© *Acta hydrotechnica* **21/35 (2003)**, Ljubljana
ISSN 1581–0267

UDK/*UDC*: 504.4:556.53:574.5 Prejeto/*Received*: 18. 6. 2004
Izvirni znanstveni članek – *Original scientific paper* Sprejeto/*Accepted*: 14. 12. 2004

UPORABA PERIFITONA IN VEČJIH VODNIH NEVRETENČARJEV PRI DOLOČANJU EKOLOŠKO SPREJEMLJIVEGA PRETOKA NA REKI RIŽANI, SLOVENIJA
THE USE OF PERIPHYTON AND MACROZOOBENTOS IN DETERMINATION OF ECOLOGICALLY ACCEPTABLE FLOW FOR THE RIŽANA RIVER, SLOVENIA

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Edini večji izvir v slovenski Istri je kraški izvir reke Rižane, ki predstavlja najpomembnejši vir oskrbe z vodo za slovensko obalno območje. V poletnih mesecih je naravni pretok dokaj nizek, saj voda delno pronica v tla, nekaj pritokov reke Rižane pa se izsuši. Istočasno pa sta v tem letnem času potreba po oskrbi s pitno vodo in namakanje največja. V obdobju od 1995 do 1996 je bil izdelan seznam vseh porabnikov vode in popis onesnaževalcev. Izvedene so bile hidrološke analize od izvira do ustja reke Rižane. Z analizami perifitonskih alg in večjih vodnih nevretenčarjev se je ugotavljala kakovost vodnega ekosistema na različnih odsekih reke Rižane. Zaradi velikega odvzema vode in onesnaženja je prišlo do sprememb v raznolikosti združb večjih vodnih nevretenčarjev, perifitonskih alg in biomase perifitona (suhe teže brez pepela (AFDW), suhe teže (DW), klorofila-a (chl-a)). Na podlagi saprobioloških analiz je bila reka uvrščena v I.–II. kakovostni razred. Ocena kakovosti, ki je temeljila na indeksu (ocenjevalnem sistemu) BMWP (Biological Monitoring Working Party) in indeksu EBI (Extended Biotic Index), je pokazala na poslabšanje kakovosti vodnega okolja v nižjih delih reke. Da bi ohranili ekološko ravnovesje, je bil določen ekološko sprejemljiv pretok za poletne mesece na osnovi ekološke metode.
Ključne besede: *perifiton, večji vodni nevretenčarji, ekološko sprejemljiv pretok, kakovost vode, kakovost vodnega okolja*

The only major spring in the Slovenian Istria is the karst spring of the Rižana River, which is the most important source of water supply for the Slovenian coastal area. In summer months the natural flow is very low, whereby part of water drains off into the underground and several tributaries of the Rižana River dry up. At the same time, the need for water supply and irrigation are at their highest. In the period from 1995 to 1996, the list of all water users and the inventory of polluters were made. From source to mouth of the Rižana River, the hydrological analyses were carried out. The river ecosystem was evaluated according to analyses of periphytic algae and macroinvertebrates on different sections of the Rižana River. Because of large water abstraction and pollution of the river, changes in diversity of macroinvertebrates, in diversity of periphytic algae and in periphyton biomass (ash free dry weight (AFDW), dry weight (DW), chlorophyll a (chl a)) were established. Based on saprobiological analyses, the river is classified as quality class I–II. The evaluation of quality based on BMWP score system and EBI, indicated a deterioration of the aquatic environment in lower parts of the river. In order to maintain the ecological balance, the ecologically acceptable flow (EAF) was determined according to the ecological method for summer months.
Key words: *periphyton, macrozoobenthos, ecologically acceptable flow, water quality, quality of aquatic environment*

1. UVOD

Podobno kot drugje v Sredozemlju je na območju slovenske Istre malo vodnih virov. Edini večji izvir je kraški izvir reke Rižane, ki predstavlja najbolj pomemben vir oskrbe z vodo za slovensko obalno območje. Dolvodno je opaziti povečano gostoto prebivalstva z vsemi spremljajočimi, tudi negativnimi pojavi, kot so poseljevanje, kmetijstvo, industrija, trgovina, promet in odlagališča. Potrebe po pitni vodi, vodi za kmetijstvo in industrijo presegajo vodne kapacitete reke Rižane.

Za določitev minimalnega sprejemljivega pretoka obstaja nekaj metod (Petts & Maddock, 1995): hidrološke metode (Schälchli, 1991; Mader, 1992), metode za oceno vodotokov (Büttiker, 1982; Bundi & Eichenberger, 1989; Statzner & Müller, 1989; Schälchli, 1991; DVWK, 1995; Bernardo & Alves, 1999) in PHABSIM (Physical HABitat SIMulation) (Institute of Hydrology & Institute of Freshwater Ecology, 1993; Lamb, 1995; Maddock *et al*., 2001). Ob upoštevanju hidroloških, hidravličnih, morfoloških in ekoloških kriterijev se v Sloveniji trenutno uporabljata dve metodi: hidrološka in ekološka metoda (Vrhovšek *et al*., 1994; Vrhovšek & Smolar, 1997; Smolar *et al*., 1998; Smolar - Žvanut & Vrhovšek, 2002).

Zaradi velikega odvzema vode in skoraj popolne odsotnosti vode poleti v spodnjih delih reke Rižane je bila ocenjena vrednost ekološko sprejemljivega pretoka (Qes) z interdisciplinarnim pristopom (ekološka metoda) z namenom, da se zagotovi izboljšanje razmer za vodne organizme (Smolar *et al*., 1997).

V članku se osredotočamo predvsem na uporabo večjih vodnih nevretenčarjev in perifitonskih alg pri določanju ekološko sprejemljivega pretoka za reko Rižano.

1. INTRODUCTION

Like throughout the Mediterranean, the area of Slovenian Istria is very poor in water sources. The only major spring is the karst spring of the Rižana River, which is the most important source of water supply for the Slovenian coastal area. Downstream, the increasing density of population with all relevant, and also negative phenomena, such as settlements, agriculture, industry, trade, traffic and landfill-sites can be observed. The demand for drinking water, as well as the industrial and agricultural exploitation of the Rižana River have exceeded the water capacity of the river.

There are some methods available for the estimation of minimum acceptable flows (Petts & Maddock, 1995): hydrological methods (Schälchli, 1991; Mader, 1992) river assessment methods (Büttiker, 1982; Bundi & Eichenberger, 1989; Statzner & Müller, 1989; Schälchli, 1991; DVWK, 1995; Bernardo & Alves, 1999); and PHABSIM (Physical HABitat SIMulation) (Institute of Hydrology & Institute of Freshwater Ecology, 1993; Lamb, 1995; Maddock *et al*., 2001). Based on the hydrological, hydraulic, morphological and ecological criteria, the hydrological and ecological method is currently being applied in Slovenia (Vrhovšek *et al*., 1994; Vrhovšek & Smolar, 1997; Smolar *et al*., 1998; Smolar - Žvanut & Vrhovšek, 2002).

Because of major water exploitation and an almost complete absence of water in summer in lower parts of the Rižana River, the relevant ecologically acceptable flow (EAF) value was evaluated by means of the interdisciplinary approach (ecological method) in order to achieve the improvement of conditions for water organisms (Smolar *et al*., 1997).

This paper describes specifically the use of macroinvertebrates and periphytic algae in determining the EAF in the Rižana River.

2. MESTO RAZISKAV

Prispevno območje 14 km dolge reke Rižane (slika 1) obsega 204,5 km^2. Reka teče po kraškem zaledju s pretežno flišnim območjem, z izlivom v Jadransko morje čez brakično mokrišče.

Za območje je značilna blaga submediteranska klima z blagimi zimami in dokaj visokimi poletnimi temperaturami predvsem od začetka maja do konca septembra. Suše so v tem obdobju pogoste. Srednja letna raven padavin je približno 1000 mm v obalnem območju, v višjih legah reke Rižane pa je letna količina padavin povprečno 1150 mm. Letna porazdelitev padavin je neenakomerna, kar pomeni, da je poleti veliko neviht, ko voda hitro odteka in izpareva.

Reka Rižana je vir oskrbe s pitno vodo že od leta 1935. Neposredno pod akumulacijo je odvzem vode, namenjen za ribogojnico in za namakanje. Dolvodno je še 15 vodnih zajetij, poleti pa tudi nekaj nenadzorovanih odvzemov vode za namakanje. Posledice so vidne predvsem v poletnih mesecih, ko zaradi poslabšanja vodnega okolja prihaja do poginov rib. V tem območju se je izvedlo tudi več hidrotehničnih posegov.

Za strugo vzdolž vodotoka so značilni različni substrati; gorvodno so to večji kamni, dolvodno pa se struktura rečnega dna spreminja od proda do mulja. Reka Rižana ima status športno ribolovne vode, mlinščice ob reki pa so na seznamu okoljsko zaščitenih območij za trajnostno gojenje soške postrvi *Salmo marmoratus*. V bližini reke pogosto najdemo združbe *Ostryo - Quercetum pubescentis*, *Carici humulis - Centaureetum rupestris* in *Bromo - Chrysopogonetum grylli.* Obvodna vegetacija je okrnjena zaradi obdelane zemlje in bližine cest.

Na reki Rižani smo izbrali 4 vzorčna mesta: prvo vzorčno mesto (R1) je bilo izbrano poleg izvira, drugo in tretje vzorčno mesto (R2, R3) sta bili izbrani v osrednjem delu reke, zadnje vzorčno mesto (R4) pa je bilo izbrano v bližini

2. STUDY SITES

With its 14 km of length, the Rižana River (Fig. 1) drains a watershed area of 204.5 km^2. The Rižana River features karstic hinterland with predominantly flysch area, with the estuary in the Adriatic over brackish wetland.

Typical of the area is a relatively mild submediterranean climate with mild winters and relatively high summer temperatures occurring primarily from the beginning of May until the end of September. During this period droughts are quite frequent. The average levels of annual precipitation amount to approximately 1000 mm in the coastal area, whereas in the upper stream area of the Rižana River they reach approximately 1150 mm. The annual precipitation distribution is uneven, meaning that in summer the precipitation takes the form of heavy showers during which the water drains and evaporates very quickly.

The Rižana River has been the source of water supply since 1935. Directly below the accumulation there is a water abstraction for the fish-farm and irrigation requirements. There are further 15 water abstractions downstream, and in summer some uncontrolled water abstractions for irrigation. Consequences can be observed primarily in the summer period when, due to the deterioration of the aquatic environment, there were several cases of fish kill. Downstream, numerous hydrotechnical interventions were carried out, too.

Along the watercourse, the riverbed structure is characterised by various substrates which, upstream, are composed of large stones while downstream, the stone structure changes from gravel into silt. As regard the fish management, the Rižana River has a status of a sports and fishing water body, whereas mill-brooks along the river are listed as environmentally protected areas for the sustainable fish-hatching of marble trout *Salmo marmoratus*. In the vicinity of the river, the communities of *Ostryo - Quercetum pubescentis*, *Carici humulis - Centaureetum rupestris* and *Bromo - Chrysopogonetum grylli* are to be found quite frequently. The riparian vegetation along the watercourse is quite degraded due to land cultivation and vicinity of roads.

Four relevant sampling sections of the Rižana River have been selected: the first (R1) was selected near the spring, the second (R2) and third (R3) were selected in the middle part of the Rižana River and the last (R4) was izliva v Jadransko morje.

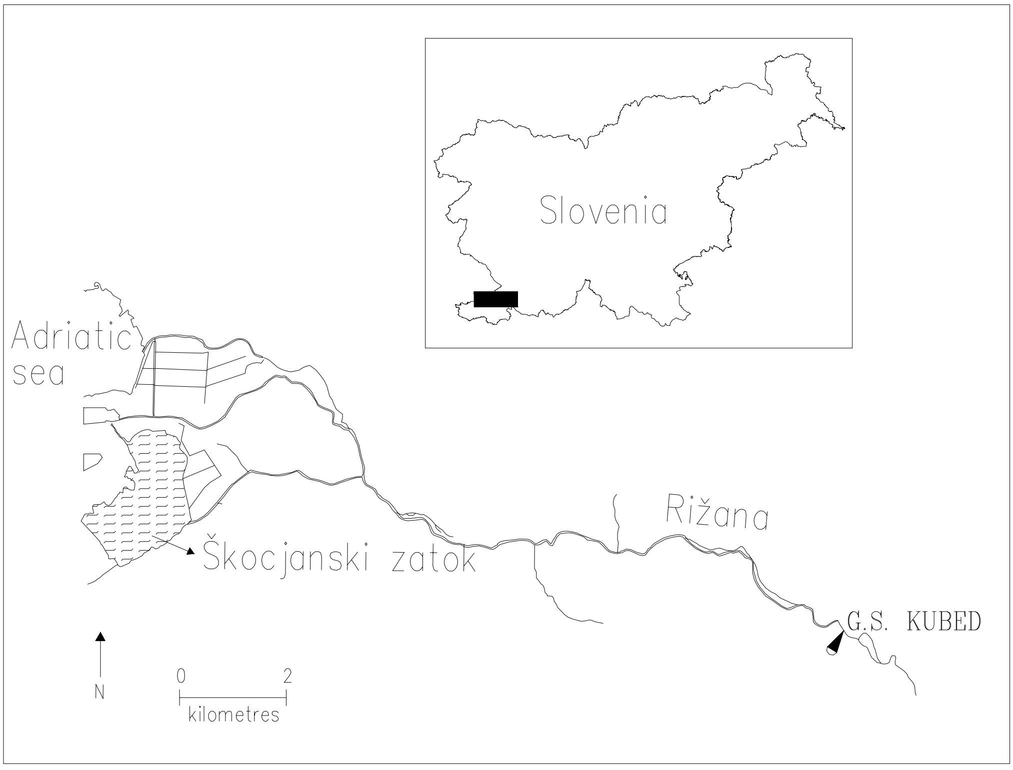
Zaledje reke Rižane je pretežno kraško z značilnimi hidrogeološkimi pojavi, kar se kaže tudi v letnih hidrogramih. Količina vode v Rižani je odvisna od vodostaja podtalnice, padavin in vodnatosti pritokov Rižane. Pritoki, ki se nahajajo na kraškem svetu, so kratki in strmi z značilnostmi hudournikov, ki se v poletnem času izsušijo (Peroša *et al*., 1993). Manjši odvzemi vode ob reki v času visoke vode (tj. spomladi in jeseni) bistveno ne spreminjajo hidrologije reke, medtem ko se v sušnem obdobju količina vode zmanjša zaradi prej omenjenih odvzemov vode.

Eden od poglavitnih parametrov pri določanju ekološko sprejemljivega pretoka so vrednosti pretokov vode. Količina vode se nanaša na merilno postajo Kubed, ki se nahaja pod odvzemom za sistem oskrbe s pitno vodo, katerega maksimalna količina znaša 0,35 m^3/s. Hidrološke značilnosti pretokov reke Rižane na merilni postaji Kubed za obdobje 1966–1995 so predstavljene v preglednici 1.

selected in the very vicinity of its estuary in the Adriatic Sea.

The hinterland of the Rižana River is primarily composed of karst characterised by specific hydrogeological features, which is reflected by the annual hydrographs. The quantity of water feeding the Rižana River depends on the water-level of the groundwater, the precipitation and the capacity of the Rižana River tributaries. The tributaries of the river, located in the karst region, are short and steep, having all the characteristics of torrents drying in summer periods (Peroša *et al*., 1993). Minor water abstractions along the watercourse during the period of high flows (i.e. in spring and autumn) do not essentially change the hydrology of the river, whereas in drought periods the water quantity along the watercourse decreases due to the mentioned abstractions.

One of the basic parameters in estimating EAF are the flow values. The water quantity data refer to the Kubed gauge station, which is located below the abstraction for water supply system, whose maximum delivery amounts to 0.35 m^3/s. The hydrological characteristics of the Rižana River flows at the Kubed gauge station for the thirty year period (1966–1995) are represented in Table 1.



Slika 1. Reka Rižana.
Figure 1. The Rižana River.

Preglednica 1. Hidrološki podatki za reko Rižano na merilni postaji Kubed za obdobje 1966–1995.
Table 1. Hydrological data for the Rižana River at the gauge station Kubed, for period 1966–1995.

Parameter/*parameter*	Vrednost/*value*
prispevno območje/*catchment area*	204.5 km^2
srednji letni pretok/*mean annual flow*	4.101 m^3/s
srednji minimalni pretok/*mean minimum flow*	0.222 m^3/s
minimalni pretok/*minimum flow*	0.010 m^3/s
Q300d	0.500 m^3/s
Q347d	0.160 m^3/s

3. MATERIALI IN METODE

Na štirih vzorčnih mestih (R1, R2, R3, R4) reke Rižane so bili za kvantitativne in kvalitativne analize odvzeti vzorci (do štirje odvzemi) perifitona in večjih vodnih nevretenčarjev. Vzorci so bili pobrani na 4 točkah vzorčnega mesta v prečnem profilu. Označeni so bili kot R1.1–R1.4 od levega proti desnemu bregu.

Kvantitativne vzorce vodnih nevretenčarjev smo zbrali z vzorčevalnikom Surber (pravokotnik 21,5 krat 17,5 cm, z velikostjo okenca 0,3 mm). Vzorce perifitona in večjih vodnih nevretenčarjev smo konzervirali na terenu s 36-odstotnim formaldehidom in jih prenesli v laboratorij na sortiranje. Kjer je bilo mogoče, so bili večji vodni nevretenčarji določeni do nivoja vrste, medtem ko se je pri večini določil le rod, v nekaterih primerih pa le družina. Večina perifitonskih alg je bila določena do nivoja vrste. Po pregledu organizmov se je ocenila pogostost posameznih vrst perifitonskih alg in večjih vodnih nevretenčarjev, to pa se je označilo z 1 – redko, posamezno, 3 – srednje pogosto, 5 – pogosto, množično.

Vzorci perifitona, namenjeni za kvantitativno analizo perifitonske biomase, so bili odvzeti iz rečnih sedimentov, premera 50–200 mm. Na vsaki točki vzorčnega mesta smo postrgali 5 plavin, in sicer smo iz vsake postrgali površino 200 mm^2. V laboratoriju smo ovrednotili suho težo in organsko snov (suha teža brez pepela) po metodiki APHA.AWWA.WPC (1992). Koncentracijo klorofila-*a* smo določili s filtracijo skozi filtre Watman GF/C in z ekstrakcijo z vročim

3. MATERIALS AND METHODS

In four sampling sections (R1, R2, R3, R4) of the Rižana River, up to four samples of periphyton and macroinvertebrates were taken for quantitative and qualitative analyses. The samples were taken at 4 sampling points in the sampling section in a river cross-section. They were designated f.e. R1.1–R1.4 from the left to the right bank.

Quantitative samples of macroinvertebrates were collected with the Surber sampler (square 21.5 by 17.5 cm, mesh size 0.3 mm). The samples of periphyton and macroinvertebrates for qualitative analyses were preserved in the field with 36 % formaldehyde and returned to the laboratory for sorting. Where possible, some macroinvertebrates were identified to species level, whereas the majority was identified to genus level, and in few cases only to family level. The majority of periphytic algae taxa were identified to species level. After surveying the organisms, abundance of individual taxa of algae and macroinvertebrates was assessed, marked by 1 – rare, occasional, 3 – frequent, 5 – dominant.

Periphyton samples intended for quantitative analysis of the periphyton biomass were taken from river sediments 50 mm to 200 mm in diameter. At each sampling point in the sampling section, 5 sediment particles were scraped off from the surface 200 mm^2. Dry weight (DW) and organic matter (ash-free dry weight – AFDW) were assessed in the laboratory using the APHA.AWWA.WPC technique (1992). The chlorophyll-*a* concentration was determined by the use of filtration through Watman GF/C filters and metanolom (Vollenweider, 1974). Vrednosti perifitonske biomase so bile izračunane za kvadratni meter substrata na rečnem dnu. Vzorčevanje je na vseh odvzemnih mestih potekalo v obdobju nizkega pretoka, tj. poleti 1996 in pozimi 1997.

V obdobju vzorčevanja se je na odvzemnih mestih merilo pretoke in maksimalno hitrost pretoka z merilcem pretoka SEBA Mini Current Meter MI.

Razlike v povprečnih vrednostih suhe teže, organske snovi in klorofila-*a* smo testirali med vzorčnimi mesti. Z izračunom Bray-Curtisovega koeficienta podobnosti (Clarke & Warwick, 1990) so se ocenile podobnosti med posameznimi mesti s pomočjo podatkov vrstnega sestava in pogostosti prisotnih vrst.

Delež primanjkljaja vrst po Kothéju 1962 (Wegl, 1983) je bil izračunan iz števila perifitonskih alg in skupin večjih vodnih nevretenčarjev v vzorcih na posameznih mestih reke.

Ocena kakovosti vode je bila ovrednotena s Pantle-Buckovim saprobnim indeksom s prilagoditvijo metodi, ki sta jo razvila Zelinka in Marvan (1961). Kakovost vodnega okolja je bila ocenjena z ocenjevalno lestvico BMWP (Armitage *et al.*, 1983) in EBI (spremenjeno po Ghetti, 1986).

extraction with hot methanol (Vollenweider, 1974). The values of periphyton biomass were calculated per square metre of river bottom substrata. In all sections, samples were taken in the period of low flow in summer 1996 and in winter 1997.

During the sampling period, the flow and the maximum current velocity in the sections were measured by SEBA Mini Current Meter MI.

The differences in AFDW averages, DW averages and chl-*a* averages were tested between sampling sections. By calculating the Bray-Curtis coefficient of similarity (Clarke & Warwick, 1990), the similarities between individual sections were evaluated as far as species diversity and their abundance were concerned.

A percentage of species deficit by Kothé, 1962 (Wegl, 1983) was calculated from the number of periphytic algae and macroinvertebrates taxa in samples between individual sampling sections of the river.

The quality of water was evaluated using the Pantle-Buck saprobic index with modification to the Zelinka and Marvan method (1961). The quality of aquatic environment was evaluated by BMWP score system (Armitage *et al.*, 1983), and Extended Biotic Index – EBI (modified by Ghetti, 1986).

4. REZULTATI IN RAZPRAVA

4.1 HITROST TOKA IN PRETOK

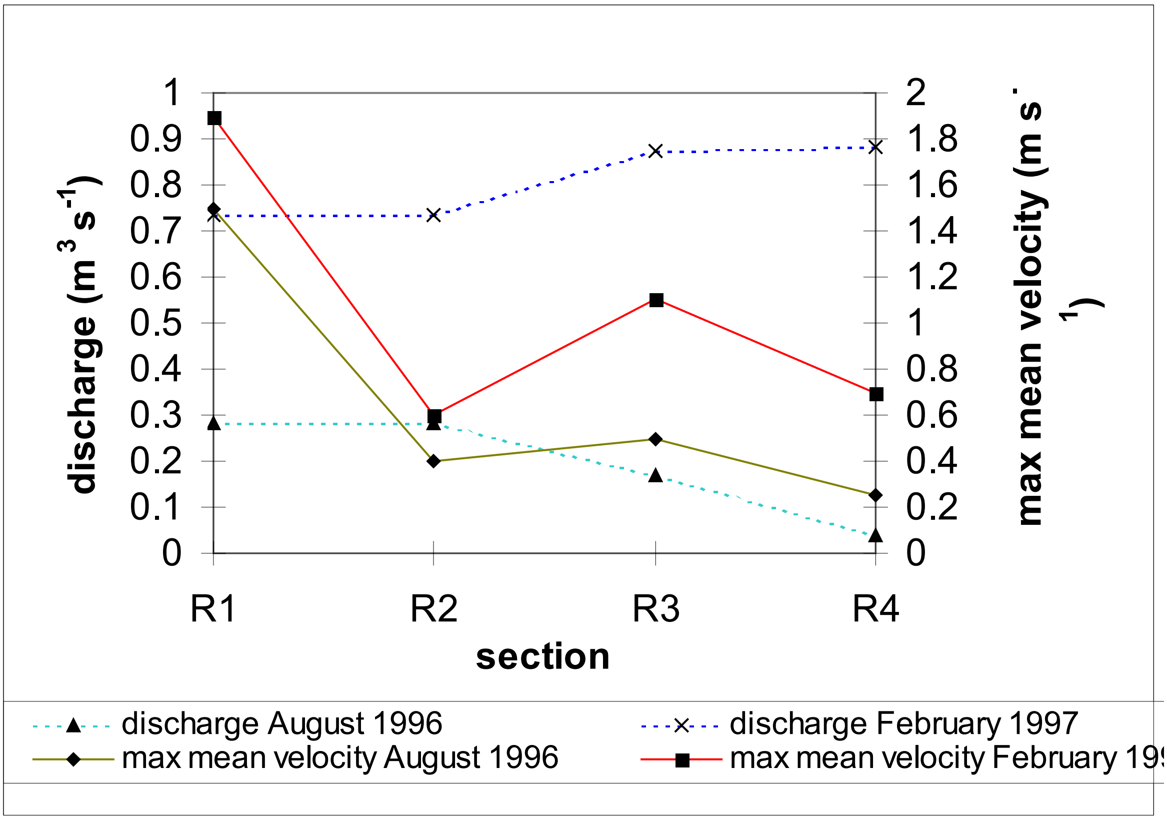
Poleti 1996 se je pretok vzdolž reke zmanjšal zaradi odvzema vode za namakanje in industrijo ter zaradi naravnega pronicanja v podtalje kot posledice intergranularne poroznosti substrata. Podobno tudi rezultati meritev 6. oktobra 1995 (Vrhovšek *et al.*, 1995) kažejo naslednje vrednosti pretokov vode: na vzorčnem mestu R1 smo izmerili pretok 1,036 m^3/s in na vzorčnem mestu R4 0,836 m^3/s. Pozimi 1997 se je pretok povečeval od vzorčnega mesta R1 proti vzorčnemu mestu R4. Maksimalna povprečna hitrost je bila vedno najvišja v območju R1; najnižja je bila poleti 1996 v območju R4 (slika 2). Rezultat naravnih in antropogenih posegov, ki so povzročili spremembe pretoka

4. RESULTS AND DISCUSSION

4.1 CURRENT VELOCITY AND DISCHARGE

The discharge in summer 1996 decreased along the river as a result of water abstraction for irrigation, industry and natural drainage into underground due to intergranular porosity of substrata. Similarly, the results of the measurements carried out on October 6, 1995 (Vrhovšek *et al.*, 1995) indicated the following values of the water flow: R1 section 1.036 m^3/s and R4 section 0.836 m^3/s. In winter 1997, the discharge increased from section R1 to section R4. Maximum mean velocity always reached its highest value in the R1 section; the lowest was in summer 1996 in the R4 section (Fig. 2). The result of natural and anthropogenically induced changes in poleti, je skoraj popolnoma suha rečna struga. Rečno strugo sestavlja pretežno trden substrat (velike in manjše skale, prodniki) kot posledica nizkega pretoka in hitrosti toka vzdolž reke; dolvodno so predvsem v območju počasnejšega toka pogostejši drobni sedimenti. Pri določanju ekološko sprejemljivega pretoka mora biti zagotovljena odstotnost ekstremnih nanosov drobnih sedimentov, potrebno pa je periodično vzdrževanje visoke vode in raznolikost v hitrostih vodnega toka v vodotoku kot tudi vzdrževanje določenega vodostaja (Bundi & Eichenberger, 1989). Treba je tudi ohraniti pestrost v različnih tipih vodnih habitatov na posameznih odsekih rek.

discharge in summer is a nearly dry river bed. As a consequence of low discharge and current velocity along the river, the river bed in the R1 and R2 sections is dominated by solid substrates (boulders, rocks and pebbles), whereas downstream soft sediments frequently occur in low current sections. The determination of EAF requires the absence of the extreme accumulation of small sediments and the periodical maintenance of high water flows and the diversity of watercourse velocity, as well as the maintenance of the specific water level (Bundi & Eichenberger, 1989). It is important to ensure the diversity in various types of water habitats within the river sections.



Slika 2. Pretok in maksimalna hitrost na vzorčnih mestih reke Rižane.
Figure 2. Discharge and maximum velocity for the sampling sections in the Rižana River.

4.2 BIOMASA PERIFITONA

V primerjavi z dolvodnimi odvzemnimi mesti so bile najvišje vrednosti suhe teže, organske snovi in klorofila-*a* izmerjene na vzorčnem mestu R1, tj. predvsem poleti 1996 (preglednica 2).

4.2 PERIPHYTON BIOMASS

In comparison with downstream sites, the highest values of DW, AFDW and chl-*a* were measured in the R1 sampling section, notably in summer 1996 (Table 2).

Preglednica 2. Minimalne (min), maksimalne (max) in povprečne (ave) vrednosti suhe teže (DW), organske snovi (AFDW) in klorofila-*a* (Chl-a) na vzorčnih mestih v reki Rižani.
Table 2. Minimum (min), maximum (max) and average (ave) values of DW, AFDW and chl-a for the sampling sections in the Rižana River.

	DW	(g/m^2)		AFDW	(g/m^2)		Chl-*a*	(mg/m^2)	
	min	max	ave	min	max	ave	min	max	ave
R1	152	327	237	30	181	86	191	773	374
R2	44	220	139	13	78	44	65	329	200
R3	19	227	140	5	79	42	10	218	113
R4	125	210	172	5	34	19	96	181	146

Predpostavljamo lahko, da je razloge potrebno iskati v negibljivem sedimentu, v morfološki raznolikosti rečne struge in v prevladi zelenih alg. Najnižje vrednosti perifitonske biomase so bile izmerjene na vzorčnem mestu R3 kot posledica drobnega gibljivega substrata, ki onemogoča razvoj stabilnih perifitonskih združb. Podobni pogoji so bili 10. junija 1995 ugotovljeni na vzorčnem mestu R4 (suha teža = 780 g/m^2), kjer je bilo onesnaženje vode še večje. Zaradi vpliva drugih okoljskih dejavnikov velike rasti alg ni bilo mogoče pojasniti samo na podlagi pretoka vode, temveč tudi z visoko vrednostjo hranilnih snovi, vplivom svetlobe in večjimi sedimentnimi zrni (Smolar – Žvanut, 2001). Vrednosti perifitonske biomase so bile pozimi 1997 nižje kot poleti 1996; podobno je bilo tudi na drugih slovenskih vodotokih: na Tržiški Bistrici, Dravinji in Branici (Smolar *et al*, 1998), Savi Bohinjki (Kosi, 1988) in Soči (Smolar – Žvanut, 2001). Pozimi 1997 so bile izmerjene zelo nizke vrednosti organske snovi na vzorčnih mestih R3 in R4 (5 g/m^2), medtem ko je bila najnižja vrednost klorofila-*a* izmerjena na vzorčnem mestu R3 (10 mg/m^2). S 95-odstotno verjetnostjo lahko potrdimo, da so bile povprečne vrednosti klorofila-*a* pozimi 1997 statistično bistveno drugačne med vzorčnimi mesti R1 in R3 ter med R1 in R4 ($p < 0,05$). Povprečne vrednosti organske snovi so se poleti 1996 statistično bistveno razlikovale med vzorčnimi mesti R1 in R2 ter med R1 in R3 (95-odstotna verjetnost). Pri določanju ekološko sprejemljivega pretoka je potrebno poznavanje naravne dinamike pojavljanja biomase perifitona. V obdobju

We may assume that the reason for this phenomenon can be found in stable sediments, in the morphological diversity of the river bed and in the predominance of green algae mats. The lowest values of periphyton biomass were measured in the R3 section as the result of small moving substrata, which disable the development of a stable periphyton community. The same conditions were established in the R4 section, where water pollution was higher. The periphyton biomass was very high on river substrata in the R4 section measured on 10 June 1995 (i.e. DW = 780 g/m^2). Due to the impact of other environmental factors, it was not possible to explain the massive growth of algae only through the low level of water flow, but also through the high nutrient level, impact of light and large sediment grains (Smolar – Žvanut, 2001). The values of periphyton biomass were lower in winter 1997 than in summer 1996; the same was the case of the Slovenian streams Tržiška Bistrica, Dravinja and Branica (Smolar *et al*, 1998), Sava Bohinjka (Kosi, 1988) and Soča (Smolar – Žvanut, 2001). Very low values of AFDW (5 g/m^2) were measured in winter 1997 in the R3 and R4 sections, while the lowest value of chl-*a* was measured in the R3 section (10 mg/m^2). With 95 % of probability we can affirm that in winter 1997 the average values of chl-*a* were statistically significantly different between the R1 and R3, and between R1 and R4 sections ($p < 0.05$). The average values of AFDW in summer 1996 differed statistically significantly between the R1 and R2 sections and between the R1 and R3 sections (95 % of probability). The knowledge of the natural dynamics of periphyton biomass in determining the EAF should be known. In the period of low flow nizkih pretokov vode je namreč potrebno zagotavljati količino in kakovost vode, da ne pride do prevelikega preraščanja dna s perifitonskimi algami.

4.3 PERIFITONSKE ALGE IN VEČJI VODNI NEVRETENČARJI

V reki Rižani smo poleti 1996 določili 70 taksonov perifitonskih alg, pozimi 1997 pa 58 taksonov. Večina taksonov je pripadala skupini diatomej (*Bacillariophyta*), vrste iz skupin *Cyanophyta, Chlorophyta, Xanthophyta* in *Rhodophyta* pa so se pojavljale redkeje, podobno kot na primer v kraški reki Unici (Vrhovšek *et al*., 1996). Na vzorčnih mestih so bile prisotne alge, ki so splošno razširjene, medtem ko sta bili na vzorčnem mestu R1 poleti 1996 množično prisotni vrsti *Tribonema vulgare* in *Microspora amoena,* ki sta značilni predstavnici za čiste reke. Rod *Batrachospermum* je v slovenskih rekah manj pogost in smo ga našli le na vzorčnih mestih R1 in R2. Zaradi sprememb morfologije in pretoka v reki Rižani so bile na vzorčnih mestih R3 in R4 pogostejše epipelične in epizamne alge kot v območjih R1 in R2, kjer so prevladovale epilitske alge. Če bi v reki vzdrževali raven ekološko sprejemljivega pretoka, do tako velikih sprememb v perifitonski združbi ne bi prihajalo.

Večina od 61 skupin večjih vodnih nevretenčarjev je bila prisotna na vzorčnih mestih R1 in R2. V vsakem vzorcu smo določili več kot 30 taksonomskih skupin, na območju R3 in R4 pa je bilo število skupin na vzorec nižje (od 10 do 24), z izjemo zime 1997, ko je bilo na vzorčnem mestu R4 v vzorcu najdenih 35 taksonov večjih vodnih nevretenčarjev.

Prevladujoče taksonomske skupine večjih vodnih nevretenčarjev na vzorčnih mestih v obeh letnih časih so bile vrste *Gammarus fossarum*, rod *Baetis*, družina *Elmidae*. Rod *Baetis* je prevladoval na vseh vzorčnih mestih, z izjemo poletja 1996, ko ga na vzorčnem mestu R3 in R4 nismo našli.

Dolvodno je številčnost narasla le pri taksonomskih skupinah *Oligochaeta* iz družine *Lumbriculidae* in *Tubificidae*.

such quantity and quality of water should be assured in the river, so that there is no proliferation of periphytic algae on the riverbed.

4.3 PERIPHYTIC ALGAE AND MACROINVERTEBRATES

A total of 70 taxa of periphytic algae were recorded in summer 1996, and 58 taxa in winter 1997 in the Rižana River. The majority of them belonged to *Bacillariophyta*, whereas the species of *Cyanophyta, Chlorophyta, Xanthophyta* and *Rhodophyta* were less pronounced, e.g. in the karst river Unica (Vrhovšek *et al*., 1996). Periphytic algae found in sections discussed consisted of several frequently occurring species, while in the R1 section, *Tribonema vulgare* and *Microspora amoena* were dominant in summer 1996. Both species are representatives for unpolluted rivers. The genus of *Batrachospermum* is less frequent in the Slovenian rivers and it was found only in the R1 and R2 sections. Because of the morphological and discharge changes in the Rižana River in the R3 and R4 sampling sections, epipelic and epipsamic algae were more frequent compared to the R1 and R2 sections, where epilithic algae were dominant. Had the EAF in the river been maintained, such major changes in periphyton community could not occur.

The majority of 61 taxa of macroinvertebrates were present in the R1 and R2 sections. We found more than 30 taxa in each sample in the first two sampling sections, while on other two sites the number of taxa per sample was lower (from 10 to 24), with the exception of R4 featuring 35 taxa of macrozoobenthos in winter 1997.

The dominant taxa of macroinvertebrates in the sections in both seasons were species *Gammarus fossarum*, genus *Baetis* and family *Elmidae*. The genus *Baetis* was dominant in all sections, except in summer 1996 in the R3 and R4 sections when it was not found.

The only taxa whose abundance increased downstream were *Oligochaetes* from families *Lumbriculidae* and *Tubificidae*.

The average density of *Gammarus fossarum* increased downstream from 25.4 per

Povprečna gostota vrste *Gammarus fossarum* je poleti 1996 dolvodno narasla s 25,4 na vzorec na vzorčnem mestu R1 na 277 na vzorčnem mestu R3 in se rahlo znižala na vzorčnem mestu R4. Povprečna gostota taksonov *Ephemeroptera* se je pozimi 1997 zmanjšala dolvodno (z 99 na vzorčnem mestu R1 na 0 na vzorčnem mestu R3), gostota pa je bila najvišja na vzorčnem mestu R4 (rod *Baetis*). Gostota *Coleoptera* je bila najvišja na R2 pozimi 1997 in na R1 poleti 1996; v obeh primerih je bila najnižja gostota na vzorčnem mestu R3.

Zaradi zmanjšanja pretoka in nizke kakovosti vodnega okolja vzdolž reke smo poleti 1996 zabeležili velik primanjkljaj skupin večjih vodnih nevretenčarjev (preglednica 3). Tako je imelo poslabšanje kakovosti vodnega okolja velik vpliv na združbo večjih vodnih nevretenčarjev. V istem času vzorčevanja pa primanjkljaj v številu taksonov perifitonskih alg ni bil velik; na vzorčnih mestih R2 in R3 je bilo najdenih več vrst kot na referenčnem mestu R1 (preglednica 3). Podobni so bili rezultati raziskav na Tržiški Bistrici (Smolar, 1997), kjer v strugi, ki je bila pod vplivom odvzema vode ni bilo sprememb v številu vrst. Pozimi 1997 smo opazili večji primanjkljaj vrst perifitonskih alg na vzorčnih mestih R2 in R3. Kljub zelo nizkemu pretoku vode poleti 1996 na vzorčnem mestu R4 ni bilo primanjkljaja v številu taksonov perifitonskih alg, kar kaže na slabost uporabljenega indeksa, saj ta ne poda evidence o strukturnih spremembah, ki se ne odražajo v zmanjševanju števila taksonov perifitonskih alg.

Bray-Curtisov koeficient podobnosti (slika 3) je pokazal veliko podobnost med vzorci, ki so bili pozimi 1997 odvzeti na vzorčnih mestih R1, R2 in R4. Dokaj nizko število vrst in velika podobnost med poletnimi in zimskimi vzorci na vzorčnem mestu R3 je verjetno odraz gibljivega substrata manjše velikosti, ki ne omogoča naselitve večjega števila perifitonskih alg in večjih vodnih nevretenčarjev. Pozimi 1997 je bilo vzorčno mesto R4 bolj podobno vzorčnima mestoma R1 in R2 kot vzorčnemu mestu R4 poleti 1996.

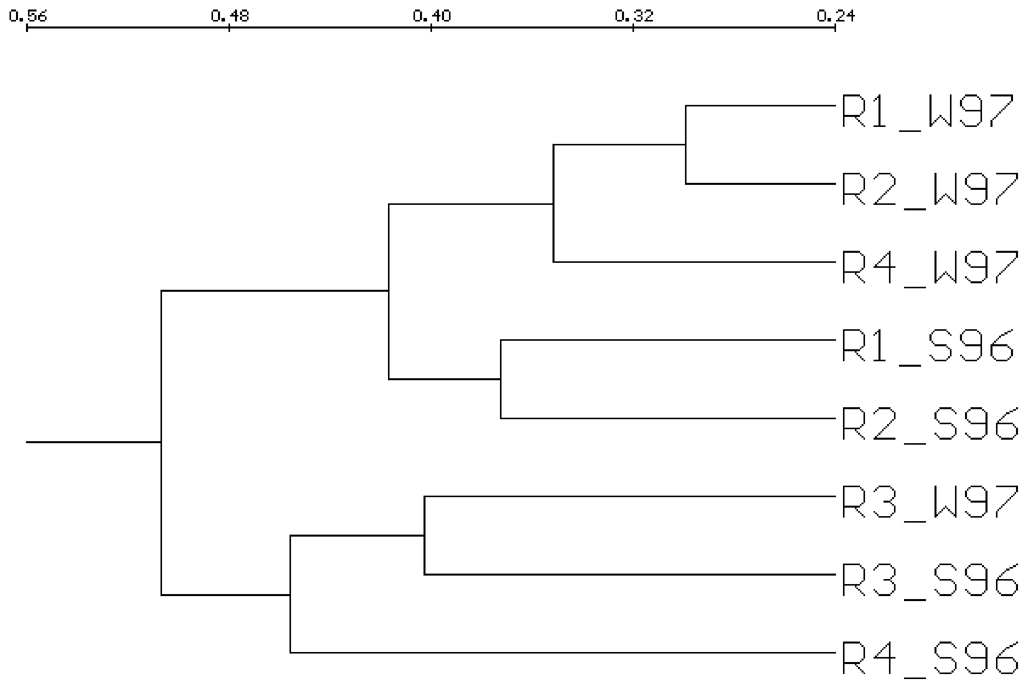
sample in the R1 section to 277 in the R3 section in summer 1996. In winter 1997, the difference decreased from 64 in the R1 sampling section to 111 in the R3 section, and was slightly reduced in the R4 section. The average density of *Ephemeroptera* decreased downstream in winter 1997 (from 99 in the R1 sampling section to 0 in the R3 section), while the density reached its maximum in the R4 section (genus *Baetis*). The density of *Coleoptera* was at its highest in the R2 section in winter 1997 and in the R1 section in summer 1996; the lowest density was in both cases in the R3 sampling section.

Due to the reduction in discharge and a low quality of aquatic environment along the river in summer 1996, a high deficit of macroinvertebrates taxa was recorded (Table 3). Consequently, a lower quality of aquatic environment had a large effect on the macroinvertebrate community. The deficit in the number of taxa of periphytic algae at the same sampling time was not high; in the R2 and R3 sampling sections more species were determined than in the R1 reference section (Table 3). Similar were the result of the investigations of the river Tržiška Bistrica (Smolar, 1997), where no changes in the number of species were observed in the river section, which was effected by water abstraction. In winter 1997, a higher species deficit of periphytic algae in the R2 and R3 sections was detected. In spite of a very low water flow in the R4 section in summer 1996, there was no deficit of periphytic algae, indicating the deficiency of the applied index, as the latter does not provide for the evidence on the structural changes, including the reduction of the number of taxa of periphytic algae.

The Bray-Curtis coefficient of similarity (Fig. 3) showed high similarity between the samples found in sections R1, R2 and R4 in winter 1997. A relatively small number of species and a high similarity between the summer and winter samples of the R3 section is probably the reflection of a small-sized moving substrata, which do not allow for the colonisation of a large number of periphytic algae and macroinvertebrates. In winter 1997, the R4 section was more similar to sections R1 and R2 than to the R4 section in summer 1996.

Preglednica 3. Kothéjev indeks za primerjavo vzorčnih mest R2, R3 in R4 z referenčnim vzorčnim mestom R1.
Table 3. Kothé index for comparison of the sampling sections R2, R3 and R4 with the reference sampling section R1.

Datum/ *Date*	Vzorčno mesto/ *Sampling section*	Število vrst perifitonskih alg / *Number of periphytic algae species*	Odstotek primanjkljaja vrste /*Percent of species deficit (%)*	Število skupin vodnih nevretenčarjev /*Number of macroinvertebrate taxa*	Odstotek primanjkljaja taksona /*Percent of taxa deficit (%)*
26. 8. 1996	R1	43		30	
	R2	57	–24.6	37	–23.3
	R3	37	14.0	10	66.7
	R4	45	–4.7	16	46.7
18. 2. 1997	R1	41		37	
	R2	31	24,4	36	2.7
	R3	31	24.4	24	35.1
	R4	38	7.3	35	5.4



Slika 3. Bray-Curtisov koeficient podobnosti za vzorce večjih vodnih nevretenčarjev in perifitonskih alg v reki Rižani poleti 1996 (S96) in pozimi 1997 (W97).
Figure 3. Bray-Curtis coefficient of similarity for samples of macroinvertebrates and periphytic algae in the Rižana River in summer 1996 (S96) and in winter 1997 (W97).

4.4 KAKOVOST VODE

Vrednosti saprobnega indeksa (SI) so vzdolž reke rahlo narasle, kljub temu pa je bila reka na vseh vzorčnih mestih uvrščena v I.–II. kakovostni razred. Podobni so bili rezultati raziskav na vzorčnem mestu R4 leta 1995 (Vrhovšek *et al*., 1995). Primerjava rezultatov rednega državnega programa monitoringa na vzorčnem mestu R2 in dolvodno od vzorčnega mesta R4 med letoma 1987 in 1993 (Peroša *et al*., 1993) je pokazala višje vrednosti saprobnega indeksa pod območjem R4, kar reko pod tem mestom uvršča v II.–III. kakovostni razred.

Poleti 1996 sta bili vzorčni mesti R3 in R4 na podlagi vrednosti EBI (slika 4) uvrščeni v IV. kakovostni razred, medtem ko bi območji R3 in R4 na podlagi vrednosti BMWP (slika 5) lahko uvrstili v V. razred. Tako indeks BMWP kot indeks EBI sta pozimi 1997 kazala nižjo kakovost vodnega okolja na vzorčnih mestih R3 in R4. Na podlagi tako dobljenih podatkov lahko sklepamo, da indeksa EBI in BMWP kažeta na poslabšanje kakovosti vodnega okolja, indeks SI pa kaže stopnjo onesnaženosti vode. Podobni so bili tudi rezultati analiz reke Dravinje (Krušnik & Černač, 1996).

5. ZAKLJUČKI

Z ozirom na odvzeme vode za potrebe oskrbe z vodo so rezultati hidroloških analiz pokazali, da je bil zaradi izjemno velikega odvzema vode vzdolž vodotoka in intergranularne poroznosti substrata v spodnjem delu reke Rižane pretok vode v poletnih mesecih zelo nizek. To se je odražalo v poslabšanju vodnega okolja. Upoštevajoč hidrološke, ekološke, krajinske, morfološke in ihtiološke značilnosti in na podlagi ocene habitatov smo predlagali vrednosti ekološko sprejemljivega pretoka za poletno sušno obdobje 0,160 m^3/s, kar bi – ob zmanjšanju onesnaženja – omogočilo ohranjanje ekološkega ravnovesja tako v reki kot v obrežnem prostoru.

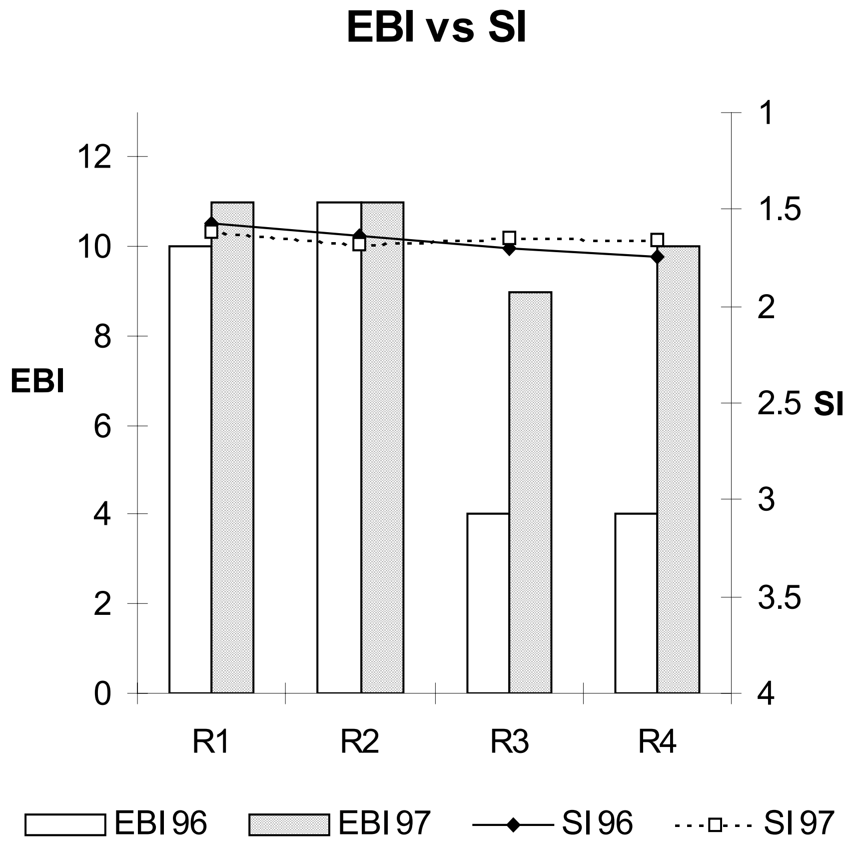
4.4 WATER QUALITY

The values of saprobic index (SI) slightly increased along the river, nevertheless it was classified in all sampling sections as quality class I–II. Similar were the results of the investigations in the R4 section in 1995 (Vrhovšek *et al*., 1995). The comparison of the results of the regular National Monitoring Programme in the R2 and below R4 section between 1987 and 1993 (Peroša *et al*., 1993) showed higher values of the saprobic index below R4 section, thus classifying the river below this section into the II–III quality class.

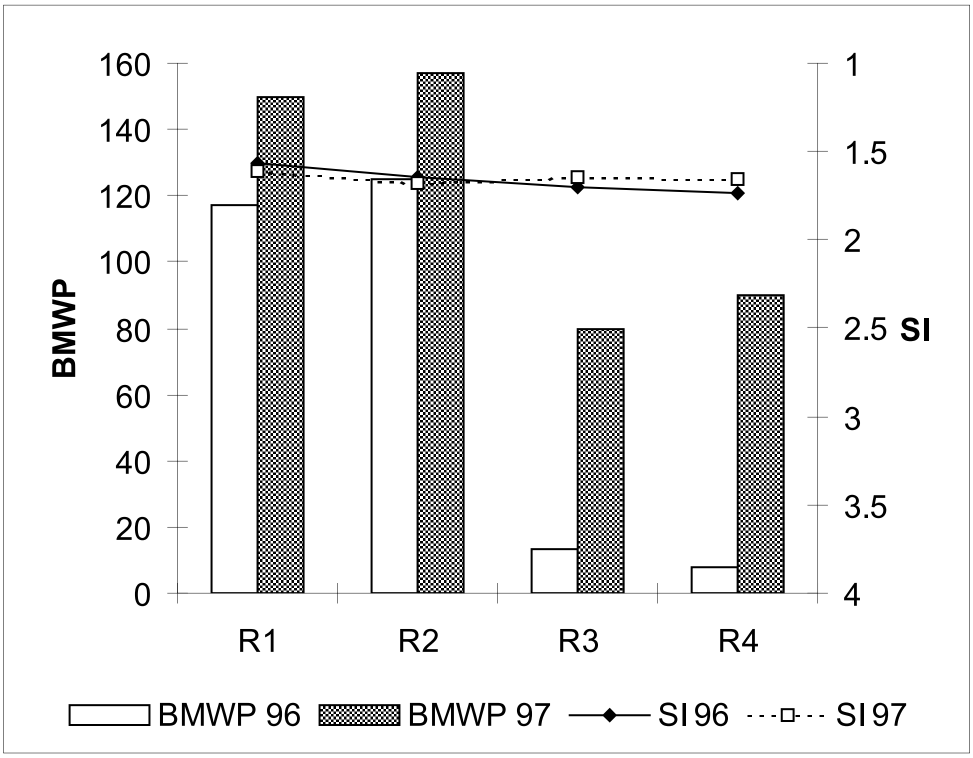
In summer 1996, the EBI values (Fig. 4) classified sampling sections R3 and R4 into quality class IV, whereas, based on the BMWP values (Fig. 5) the R3 and R4 sections could be classified as quality class V. Both the BMWP and EBI indices showed in winter 1997 a lower quality of the aquatic environment in the R3 and R4 sections. Based on the results thus obtained we may conclude, that the EBI and BMWP indices indicate the deterioration of the aquatic environment quality, while the SI shows the pollution degree of water. Similar results were obtained in analysing the Dravinja River (Krušnik & Černač, 1996).

5. CONCLUSIONS

With regard to the water abstraction for the water supply purposes, the results of the hydrological analyses showed that due to extremely high water abstractions along the watercourse and the intergranular porosity of substrata in the lower part of the Rižana River, the flows were very low during the summer period. This has been reflected in the deterioration of the aquatic environment. Taking into consideration the hydrological, ecological, landscape, morphological and ichthyological characteristics and habitat evaluation, we proposed the EAF values for the dry summer period amounting to 0.160 m^3/s, which, by reducing the pollution level, will enable the maintenance of the ecological balance both in the river and in the riparian zone.



Slika 4. Vrednosti EBI v primerjavi z vrednostmi SI za reko Rižano.
Figure 4. The values of EBI in comparison with the values of SI for the Rižana River.



Slika 5. Vrednosti BMWP v primerjavi z vrednostmi SI za reko Rižano.
Figure 5. The values of BMWP in comparison with the values of SI for the Rižana River.

Najpomembnejši ukrepi, ki jih predlagamo, so racionalna raba vode, iskanje novih virov pitne vode, čiščenje voda, nadzorovanje onesnaženja vode, ocena iztoka vode iz načrtovane akumulacije in zagotavljanje ekološko sprejemljivega pretoka.

The rational use of water, search for new sources of drinking-water, waste water treatment, control of water pollution, evaluation of outflow from the planned accumulation and preservation of the ecologically acceptable flow are the most important arrangements that we suggested.

ZAHVALA

Delo je finančno podprlo Ministrstvo za okolje, prostor in energijo. Zahvaljujemo se tudi Petru Mucku in Darku Burji, ki sta priskrbela hidrološke podatke, in Miljanu Šišku za opravljene statistične analize.

ACKNOWLEDGEMENTS

This work was funded by the Ministry of the Environment and Physical planning. We thank Peter Muck and Darko Burja who provided hydrological data and Miljan Šiško for statistical analyses.

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