyzontidae	*Eudontomyzon vladykovi* (Oliva & Zanandrea, 1959)	+	+	+	+	+	+	+	

Legend: SS 1 = sampling site Zagrad, SS 2 = sampling site Mirna 1, SS 3 = sampling site Mirna 2, SS 4 = sampling site Mirna 3, SS 5 = sampling site Puščava, SS 6 = sampling site Pijavica, SS 7 = sampling site Gabrje, SS 8 = sampling site Zapuže, + = present native species, + + = present allochthonous species

was recorded at the sampling site located after the town as a result of the flow of purified water from the water treatment plant and a large number of invertebrates, which are an important food source. The minimum number of specimens per 100 m^2 (86) and the minimum biomass of fish per 100 m^2 (457 g) was measured at the relatively natural part of the channel. The most common causes for this are low temperatures, less food and a fast, turbulent flow. The same applies to the regulated

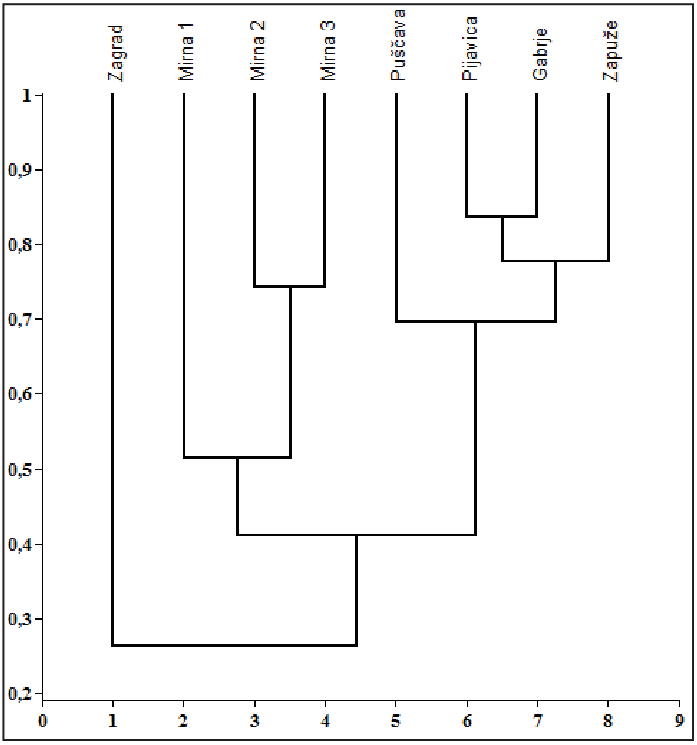

Figure 3: Comparison of different sampling sites based on Bray – Curtis similarity index.
Slika 3: Primerjava različnih vzorčnih mest na osnovi Bray – Curtisovega indeksa podobnosti.

part of the channel, which is also in accordance with the results of other researchers (Pollux et al. 2006, Dauwalter et al. 2007).

Conclusions

The Mirna river system has a typical longitudinal alteration of abiotic conditions such as stream width, water depth, type of inorganic substrate, type of water flow, embankment regulation and vegetation and fairly similar temperature, pH and conductivity levels. The fish community was analyzed at selected sites along the river and 29 fish species along with one species of Danubian brook lamprey (*Eudontomyzon vladykovi*) were confirmed. 26 species were native and three allochthonous (*Oncorhynchus mykiss*, *Carassius gibelio* and *Lepomis gibbosus*).

According to the Slovenian "Regulations on the classification of endangered plant and animal species on the Red List" (Official Gazette of RS, no. 82/02) 10 endangered species can be found in the Mirna River, namely: *Salmo trutta m. fario, Cyprinus carpio*, *Barbus barbus*, *Rutilus virgo*, *Telestes souffia*, *Chondrostoma nasus*, *Vimba vimba*, *Rhodeus amarus*, *Cobitis elongata*, *Sabanejewia balcanica* and 5 vulnerable fish species: *Romanogobio vladykovi*, *R. kessleri*, *R. uranoscopus*, *Cobitis elongatoides*, *Cottus gobio*. Among the endangered species the Danubian brook lamprey (*Eudontomyzon vladykovi*) has been detected in Mirna River.

The analyzed sites varied according to the number of species present, and the number of specimens and biomass per 100 m^2. The maximum species diversity was determined at Puščava site, where the morphologic parameters were the most heterogeneous. The highest mean number of fish per 100 m^2 and maximum average biomass of fish per 100 m^2 were determined at Mirna 3 sampling site. We assume that this is due to the partially cleaned water from the biological wastewater treatment plant being released to the Mirna River, providing greater nutrient intake, and consequently more fish food.

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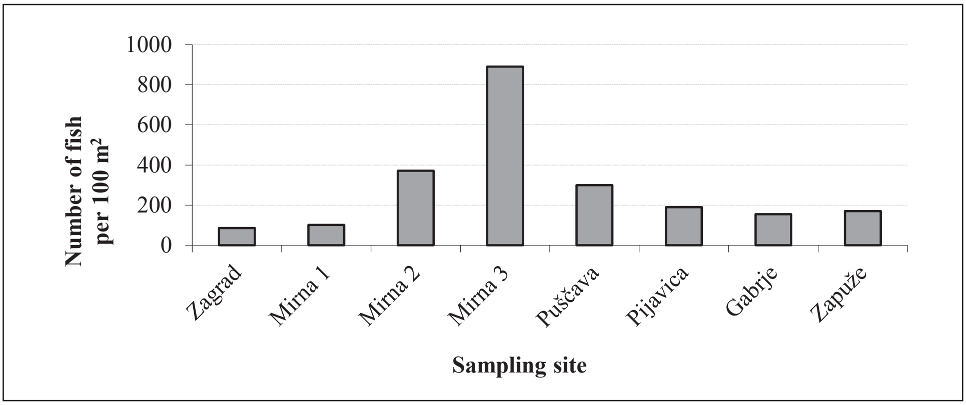

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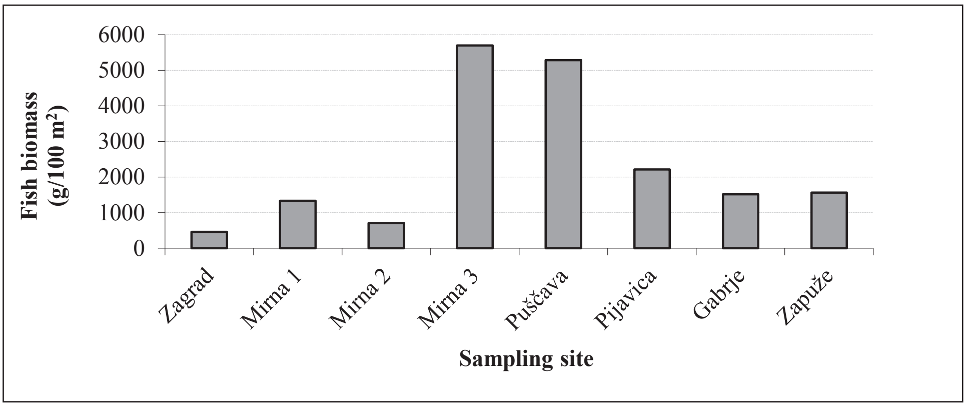

Figure 4: Number of fish per 100 m^2 (A) and fish biomass (g/100 m^2) (B) at each sampling site.
Slika 4: Število rib na 100 m^2 (A) in biomasa rib (g/100 m^2) (B) na posameznih vzorčnih mestih.

Povzetek

Članek govori o vrstni pestrosti strukture ribje združbe na odsekih reke Mirne in podaja ugotovitve o vplivih nekaterih abiotskih in antropogenih dejavnikov na njihovo združbo. Na izbranih delih reke od izvira do izliva smo izmerili in ocenili določene hidromorfološke, fizikalne in kemijske parametre, ki so nam omogočili oceno vplivov na prisotno združbo rib. V reki Mirni smo ugotovili prisotnost 29 vrst rib, od tega 26 avtohtonih in 3 alohtone vrste ter vrsto donavskega potočnega piškurja (*Eudontomyzon vladykovi*). Ugotovljene vrednosti, kot so število vrst, število osebkov na 100 m^2 in biomasa na 100 m^2, so bile na različnih odsekih reke različne in v veliki meri odvisne od abiotskih dejavnikov in oblikovanosti struge. Največje vrstno bogastvo smo ugotovili na srednjem delu toka (Puščava), kjer so bili hidromorfološki parametri najbolj heterogeni, meandrirana struga z mirnim tokom. Pričakovano najmanjše število vrst je bilo na izvirnem delu s homogenim substratom, hitrim vodnim tokom in 100 % zasenčenostjo struge. Vrstno bogastvo na posameznih vzorčnih delih struge smo prikazali z Margalefovim indeksom vrstnega bogastva in s Shannon-Wienerjevim diverzitetnim indeksom. Na podlagi Bray-Curtisovega indeksa podobnosti smo največjo podobnost združb rib ugotovili na štirih vzorčnih mestih pred izlivom Mirne v

reko Savo in na treh vzorčnih mestih gornjega dela struge. Združba rib izvirnega dela (Zagrad) se je od preostalih združb najbolj razlikovala. Največje povprečno število rib na 100 m^2 in največjo povprečno biomaso na 100 m^2 smo določili na delu reke za naseljem, na katerega vplivajo delno očiščene vode iz biološke čistilne naprave. Posledično je v reki večja vsebnost hranil, intenzivnejša obrast in več nevretenčarjev, pomembne hrane za ribe. Najmanjšo povprečno število rib na 100 m^2 in najmanjšo povprečno biomaso rib na 100 m^2 smo pričakovano ugotovili na izvirnem delu struge v Zagradu. Na takšno stanje najpogosteje vplivajo nizka temperatura, pomanjkanje hrane in hiter tok vode.

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