© *Acta hydrotechnica* **23/39 (2005)**, Ljubljana
ISSN 1581-0267

UDK/*UDC*: 504.4:556.3:627.132
Izvirni znanstveni članek – *Original scientific paper*

Prejeto/*Received*: 17. 1. 2006
Sprejeto/*Accepted*: 20. 4. 2007

VPLIV ZAJEZITVE NA REKI BISTRICI NA VODNI EKOSISTEM
THE IMPACT OF THE DAM IN THE BISTRICA RIVER ON THE AQUATIC ECOSYSTEM

Nataša SMOLAR - ŽVANUT, Matjaž MIKOŠ, Barbara BREZNIK

Na reki Bistrici smo ugotavljali vpliv zajezitve in odvzema vode za malo hidroelektrarno Mojstrana na hidrološke, morfološke in biološke parametre vodnega ekosistema. Izmerili smo pretoke vode, hitrosti vodnega tok in določili osnovne hidrološke parametre. Analizo plavin smo opravili z linijskim načinom odvzema vzorca. Izdelali smo krivuljo zrnavosti podlage in krovnega sloja s pomočjo preračuna linijske – številčne analize krovnega sloja in togim oziroma prilagodljivim sestavljanjem s Fullerjevo zrnavostno krivuljo kot oceno zrnavosti podlage. Opravili smo popis mezohabitatov ter vzorčevali fitobentos. Rezultati so pokazali na hidrološke, biološke in morfološke spremembe v vodnem ekosistemu pod jezom. Pod jezom je prišlo do fragmentacije mezohabitatov, zmanjšanja v njihovi pestrosti, velikosti in hidroloških značilnostih. Izmerjeni so bili manjši pretoki vode in hitrosti vodnega toka, ugotovili smo veliko stopnjo dolvodne drobnitve plavin. Zaradi zajezitve in odvzema vode je prišlo do spremembe v vrstnem sestavu in pogostosti fitobentosa.
Ključne besede: *zajezitev, pretok vode, mezohabitati, plavine, fitobentos*

On the Bistrica River we tried to find out the effects of damming and abstracted water for the small hydropower plant Mojstrana, as reflected in the hydrological, morphological and biological parameters of the aquatic ecosystem. Water flow and flow velocity were measured and the basic hydrologic parameters were determined. Sediment analysis was carried out with Wolman sampling. A grading (particle-size) curve of the surface and subsurface layer were prepared based on combining of the Wolman samples of the surface layer and rigid or adaptable composition with the Fuller grading curve providing grain-size assessment of the subsurface. Further, we performed an inventory of mesohabitats and phytobenthos sampling. The results have indicated hydrological, biological and morphological changes in the water ecosystem below the dam. There also occurred fragmentation of mesohabitats, and reduction in diversity, size and hydrological characteristics. Lower discharge and flow velocities were measured and a high level of downstream fining was identified. Due to the damming and water abstraction there occurred changes in species composition and abundance of phytobenthos.
Key words: *damming, water flow, mesohabitats, river sediments, phytobenthos*

1. UVOD

Spreminjanje pretokov vode pod rečnimi jezovi je eden izmed stresnih dejavnikov, ki vplivajo na vodni in obvodni ekosistem. Ti vplivi so pogosto v povezavi s fragmentacijo vodnih habitatov (Maddock s sod., 2005), toksičnimi snovmi, ki so prisotne v sedimentih in v vodi, invazijo tujerodnih vrst ter onesnaženjem (Biggs & Close, 1989), zato je treba pri vplivih zajezitev in odvzemih vode obravnavati vse dejavnike med seboj

1. INTRODUCTION

Alteration of water flow below dams is one of the most stressful factors influencing the aquatic and riverside ecosystem. These effects are often related to fragmentation of water habitats (Maddock et al., 2005), toxic matter in sediments and water, invasive alien species and pollution (Biggs & Close, 1989). When trying to analyse the effects of damming and abstractions one needs to deal with all the factors in a connected manner.

The effects of damming on hydrological

povezano.

Vplivi zajezitev na hidrološke parametre se odražajo v spremenjeni dinamiki pretokov vode pod pregradami, trajanju in pogostosti pretokov vode ter v zmanjšanju hitrosti in časovni enakomernosti vodnega toka. Plavine, ki jih voda ne premešča, se odlagajo iz vodnega toka kot naplavine ali usedline (Mikoš, 1989). Antropogeni vplivi, kot so regulacije strug, lahko povzročijo zmanjšanje odlaganja, zastajanje in spiranje drobnih sedimentov. V času nizkih pretokov se v vodotokih kopičijo drobni sedimenti (Milhous, 1998) in povečano je odlaganje organskih delcev, predvsem v tolmunih in na odsekih, kjer voda zastaja (Everard, 1996).

Velikost in struktura vodnih habitatov vplivata na združbo vodnih organizmov (Aadland, 1993, Maddock 1999, Gehrke & Harris 2000, Maddock *et al*., 2004). V svetu so raziskovalci razvili številne metodologije, s katerimi ocenjujejo učinke povečane izrabe vodnih virov na vodne habitate (Maddock & Bird, 1996). V zadnjem času se za določitev ocene učinkov izrabe vodnih virov na vodotoke uveljavlja metoda kartiranja mezohabitatov, ki temelji na določitvi mezohabitatov na izbranem odseku vodotoka (Maddock in Bird, 1996). Prednost metode kartiranja mezohabitatov pred drugimi metodami je hitra ocena dolgih odsekov vodotoka, ki temelji na vizualni oceni habitata ter fizikalnih meritvah, ki določajo mezohabitat (globina, hitrost) (Maddock *et al*., 2001). Fizikalne meritve so bistvene za dokaj natančno oceno vplivov na mezohabitat in nam služijo kot objektivni kriterij, ki dopolnjuje subjektivno vizualno oceno mezohabitata (Maddock & Bird, 1996).

Z odvzemom vode pride v večini primerov do sprememb v fizikalno-kemijskih parametrih vode, do zmanjšanja biodiverzitete vodne in obvodne flore, spremenjene lokalne razmere pa lahko omogočajo povečevanje biomase posameznih vrst, ki lahko povzročijo okoljske probleme (Biggs, 1996).

V Novi Zelandiji so bile izdelane številne študije pojavljanja fitobentosa glede na substrat in hitrosti vodnega toka (Biggs *et al*., 1998; Biggs *et al*., 2001). Vpliv zmanjšanih pretokov vode na fitobentos pa so proučevali v

parameters are to be found in a changed dynamics of flow below dams, duration and frequency of water flow and reduction of velocity and temporal uniformity of water flow. The sediments that are not transported are deposited as alluvial deposits or sediments (Mikoš, 1989). Anthropogenic effects, such as water channel regulations, may cause reduction in deposition, impoundments and denudation/removal of fine sediment. During low flow fine sediment accumulates in the watercourses (Milhous, 1998) and deposition of organic matter is increased, particularly in river pools and in reaches where the water is impounded (Everard, 1996).

The size and structure of aquatic habitats influences the community of aquatic organisms (Aadland, 1993, Maddock 1999, Gehrke & Harris 2000, Maddock *et al.*, 2004). Worldwide several methodologies have been developed, which assess the effects of increased exploitation of water sources to aquatic habitats (Maddock & Bird, 1996). Recently, a new method of mapping mezohabitats has been introduced for assessment of effects of the use of water sources on rivers, which is based on the identification and analysis of mesohabitats in the chosen reach of a watercourse (Maddock & Bird, 1996). The advantage of the mesohabitat mapping method lies in the quick assessment of long reaches of the river, which is based on the visual assessment of the habitat and physical measurements for determination of the mesohabitat (depth, velocity) (Maddock *et al.*, 2001). Physical measurements are essential to the fairly accurate assessment of effects on the mesohabitat and serve as an objective criterion, which complements the subjective visual assessment of the mesohabitat (Maddock & Bird, 1996).

The abstraction of water in most cases results in changes of physico-chemical parameters of water, reduction of biodiversity of aquatic and riparian flora; the changed local conditions enable the increase in biomass of particular species, which may cause environmental problems (Biggs, 1996).

In New Zealand many studies of occurrence of phytobenthos in relation to the substrate and water flow velocity have been performed (Biggs *et al.*, 1998; Biggs *et al.*, 2001). The effects of reduced water flow to phytobenthos

Avstriji (Rott & Pfister, 1988), Švici (Bundi & Eichenberger, 1989) in na Češkem (Opravilova & Komarek, 1995; Koudelkova, 1999). V Sloveniji smo vpliv odvzema vode iz vodotokov ocenjevali v alpskih (Smolar - Žvanut *et al.,* 1998b; Smolar - Žvanut, 2001), nižinskih (Smolar - Žvanut *et al.,* 1998a) in kraških (Smolar - Žvanut *et al.,* 2004a; 2004b) vodotokih.

Namen našega dela je bil ugotoviti vpliv zajezitve in odvzema vode za malo hidroelektrarno (MHE) Mojstrana na hidrološke, morfološke in biološke komponente vodnega ekosistema.

2. MESTO RAZISKAV

Bistrica je vodotok, ki priteka iz osrčja Julijskih Alp in se izliva v Savo Dolinko v Mojstrani. Izvir je neposredno pod Severno triglavsko steno. Voda se izceja iz obsežnih melišč v vznožju stene. Na poti do Save Dolinke se pretok Bistrice povečuje iz stranskih pritokov. Vpliv topljenja snega sega v pozno poletje. V osojnih krnicah in grapah se sneg zadržuje tudi celo leto. Povodje Bistrice je v spodnjem delu v celoti poraslo z gozdom.

Dolina Vrata je ledeniškega izvora. Ledeniki so pustili za seboj v vznožju doline dobro sprijete bočne morene, ki vplivajo skupaj z drugimi hidrološkimi parametri na počasnejši odtok s pobočij doline. Masiv Julijskih Alp ima v tem delu enotno geološko sestavo, kjer do višine 1400 m prevladujejo dolomiti, nad to višino pa so pretežno skladoviti apnenci. Povodje Bistrice je sestavni del Triglavskega narodnega parka.

Odjemni objekt vode za MHE Mojstrana je na reki Bistrici nad krajem Mojstrana. Dolžina struge Bistrica, na kateri je odvzem vode za MHE Mojstrana, je 1220 m. V širšem območju TNP se nahaja 820 m tega odseka od odvzema navzdol. Odvzem vode iz Bistrice za energetske namene je na tem odseku prisoten že desetletja. Pred drugo svetovno vojno je bila v Mojstrani cementarna, ki je imela odvzem za industrijsko vodo iz istega profila, kot ga ima MHE Mojstrana. MHE Mojstrana obratuje v obstoječem stanju od leta 1989.

have been studied in Austria (Rott & Pfister, 1988), Switzerland (Bundi & Eichenberger, 1989) and in the Czech Republic (Opravilova & Komarek, 1995; Koudelkova, 1999). In Slovenia the impact assessment of water abstraction from surface waters has been made in alpine (Smolar - Žvanut *et al.,* 1998b; Smolar - Žvanut, 2001), lowland (Smolar - Žvanut *et al.,* 1998a) and karst (Smolar - Žvanut *et al.,* 2004a; 2004b) rivers.

The purpose of the study was to find out the effect of damming and water abstraction for small hydropower plant (SHPP) Mojstrana on the hydrological, morphological and biological components of aquatic ecosystem.

2. STUDY SITE

The Bistrica River emerges from the heart of the Julian Alps, and flows into the Sava Dolinka river in Mojstrana. It originates directly under the northern wall of the Triglav Mountain. The water percolates from extensive scree at the foot of the wall. On its way to the Sava Dolinka, the Bistrica discharge is increased from lateral tributaries. The impacts of snow melt are still evident in late summer. In shady cirques and mountain gorges the snow lingers all year long. The catchment area of the Bistrica is overgrown with forest in its lower part.

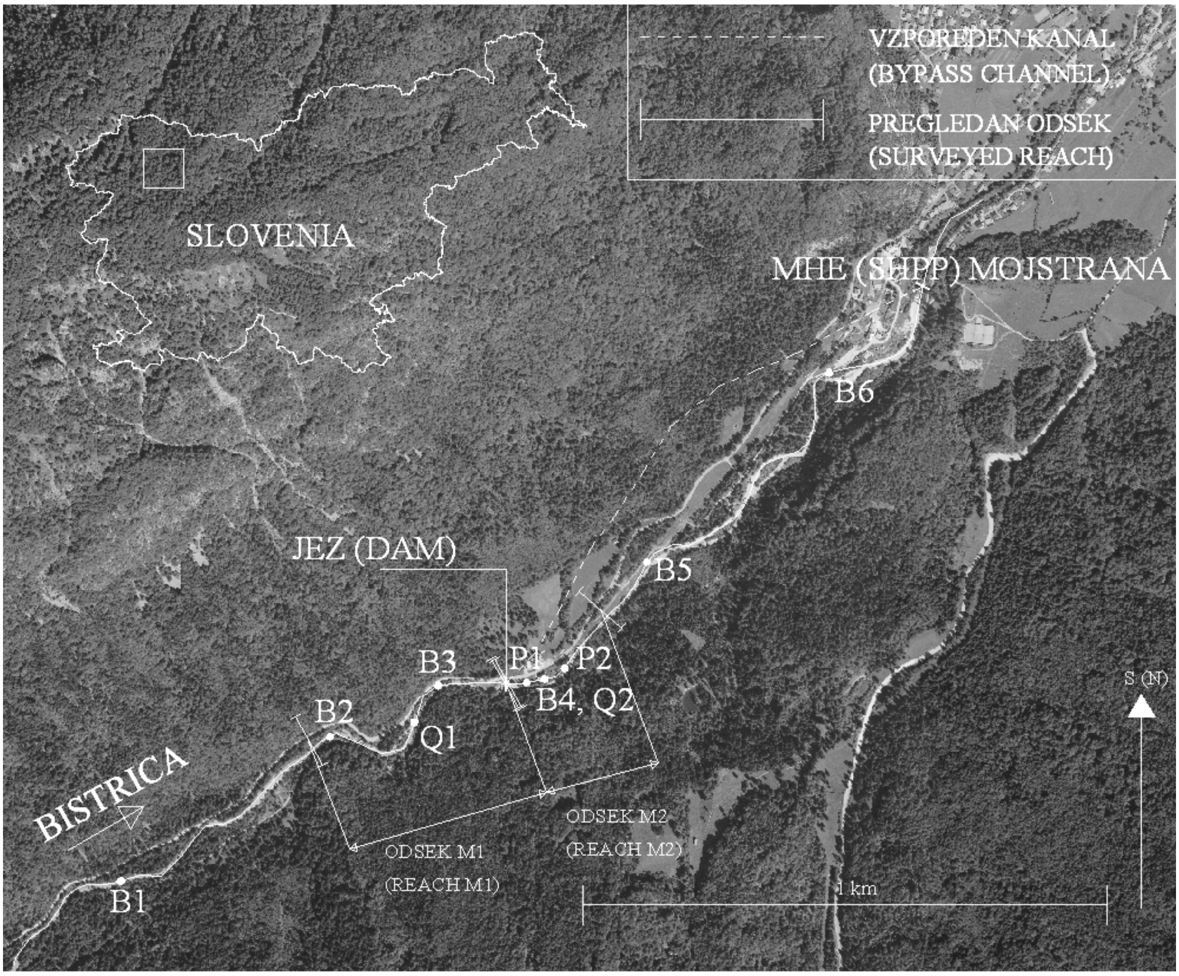
The Vrata Valley is of glacier origin. At the foot of the valley, the glaciers have left behind well consolidated lateral moraines that cause, together with other hydrological parameters, a slower run-off from the valley slopes. In this section, the Julian Alps massif has a uniform geological composition, with the prevalence of dolomites up to the height of 1400 m, and limestone strata above the height of 1400 m. The Bistrica River catchment is part of the Triglav National Park.

The abstraction facility for the small SHPP Mojstrana is located on the Bistrica river above the town of Mojstrana. The length of the Bistrica channel, where the abstraction for the Mojstrana SHPP is located, is 1220 m, out of which 820 m sits in the wider area of the Triglav National Park, that is, from the abstraction site downwards. Abstraction from the Bistrica river for energy production has been conducted for several decades. Before World War II there was a cement factory in Mojstrana, which abstracted water for industrial purposes at the same cross-section as does the Mojstrana SHPP nowadays. The

Na reki Bistrici smo izbrali odvzemna mesta nad in pod zajezitvijo za MHE Mojstrana. Odvzemna mesta za meritve pretoka vode, plavine in fitobentosa ter odseke, kjer smo kartirali mezohabitate, smo označili na sliki 1.

Mojstrana SHPP, as it is today, has been in operation since 1989.

On the Bistrica river the sampling sites were chosen above and below the damming made for the Mojstrana SHPP. The abstraction sites for measurements of water flow, sediments and phytobenthos, as well as the sections, where the mesohabitats were mapped, are indicated in Figure 1.



Slika 1. Reka Bistrica z odvzemnimi mesti (B1–B6 = odvzemna mesta za fitobentos, P1 in P2 = odvzemni mesti za plavine, Q1 in Q2 = mesti za meritev pretokov vode, odsek M1 in odsek M2 = odseka za popis mezohabitatov).

Figure 1. The Bistrica River with sampling sites (B1–B6 = sampling sites for phytobenthos, P1 and P2 = sampling sites for sediments, Q1 and Q2 = sites for measurements of water flow, reach M1 and reach M2 = reach for inventory of mesohabitats).

Vse terenske meritve so bile opravljene 21. 3. 2005. Pretok vode smo merili nad in pod zajezitvijo za MHE Mojstrana na odvzemnih mestih Q1 in Q2. Mezohabitate smo popisali na 687 m dolgem odseku reke Bistrice, od tega 441 m nad jezom (Odsek M1) in 246 m pod jezom (Odsek M2). Popisani odsek pod jezom

All field investigations were performed on March 21, 2005. Water flow was recorded above and below the damming at sampling sites Q1 and Q2. An inventory of mesohabitats was made on the 687-m reach of the Bistrica river, out of which 441 m were above the dam (reach M1) and 246 m below it (reach M2).

je bil krajši, zaradi ponavljanja le 2 tipov mezohabitatov na celotni dolžini, ki je bila pod vplivom odvzema vode za MHE.

Plavine v strugi Bistrice smo vzorčevali na dveh mestih pod zajezitvijo:

- odvzemno mesto P1 je bilo na nespranem prodišču na levem bregu Bistrice neposredno pod jezom MHE Mojstrana;
- odvzemno mesto P2 je bilo na neomočenem dnu na desnem bregu Bistrice 100 m pod jezom za MHE Mojstrana.

Vzorčevanje fitobentosa je potekalo na 6 vzorčnih mestih, in sicer na treh mestih nad pregrado (B1–B3) in na treh mestih pod pregrado (B4–B6).

The surveyed reach below the dam was shorter, since there were only 2 mesohabitats indentified in the section, which appeared to be affected by the water abstraction for the SHPP.

The sediments in the Bistrica channel were sampled in two sites under the damming:

- Sampling site P1 was located in a washed off gravel pit on the left bank of the Bistrica located directly under the Mojstrana;
- Sampling site P2 was on the dry bottom on the right bank of the Bistrica, 100 m below the dam for SHPP Mojstrana.

The phytobenthos sampling was performed in 6 sampling sites, that is, at three sites above (B1–B3) and at three sites below the dam (B4–B6), respectively.

2.1 HIDROLOŠKE ZNAČILNOSTI REKE BISTRICE

Na Bistrici je v naselju Mojstrana delovala vodomerna postaja Mojstrana do leta 1990. Pri hidroloških obdelavah so bili upoštevani podatki o pretokih za obdobje od leta 1959 do leta 1989, nakar je bila postaja ukinjena. Površina vodozbirnega področja Bistrice do vodomerne postaje Mojstrana je 47 km^2.

2.1 HYDROLOGIC PROPERTIES OF THE BISTRICA RIVER

Until 1990, there was a water gauging station on the Bistrica River in the village of Mojstrana. In the processing of hydrological data, the data on water flow for the period from 1959 to 1989 were considered; then the gauging station was shut down. The surface area of the catchment area of the Bistrica to the gauging station of Mojstrana is 47 km^2.

Preglednica 1. Hidrološki podatki za reko Bistrico na jezu za MHE Mojstrana.
Table 1. Hydrological data for the Bistrica River at the dam for the Mojstrana HPP.

Parameter / *Parameter*	Vrednost / *Value*
površina vodozbirnega območja (F) / *Catchment area*	43 km^2
srednji pretok v obdobju (sQs) / *Mean flow in the period*	2.90 m^3/s
srednji mali pretok v obdobju (sQn) / *Mean low flow in the period*	1.20 m^3/s
najmanjši mali pretok v obdobju (nQn) / *Lowest low flow in the period*	0.65 m^3/s
Q300dni / *Q300days*	1.35 m^3/s
Q347dni / *Q347days*	0.85 m^3/s

Na osnovi podatkov o pretokih Bistrice v prerezu v. p. Mojstrana, razmerja površin vodozbirnih območij in vrednosti pretokov, dobljenih pri simultanih meritvah, so privzeti sledeči hidrološki parametri za prerez Bistrice – jez za MHE Mojstrana, podani v preglednici 1. Najnižji pretoki reke Bistrice se pojavljajo v zimskem obdobju od decembra do aprila.

Based on the data on the Bistrica flow in the cross-section of the Mojstrana gauging station, the relationship of surface areas of catchment areas and flow values obtained in simultaneous measurements, the following hydrological parameters for the Bistrica at the dam Mojstrana were adopted, given in Table 1. The flow of the Bistrica River is lowest during winter, that is, from December to April.

3. METODE DELA

3.1 HIDROLOŠKE MERITVE IN ANALIZA MEZOHABITATOV

Pretok vode smo merili z merilnikom Flo-tracer.

Mezohabitat je definiran kot področja relativno homogene globine in pretoka vode, ki jih povezujejo izraziti gradienti, tako v globini kot v pretoku vode (Hawkins et al., 1993). Ocenjevanje mezohabitatov na terenu je zajemalo kombinacijo vizualnih in fizičnih meritev. Mezohabitate smo identificirali z uporabo spremenjene različice klasifikacijskega sistema po Hawkinsu et al. (1993). Metoda identifikacije mezohabitatov vključuje vizualno oceno z določitvijo tipov mezohabitatov s hojo ob strugi. Tipi mezohabitatov so naslednji: kaskada, drča, visokovodna brzica, nizkovodna brzica, rahlo valovanje, gladki tok, tolmun, zastal tolmun, ostalo (Hawkins et al. 1993).

Na reprezentativnih točkah znotraj vsakega mezohabitata sta bili izmerjeni širina struge in širina omočenosti struge z uporabo merilnika Bushnell Yardage Pro. Izmerjeni podatki za širino in dolžino so bili uporabljeni v izračunavanju skupne površine vode za vsak analiziran odsek reke posebej ter za posamezne vrste mezohabitata na vsakem odseku. Za potrebe opisnih opredelitev je bila določena in opredeljena ocena velikosti plavin (ki temelji na klasifikaciji po Wentworthu) kot 'prevladujoča', 'manj prevladujoča' in 'prisotna'. Povprečna globina vode za vsak mezohabitat je bila izmerjena z metrom na centimeter natančno, povprečna hitrost vodnega toka pa je bila izmerjena z merilnikom Flo-tracer v m/s. Cilj slednje meritve je bil, da se potrdi hidravlične karakteristike v in med mezohabitati. Vsak mezohabitat smo fotografirali in ga opremili s številko.

3.2 ANALIZA PLAVIN

Analizo plavin smo opravili z linijskim načinom odvzema vzorca in preračunom s programom ZPP, napisanem v programskem okolju EXCEL (Mikoš, 1999). Izdelali smo

3. WORK METHODS

3.1 HYDROLOGICAL MEASUREMENTS AND ANALYSIS OF MESOHABITATS

Water flow was measured with the Flo-tracer flowmeter.

Mesohabitats are defined as areas of relatively homogeneous depth and water flow, which are connected with characteristic gradients in terms of depth and water flow (Hawkins *et al.* 1993). Assessment of mesohabitats in the field included a combination of visual and physical measurements. The mesohabitats were identified by using a modified version of the classification system adopted after Hawkins *et al.* (1993). The identification method of mesohabitats includes the visual assessment involving the classification of mesohabitats by walking along the channel. The types of mesohabitats are the following: cascade, chute, rapid, riffle, run, glide, pool, ponded, and other (Hawkins *et al.* 1993).

In the representative sites within each of the mesohabitats the channel width and the wet channel width by using the Bushnell Yardage Pro device were measured. The data on width and length were used for calculation of the total water surface area for each analysed reach of the river separately, and for each type of mesohabitats in each reach. Sediment grading (based on the classification proposed by Wentworth) was performed and for the purpose of a descriptive definition the assessment was classified as 'prevalent', 'less prevalent' or 'present'. The average water depth for each mesohabitat was measured at centimetre accuracy, and average water flow was recorded with Flo-tracer in m/s. The objective of the latter measurement was to validate the hydraulic characteristics in and between mesohabitats. Each mesohabitat was photographed and numbered.

3.2 SEDIMENT ANALYSIS

Sediment analysis was performed by Wolman transect sampling and by using the ZPP program in Excel (Mikoš, 1999). A sediment grading curve of the sublayer and the krivuljo zrnavosti podlage in krovnega sloja s pomočjo preračuna linijske – številčne analize krovnega sloja in s togim sestavljanjem s Fullerjevo zrnavostno krivuljo kot nadomestkom za zrnavost podlage. Iz vsotne zrnavostne krivulje je mogoče odčitati značilna zrna, kot so d_{90}, d_{84} in d_{16}. Končni rezultat računa v obliki preglednice je bila določitev aritmetičnega srednjega zrna prodnatih plavin d_m in 90-odstotnega zrna rinjenih plavin d_{90}.

3.3 FITOBENTOS

Vzorce fitobentosa za kvalitativno analizo smo pobirali tako, da smo postrgali površino prodnikov, kamnov, skal, peska, makrofitov in potopljenega lesa na izbranem območju odvzema. Vzorce fitobentosa smo že na terenu fiksirali s 5 % formalinom. V laboratoriju smo fitobentos pregledali pod svetlobnim mikroskopom, s fazno kontrastno optiko pri povečavah do 1000-krat. Pri pregledu vzorcev smo ocenili pogostost posameznih taksonov (vrst) fitobentosa (z oznako: 1 – posamezno, 3 – srednje pogosto, 5 – pogosto) in pripisali saprobno vrednost.

Primerjavo združb fitobentosa med odvzemnimi mesti smo izvršili s pomočjo podatkov vrstnega sestava in relativne pogostosti prisotnih vrst. Podobnost oziroma različnost združb perifitonskih alg smo vrednotili z multivariantno klastersko analizo (Bray-Curtisov koeficient podobnosti) (Clarke in Warwick, 1990), s pomočjo podatkovnega sistema "DABA".

4. REZULTATI IN RAZPRAVA

4.1 MEZOHABITATI

V mesecu marcu 2005 smo nad jezom izmerili pretok vode 776 l/s, pod jezom pa smo izmerili pretok 15 l/s, torej se pod pregrado pretakalo le 2 % celotnega pretoka vode v vodotoku. Zaradi zmanjšanih pretokov vode pod jezom je prišlo v primerjavi z odsekom nad zajezitvijo do bistvenih sprememb v tipih, velikosti, pestrosti in razporeditvi mezohabitatov.

armour layer were made by way of calculating of Wolman transect samples into volume samples and then by rigid composition with the Fuller grading curve as a substitute for sublayer. From the total grading curve it is possible to identify the characteristic grains, such as d_{90}, d_{84} and d_{16}. The end result of the calculation in the form of a table was the determination of the arithmetic mean grain of sediment d_m and 90-percent grain of bed load sediment d_{90}.

3.3 PHYTOBENTHOS

The samples of phytobenthos for qualitative analysis were taken by scraping off the surface of gravel, pebbles, rocks, sand, macrophytes and sunken wood in the chosen sampling site. The phytobenthos samples were fixed *in situ* with 5% formalin. In the laboratory, the phytobenthos was investigated under the light microscope, with phase contrast optics and at magnification of up to 1000x. During the investigation of samples, the frequency of taxa (species) of phytobenthos (marked as 1 – rare, 3 – frequent, 5 – dominant) was assessed and the saprobic values were recorded.

The comparison between phytobenthos assemblages between the sampling sites was performed based on the data on species composition and relative frequency of the species present. The similarity or variety of periphytic algae was assessed with the multi-variant cluster analysis (Bray-Curtis coefficient of similarity) (Clarke & Warwick, 1990), supported by the "DABA" data system.

4. RESULTS AND DISCUSSION

4.1 MESOHABITATS

In March 2005, the water flow measured above the dam was 776 l/s, and below the dam 15 l/s, which was only 2 % of the total water flow. Due to the reduced water flow below the dam, as compared to the section above the dam, considerable changes in terms of type, size, diversity and distribution of mesohabitats occurred.

The adverse effects of the excessive abstraction of water for the HPP was reflected

Negativni vpliv prevelikega odvzema vode za potrebe MHE se je pokazal v številu popisanih tipov mezohabitatov: nad pregrado smo popisali 5 tipov mezohabitatov in pod pregrado le dva. Nad pregrado sta izmed petih tipov mezohabitatov prevladovala visokovodna brzica (34 %) in nizkovodna brzica (31 %), nato si sledijo zastal tolmun (19 %), gladki tok (9 %) in rahlo valovanje (7 %).

V reki Bistrici, pod jezom, pa kar 71 % popisanega odseka reke Bistrice zavzema mezohabitat rahlo valovanje, ostalih 29 % pa tolmun (preglednica 2).

Tudi Maddock et al. (2005) je v raziskavi na reki Soči ugotovil manjše število tipov mezohabitatov pri nižjem pretoku vode. Poleg tega so se prav tako kot v naši raziskavi pojavljali mezohabitati, kjer prevladujejo neturbulentne vode (tolmuni, gladki tok).

in the number of the recorded types of mesohabitats: there were 5 types of mesohabitats identified above the dam and only 2 mesohabitats below the dam. Among the existing five mesohabitat types above the dam, rapid (34 %) and riffle (31 %) prevailed, followed by ponded water (19 %), glide (9 %) and run (7 %).

In the Bistrica River, below the dam, as much as 71 % of the river reach was identified as glides, and the rest 29 % as pools (Table 2).

Similarly, in the study conducted on the Soča River, Maddock *et al.* (2005) identified a smaller number of mesohabitat types in low flow. Also, there was a prevalence of mesohabitats with non-turbulent water (pools, glides).

Preglednica 2. Delež površine posameznega mezohabitata glede na celotno površino vseh mezohabitatov na odseku nad in pod pregrado.
Table 2. Proportion of the surface area of mesohabitats against the total surface area of all mesohabitats in the reach above and below the dam.

Odsek *Reach*	Delež površine posameznega habitata (%) *Proportion of the surface area of mesohabitats (%)*
Odsek M1/*Reach M1*	
Visokovodna brzica/*Rapid*	34
Nizkovodna brzica/*Riffle*	31
Zastal tolmun/*Ponded*	19
Gladki tok/*Glide*	9
Rahlo valovanje/*Run*	7
Odsek M2/*Reach M2*	
Rahlo valovanje/*Run*	71
Tolmun/*Pool*	29

Preglednica 3. Število in fragmentiranost mezohabitatov vzdolž odseka.
Table 3. Number and fragmentation of mesohabitats along the reach.

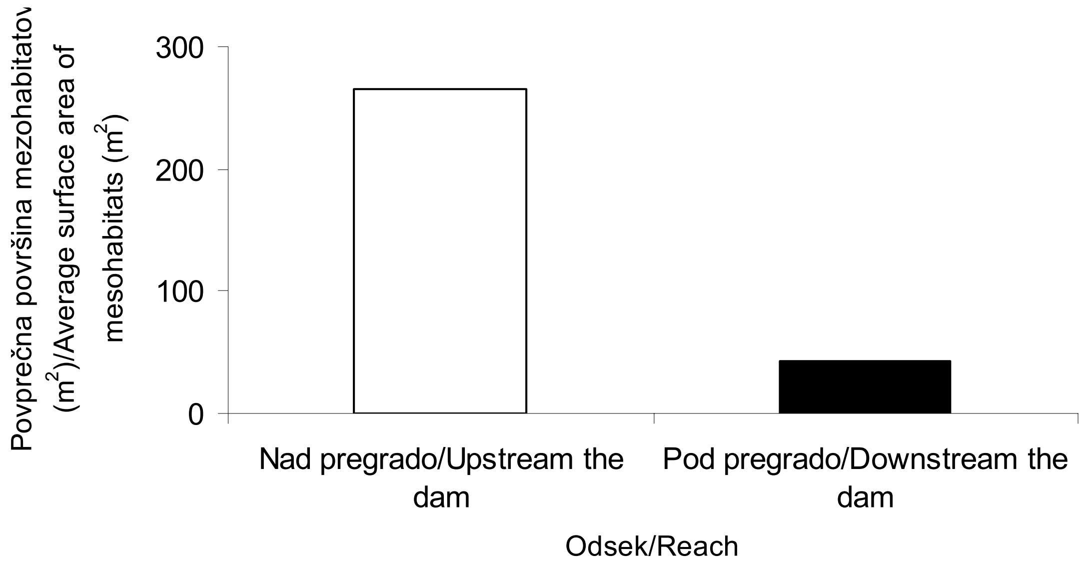
Odsek *Reach*	Dolžina odseka (km) *Length of reach (km)*	Skupno število mezohabitatov v odseku *Total number of mesohabitats in the reach*	Število mezohabitatov/km *Number of mesohabitats/km*
M1	0.441	15	34
M2	0.246	20	81

Vplivi odvzema vode so pogosto povezani ne le s številom habitatov, temveč tudi s fragmentacijo habitatov. Rezultat nižjega pretoka vode pod jezom je večje število mezohabitatov na kilometer v primerjavi z odsekom nad jezom (preglednica 3). Primerjava fragmentacije mezohabitatov na območju pod jezom nakazuje večjo diverziteto mezohabitatov in posledično večjo biodiverziteto. Kakorkoli, rezultati popisa mezohabitatov so pokazali, da sta pod jezom zastopana le dva tipa mezohabitatov.

Tudi povprečna površina mezohabitatov je manjša pod jezom v primerjavi s povprečno površino mezohabitatov nad jezom (slika 2). Kljub večji fragmentaciji na odseku pod jezom menimo, da je celotni učinek jezu in povzročenega manjšega pretoka dolvodno negativen. Maddock *et al.* (2005) sta prav tako poročala o večji fragmentaciji mezohabitatov v reguliranem odseku reke Soče, toda celotni učinek zajezitve na vodni ekosistem je bil negativen.

Also, the effects of water abstraction are often related to the fragmentation of habitats. The low flow below the dam results is a large number of mesohabitats per kilometre as compared to the reach above the dam (Table 3). The comparison of fragmentation of mesohabitats in the area below the dam indicates a greater diversity of mesohabitats and thus larger biodiversity. Whatever the case may be, the results of the inventory of mesohabitats have shown that below the dam there were only two types of mesohabitats.

Additionally, the average surface area of mesohabitats is smaller than the one above the dam (Figure 2). Despite the bigger fragmentation in the section below the dam, we feel that the overall effect of the dam and the low flow downstream is a negative one. Maddock *et al.* (2005) also reported of larger fragmentation of mesohabitats in the regulated reach of the Soča River, however, the overall effect of the damming to the water system was a negative one.



Slika 2. Povprečna površina mezohabitatov nad in pod pregrado.
Figure 2. Average surface area of mesohabitats upstream and downstream the dam.

Velikost in količina sedimenta, ki se transportira v vodotoku, je odvisna tudi od hitrosti vodnega toka oziroma pretoka (Petts *et al.*, 1993). V raziskavi smo ugotovili, da imajo mezohabitati s podobno hitrostjo toka enak prevladujoč substrat. Tako v visokovodni brzici in v rahlem valovanju, kjer je povprečna hitrost 0,81 m/s oziroma 0,7 m/s, prevladuje

Size and volume of sediment transported in the river also depends on the current/flow velocity and discharge, respectively (Petts *et al.*, 1993). Within the study it was established that the mesohabitats of similar flow velocity have the same prevalent substratum. Accordingly, in the rapid as well as in runs, substrat groblja. V mezohabitatih nizkovodna brzica in gladki tok, ki sta imela hitrost 0,37 m/s oziroma 0,4 m/s, je bil prevladujoč substrat grušč. Pri nizkovodni brzici je bil prisoten substrat tudi groblja. Do podobnih ugotovitev smo prišli tudi v mezohabitatih pod zajezitvijo (preglednica 4).

Povprečne globine vodotoka so bile v mezohabitatih nad pregrado večje v primerjavi z globinami v mezohabitatih pod pregrado (preglednica 4). Povprečne globine v mezohabitatih nad pregrado so bile 0,37 m v visokovodni brzici, 0,33 m v rahlem valovanju, 0,7 m v gladkem toku in 0,37 m v nizkovodni brzici. Prav tako smo ugotovili nižje vrednosti hitrosti toka v mezohabitatih pod pregrado. Povprečna hitrost v mezohabitatu rahlo valovanje na območju odvzema vode za MHE Mojstrana je bila 0,1 m/s in povprečna globina 0,1 m. V tolmunih je bila povprečna hitrost med 0,05 m/s in povprečna globina 0,18 m.

Zmanjšanje hitrosti vodotoka in njegove globine v obeh popisanih mezohabitatih na območju odvzema vode v primerjavi z območjem nad zajezitvijo je posledica odvzema vode za MHE Mojstrana. Raziskave vpliva zajezitev na reki Soči so prav tako pokazale zmanjšanje v hitrosti in globini vodotoka pod pregrado (Maddock *et al.*, 2005).

with the average velocity of 0.81 m/s and 0.7 m/s, respectively, boulder prevails. In mesohabitats of riffles and glides with a velocity of 0.37 m/s and 0.4 m/s, respectively, gravel was the prevalent substratum. In riffles, boulder was also present. Similar findings were reached in the mesohabitats below the damming (Table 4).

Average river depth was larger in the mesohabitats above the dam than the one below (Table 4). The average depth of mesohabitats above the dam was 0.37 m in the rapid, 0.33 m in the run, 0.7 m in the glide, and 0.37 m in the riffle. Lower values of flow velocity were also identified in the mesohabitats below the dam. The average velocity in the mesohabtiat 'run' at the abstraction site for the Mojstrana HPP was 0.1 m/s and average depth of 0.1 m. In the pools the average velocity ranged around 0.05 m/s and average depth 0.18 m.

The reduced flow velocity and depth in both mesohabitats at the abstraction site, as compared to the section above the dam, was due to the water abstraction for the Mojstrana HPP. The studies on the effect of damming in the Soča River have similarly shown the reduction in velocity and depth of the river below the dam (Maddock *et al.*, 2005).

Preglednica 4. Hidravlične značilnosti mezohabitatov na posameznem odseku.
Table 4. Hydraulic features of mesohabitats in relevant reaches.

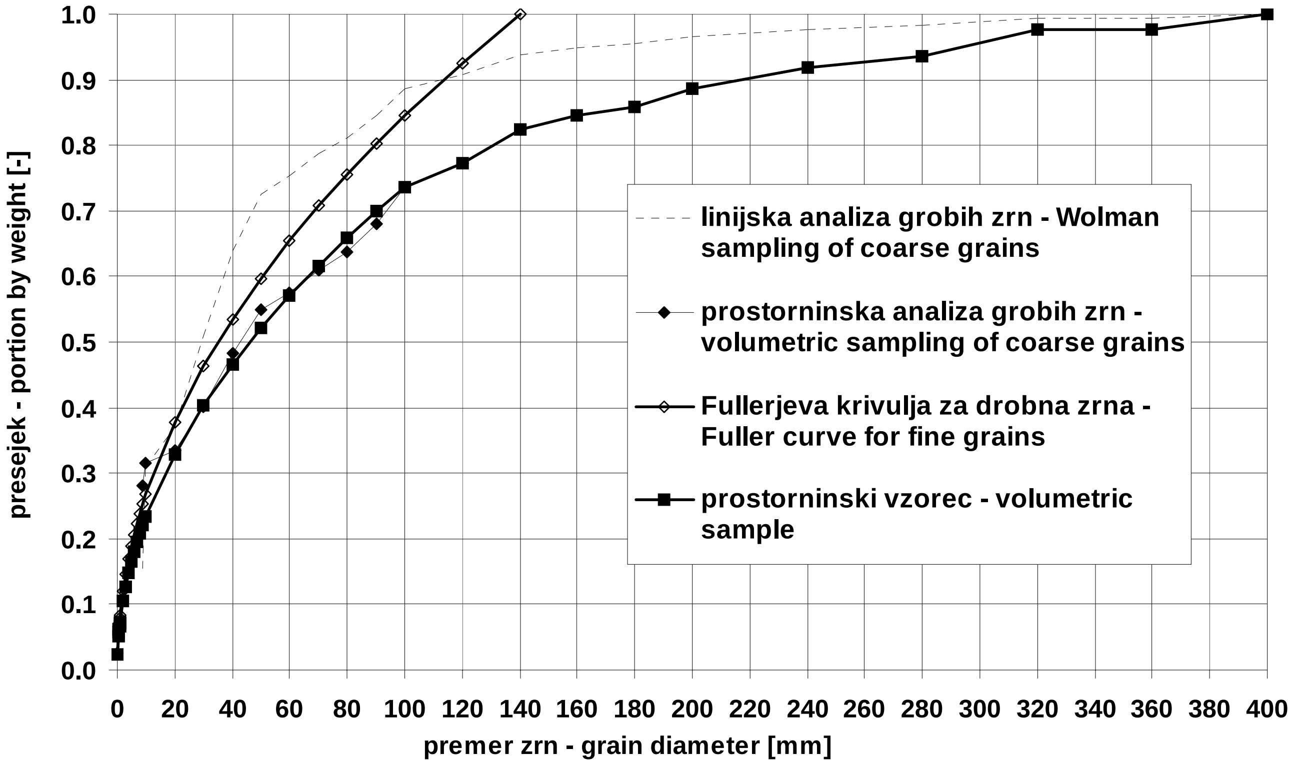
Odsek *Reach*	Povprečna globina vode (m) *Average water depth (m)*	Povprečna hitrost (m/s) *Average velocity (m/s)*
Odsek M1 / *Reach M1*		
Visokovodna brzica / *Rapid*	0.37	0.81
Nizkovodna brzica / *Riffle*	0.18	0.37
Rahlo valovanje / *Run*	0.33	0.70
Gladki tok / *Glide*	0.70	0.40
Tolmun / *Pool*	Ni prisoten / *Not present*	Ni prisoten / *Not present*
Zastal tolmun / *Ponded*	1.50	0.01
Povprečna vrednost / *Average value*	0.42	0.60
Odsek M2 / *Reach M2*		
Visokovodna brzica / *Rapid*	Ni prisotna / *Not present*	Ni prisotna / *Not present*
Nizkovodna brzica / *Riffle*	Ni prisotna / *Not present*	Ni prisotna / *Not present*
Rahlo valovanje / *Run*	0.13	0.10
Gladki tok / *Glide*	Ni prisoten / *Not present*	Ni prisoten / *Not present*
Tolmun / *Pool*	0.18	0.05
Zastal tolmun/*Ponded*	Ni prisoten / *Not present*	Ni prisoten / *Not present*
Povprečna vrednost / *Average value*	0.14	0.09

Rezultati so pokazali na očiten vpliv zajezitve na pojavljanje mezohabitatov. Čeprav vpliva na pojavljanje mezohabitatov tudi lokalna geomorfologija terena, v obravnavanem primeru to ni bistveno vplivalo na razlike v tipih mezohabitatov v primerjavi z odseki nad in pod zajezitvijo.

Zmanjšani pretok vode pod pregrado je bistveno vplival na povprečno omočenost struge, ki je bila nad pregrado 9,4 m, pod pregrado pa le 3,1 m. Prav tako je pod zajezitvijo prišlo do zmanjšanje širine struge, in sicer iz 16,8 m nad zajezitvijo na 10,4 m pod zajezitvijo. Ti rezultati se ujemajo z rezultati Petts *et al*. (1993), ki je v podobnih okoliščinah ugotovil 53 % zoženje struge v reki Rede v Veliki Britaniji.

The results have indicated the obvious effect of the damming to the occurrence of mesohabitats. Even though the occurrence of mesohabitats is also influenced by the local morphology of the terrain, in this particular case it did not greatly affect the differences between mesohabitat types when comparing the reaches above and below the damming.

The reduced water flow below the dam significantly influenced the average wetness of the channel, which was 9.4 m above the dam, and only 3.1 m below the dam. Also, below the dam the water channel shrank from 16.8 m above the dam to 10.4 m below the dam. These results correspond to the ones obtained by Petts *et al.* (1993), who in similar conditions recorded a 53 % reduction of the channel of the Rede River in Great Britain.



Slika 3. Preračun številčne – linijske analize grobih zrn na odvzemnem mestu 2 v težnostno prostorninsko analizo grobih zrn in togo sestavljanje s Fullerjevo zrnavostno krivuljo v prostorninski vzorec.

Figure 3. The calculation of the numerical Wolman analysis of coarse grains in sampling site 2 into weight/volume analysis of coarse grains and rigid composition with the Fuller curve into a volume sample.

Preglednica 5. Zrnavostni parametri plavin na Bistrici, določeni z vzorčevanjem dne 21.3.2005.
Table 5. Granulation parameters of river sediments in the Bistrica River, defined by sampling on March 21, 2005.

Odvzemno mesto *Sampling site*	Aritmetično srednje zrno (mm) *Arithmetic mean grain size (mm)*		d_{90} (mm) *d_{90} (mm)*	
	Način sestavljanja / *Way of composition*			
	Togo *rigid*	Prilagodljivo *adaptable*	Togo *rigid*	Prilagodljivo *adaptable*
mesto 1 / *site 1*	78.8	73.8	216.9	197.8
mesto 2 / *site 2*	51.6	50.8	140.3	126.0

4.3 PLAVINE

Za odvzemni mesti plavin na Bistrici smo za dva načina preračuna dobili rezultate o zrnavosti plavin, prikazane v preglednici 5. Primer preračuna in togega sestavljanja je prikazan na sliki 3.

Rezultati analize kažejo na dobro ujemanje obeh načinov sestavljanja (togega in prilagodljivega). Načeloma velja, da je boljši način togo sestavljanje, kadar je to teoretično možno. Če torej primerjamo le zrnavost, določeno s pomočjo togega sestavljanja, vidimo da je razlika v velikosti srednjega zrna med obema odvzemnima mestoma zaznavna (51,6 mm oziroma 78,8 mm). Zrnavost je primerljiva z zrnavostjo drugih podobnih alpskih vodotokov v Sloveniji, kadar v njih prevladuje latentna erozija (premestitvena zmogljivost je tam večja od dejanske prodonosnosti). Razlika med obema odvzemnima mestoma je še bolj izrazita pri 90-% zrnu (140,3 mm napram 216,9 mm), ki je parameter hrapavosti dna struge in vpliva na hidravlične pretočne razmere (hrapavostni upor toku vode).

Zanimiv rezultat analize zrnavosti plavin je velika stopnja drobnitve plavin, saj je mesto 1 le nekaj 100 m gorvodno od mesta 2, razlika v zrnavosti pa ni posledica mehanskega obrusa temveč spremenjenega prodnega režima zaradi odvzema vode za MHE. Za podrobnejši vpogled bi bilo nujno izvesti večkratno vzorčevanje, in to na daljšem odseku nad in pod zajezitvijo za odvzem vode v MHE Mojstrana.

4.3 RIVER SEDIMENTS

For the two sampling sites on the Bistrica River we obtained, by two ways of calculation, sediment grading results, shown in Table 5. An example of calculation and rigid composition is shown in Figure 3.

The results of the analysis have shown a good correlation of both ways of composition (rigid and adaptable). In principle, rigid composition is preferable when theoretically possible. If we compare only grading, determined upon rigid composition, it becomes evident that the difference in the mean grain size between both sampling sites is considerable (51.6 mm vs. 78.8 mm). Grading is comparable to the grading of other similar alpine rivers in Slovenia, when there is a prevalence of latent erosion (transport capacity is larger than the actual bed-load discharge). The difference between both sampling sites is even more considerable with the 90 % grain (140.3 mm vs. 216.9 mm), which is a parameter of river bottom roughness and affects the hydraulic flow conditions (roughness resistance to the water flow).

An interesting result of the sediment grading analysis is the large level of sediment fines, since site 1 is only several 100 m upstream of site 2 and the grading difference is not the consequence of mechanical wear but of a changed gravel regime, caused by the abstraction for the HPP. For a more detailed insight, the sampling should be repeated several times and performed in a longer section above and below the Mojstrana HPP.

4.4 FITOBENTOS

Vrstni sestav fitobentosa v vodotoku Bistrica kaže na vseh odvzemnih mestih na združbo večinoma epilitskih fitobentoških alg, med katerimi so prevladovale kremenaste alge, podobno kot smo ugotovili v raziskavah alg v podobnih tipih slovenskih rek (Kosi, 1988, Smolar - Žvanut *et al*., 1998a, Smolar - Žvanut, 2001). Najštevilneje so bile zastopane kremenaste alge (11 vrst), sledile so cianobakterije (3 vrste) in en predstavnik iz skupine rumenih alg. Prisotne vrste alg so večinoma indikatorji oligosaprobne in beta-mezosaprobne stopnje. Med območji nad in pod zajezitvijo ni prišlo do poslabšanja kakovosti vode, saj so bile izračunane vrednosti saprobnega indeksa podobne in ne nasprotujejo uvrstitvi obeh odsekov v 1. kakovostni razred.

Odvzem vode iz reke Bistrice in s tem posledično nizke hitrosti vode pod zajezitvijo so vplivale na pojavljanje vrste *Hydrurus foetidus*, ki se je pojavljala le gorvodno od zajezitve. To potrjuje dejstva številnih raziskav, da je eden izmed ključnih dejavnikov za pojavljanje te vrste poleg nizkih temperatur vode in primernega substrata tudi dovolj velika hitrost vodnega toka (Traen in Lindstrøm, 1983, Smolar - Žvanut, 2001).

Bray-Curtisov koeficient podobnosti kaže kvalitativne spremembe v strukturi združbe in zagotavlja hiter in enostaven pregled podobnosti in različnosti med biotičnimi združbami. Večja podobnost v hidroloških in morfoloških razmerah med vzorci nad zajezitvijo in med vzorci pod zajezitvijo se je odražala v večji podobnosti med vzorci teh območij odvzema, torej lahko ugotovimo, da je zaradi odvzema vode pod zajezitvijo za MHE Mojstrana prišlo do spremembe v vrstni sestavi in pogostosti fitobentosa (Slika 4).

Primerjava v vrstnem sestavu med odvzemnimi mesti nad in pod zajezitvijo je pokazala, da so se pod zajezitvijo pogosteje pojavljale vrste, ki so značilne za odseke vodotokov z nizkimi hitrostmi vodnega toka, podobno, kot so pokazali rezultati raziskav v Tržiški Bistrici, Branici (Smolar - Žvanut *et al.,* 1998a), Savi Dolinki in Soči (Smolar - Žvanut, 2001).

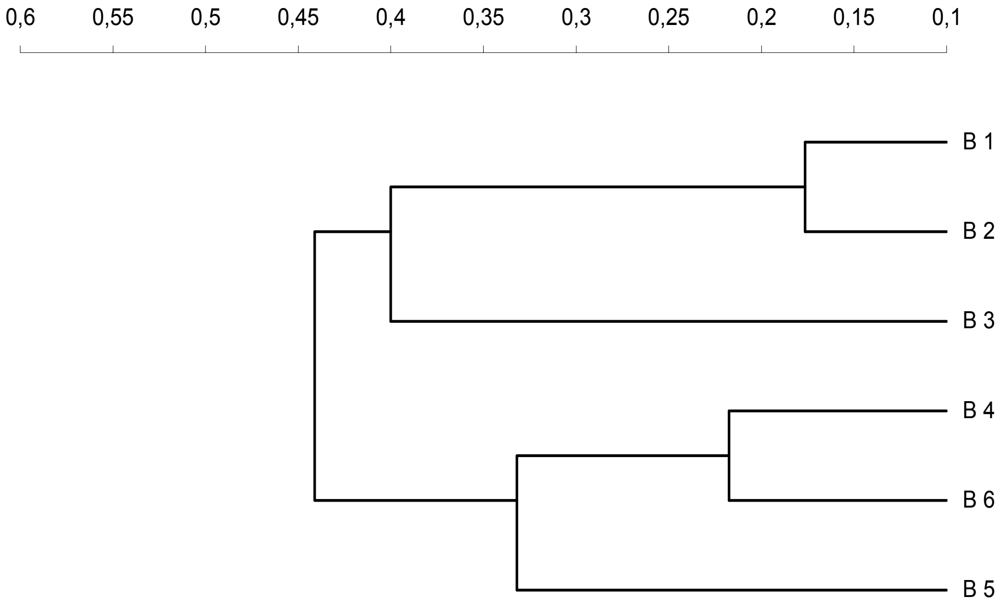
4.4 PHYTOBENTHOS

The species composition of phytobenthos in the Bistrica River in all sampling sites is the assemblage of mostly epilithic phytobenthic algae, with a prevalence of diatoms, as was established in the studies on algae conducted on similar types of Slovenian rivers (Kosi, 1988, Smolar - Žvanut *et al*., 1998a, Smolar - Žvanut, 2001). Diatoma were the most abundant (11 species), followed by cyanobacteria (3 species) and one representative from the assemblage of yellow algae. The species of algae present are mostly indicators of oligosaprobic and beta-mesosaprobic levels. The water quality above and below the dam remained the same, since the calculated values of the saprobic index remained the same; both reaches could be classified as quality class 1.

Abstraction of water from the Bistrica and the resulting low flow velocity below the dam brought about the emergence of species *Hydrurus foetidus*, found upstream of the damming. This confirms the findings of several studies, which indicate that, besides low water temperatures and the right substratum, one of the key factors supporting the emergence of the species is the high enough velocity. (Traen & Lindstrøm, 1983, Smolar-Žvanut, 2001).

The Bray-Curtis coefficient of similarity shows qualitative changes in the assemblage composition and ensures a quick and simple overview of similarities and differences between the biotic communities. The larger similarity in hydrological and morphological conditions taken below was reflected in the larger similarity between the samples, and we may conclude that the abstraction caused the changes in species composition and frequency of phytobenthos below the Mojstrana HPP (Figure 4).

A comparison of species composition between the sampling sites above and below the dam has shown that below the dam those species emerged that are characteristic of reaches with low flow velocity, similar to the results on the Tržiška Bistrica River, Branica River (Smolar - Žvanut *et al.,* 1998a), Sava Dolinka River and Soča River (Smolar - Žvanut, 2001).



Slika 4. Bray-Curtisov koeficient podobnosti za Bistrico.
Figure 4. Bray-Curtis coefficient of similarity for the Bistrica River.

5. ZAKLJUČKI

Rezultati hidroloških, morfoloških in bioloških meritev ter analiz so pokazali na zelo spremenjen vodni ekosistem na območju, kjer je odvzem vode za MHE Mojstrana, podobno, kot so pokazali rezultati drugih raziskav vpliva hidroelektrarn na slovenske vodotoke Smolar - Žvanut, 2001, Smolar - Žvanut *et al.*, 1998b, Maddock et al., 2005). Manjši pretoki vode pod zajezitvijo povzročajo zoženje struge, znatno se je zmanjšala velikost in fragmentacija mezohabitatov. Rezultat analize zrnavosti plavin je pokazal na veliko stopnjo drobnitve plavin. Zaradi sprememb v hidroloških in morfoloških parametrih pod pregrado je prišlo do sprememb v vrstnem sestavu in v pogostosti fitobentosa. Odvzemi vode so bili preveliki, na odseku ni bil zagotovljen ekološko sprejemljiv pretok vode. Za ohranjanje vodnega ekosistema v vodotokih pod zajezitvami je namreč treba zagotoviti tako količino kot tudi kakovost vode, ki zagotavlja ohranitev naravnega ravnovesja v vodnem in obvodnem ekosistemu ter hkrati ne poslabšuje ekološkega stanja v vodotoku.

5. CONCLUSIONS

The results of hydrological, morphological and biological measurements and analyses have shown a considerably changed aquatic ecosystem in the area, where water abstraction for the Mojstrana HPP is performed, similar to the results obtained in other studies on the effects of hydro-electric power stations on Slovenian rivers (Smolar - Žvanut, 2001, Smolar - Žvanut *et al.*, 1998b, Maddock *et al.*, 2005). Low flows under the dams cause shrinkage of the channel, and reduction of size and fragmentation of mesohabitats. The result of the sediment grading analysis was the large level of sediment fines. Because of the changes in hydrological and morphological parametres below the dam, changes in species composition and frequency of phytobenthos were observed. Water abstraction was too extensive, and ecologically acceptable flow was not ensured in the reach. For preservation of the aquatic ecosystem in the rivers below dams the appropriate volume as well as quality of water have to be ensured, assuring the preservation of the natural balance in the river and river-side ecosystem, which does not worsen the ecological state of the river.

ZAHVALA

Avtorji se zahvaljujemo Agenciji za raziskovalno dejavnost Republike Slovenije za finančno podporo. Dr. Gorazdu Kosi se zahvaljujemo za pomoč pri determinaciji fitobentosa, Mateju Padežniku za pomoč pri terenskem zbiranju podatkov in Iztoku Ameršku za pomoč pri izdelavi kart.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the Slovenian Research Agency for its financial support. We sincerely thank Dr. Gorazd Kosi for his help with phytobenthos determination, Matej Padežnik for field collection of data, and Iztok Ameršek for his help with map production.

VIRI - REFERENCES

Aadland, L.P. (1993). Stream habitat types: their fish assemblages and relationship to flow. *North American Journal of Fisheries Management* **13**, 790–806.

Biggs, B.J.F., Close, M.E. (1989). Periphyton biomass dynamics in gravel bed rivers: the relative effects of flows and nutrients. *Freshwater Biology* **22,** 209–231.

Biggs, B.J.F. (1996). Patterns in Benthic Algae in Streams. In: Stevenson, R.J., Bothwell, M.L., Lowe, R.L. (Eds.), *Algal Ecology Freshwater Benthic Ecosystems.* Academic Press, Inc: San Diego, 31–56.

Biggs, B.J.F., Goring, D.G., Nikora, V.I. (1998). Subsidy and stress responses of stream periphyton to gradients in water velocity as a function of community growth form. *J. Phycol.* **34**(4), 598–607.

Biggs, B.J.F, Duncan, M.J., Surren, A.M., Holomuzki, J.R. (2001). The importance of bed sediment stability to benthic ecosystems of streams. In: Mosley, M.P. (Ed.), *Gravel-Bed Rivers V.* New Zealand Hydrological Society Inc, The Caxton Press: Christchurch, 423–443.

Bundi, U., Eichenberger, E. (1989). *Wasserentnahme aus Fliessgewässern: Gewässerökologische Anforderungen an die Restwasserführung.* Schriftenreihe Umweltschutz **10**, Bundesamt für Umwelt, Wald und Landschaft, Bern.

Clarke, K.R., Warwick, R.M. (1990). Lecture notes for the training workshop on the statistical treatment and interpretation on marine community data. Proceeding “Long term Programme for Pollution Monitoring and Research in the Mediterranean Sea, Part II”, Split, 26 June–6 July 1990.

Everard, M. (1996). The importance of periodic droughts for maintaining diversity in the freshwater environment. In: Sutcliffe, D. (Ed.), *Freshwater Forum – Volume 7*. Freshwater Biological Association, 33–50.

Gehrke, P.C., Harris, J.H. (2000). Large-scale patterns in species richness and composition of temperate riverine fish communities, south-eastern Australia. *Marine and Freshwater Research* **51**, 165–82.

Hawkins, C.P., Kershner, P., Bisson, A., Bryant, D., Decker, L.M., Gregory, S.V., McCullough, D.A., Overton, C.K., Reeves, G.H., Steedman, R.J., Young, M.K. (1993). A hierarchical approach to classifying stream habitat features. *Fisheries* **18,** 3–12.

Koudelkova, B. (1999). Effects of the hydropower peaking on distribution of periphyton in the cross section of a regulated river. Dissertation Abstract, Faculty of Sciences, Masaryk, 28 p.

Kosi, G. 1988. Vpliv hipolimnijske vode Blejskega jezera iz natege in kanalizacije na primarno produkcijo perifitona v Savi Bohinjki (The impact of hypolimnetic water from Lake Bled on primary production of periphyton in the Sava Bohinjka). Unpublished Master Thesis, University of Ljubljana, Biotechnical Faculty, Ljubljana, 72 p. (in Slovenian).

Maddock, I.P., Bird, D. (1996). The application of habitat mapping to identify representative PHABSIM sites in the River Tavy, Devon, U.K.. In: Leclerc, M., Capra, H., Valentin, S., Boudreault, A., Côté, Y. (Eds.), "Proceedings of the 2nd International Symposium on Habitats and Hydraulics", Quebec, Canada. Vol. B, 203–214.

Maddock, I.P. (1999). The importance of physical habitat assessment for evaluating river health. *Freshwater Biology* **41**, 373–391.

Maddock, I.P., Bickerton, M.A., Spence, R., Pickering, T. (2001). Reallocation of compensation releases to restore river flows and improve instream habitat availability in the Upper Derwent catchment, Derbyshire, UK. *Regulated Rivers: Research and Management* **17**, 417–441.

Maddock, I.P., Thoms, M., Jonson, K., Dyer, F, & Lintermans, M. (2004). Identifying the influence of channel morphology on physical habitat availability for native fish: application to the Two-Spined Blackfish (*Gadopsis bispinosus)* in the Cotter River, Australia. *Marine and Freshwater Research* **55**, 173–184.

Maddock, I.P., Hill, G., Smolar - Žvanut, N. (2005). The effect of flow regulation on channel geomorphic unit (CGU) composition in the Soča River, Slovenia. In: Harby, A., Baptist, M., Duel, H., Dunbar, M., Goethals, P., Huusko, A., Ibbotson, A., Mader, H., Pedersen, M.L., Schmutz, S., Schneider, M. (Eds.), "Proceedings of the 7th meeting of the EU COST Action 626 in Aquatic Habitat Modelling", Silkeborg, Denmark, May 2005, 205–216.

Milhous, R.T. (1998). Modelling of instream flow needs: the link between sediment and aquatic habitat. *Regulated Rivers: Research and Management* **14**, 79–94.

Mikoš, M. (1989). Urejanje hribovskih vodotokov (Management of mountainous streams). *Acta hydrotechnica* **6** (7), 1–59 (in Slovenian).

Mikoš, M. (1999). Navodila za uporabo ZPP – verzija 1999 (Instruction for use ZPP – version 1999). Univerza v Ljubljani, FGG, Katedra za splošno hidrotehniko, 18 p. (in Slovenian).

Opravilova, V., Komarek, O. (1995). Preliminary comparative study of micromeiozoobentos and periphytic algae in three man-made streams. In: Bretschko, G., Helešic, J., Kubiček, F.V. (Eds.), *The Ecological Importance of River Bottom.* Folia Fac. Sci. Nat. Univ. Masarykianae Brunensis, Biologia 91, 107–120.

Petts, G.E., Armitage, P. & Castella, E. (1993). Physical habitat changes and macroinverebrate response to river regulation: the River Rede, UK. *Regulated Rivers: Research and Management* **8**, 167–178.

Rott, E., Pfister, P. (1988). Natural epilithic algal communities in fast-flowing mountain streams and rivers and some man - induced changes. *Verh. Internat. Verein. Limnol*. **23**, 1320–1324.

Smolar - Žvanut, N., Vrhovšek, D., Kosi, G. (1998a). Effects of low flow on periphyton in three different types of streams in Slovenia. In: Bretschko, G., Helešic, J.V. (Eds.), *Advances in River Bottom Ecology*. Backhuys Publishers, Leiden, The Netherlands, 107–116.

Smolar - Žvanut, N., Vrhovšek, D., Kosi, G. (1998b). Ocena vpliva odvzema vode iz Tržiške Bistrice na perifitonske alge (An estimation of influence of water abstraction from the stream Tržiška Bistrica on periphytic algae). *Ichthyos* **15**, 29–46 (in Slovenian).

Smolar - Žvanut, N. (2001). Vloga perifitonskih alg pri določanju ekološko sprejemljivega pretoka vode v tekočih vodah = The role of periphytic algae in the determination of the ecologically acceptable flow in running waters. *Acta hydrotechnica* **19/30**, 65–89.

Smolar - Žvanut, N., Krušnik, C., Kosi, G., Vrhovšek D. (2004a). Uporaba perifitona in večjih vodnih nevretenčarjev pri določanju ekološko sprejemljivega pretoka na reki Rižani, Slovenija = The use of periphyton and macrozoobenthos in determination of ecologically acceptable flow for the Rižana river, Slovenia. *Acta hydrotechnica* **21/35**, 129–143.

Smolar - Žvanut, N., Vrhovšek, D., Kosi, G. (2004b). Pojavljanje fitobentosa v različnih hidroloških okoljih v reki Branici (Distribution of phytobenthos in different hydraulic environments in the river Branica. *Ichthyos* **19**, 18–29 (in Slovenian).

Traen, T.S., Lindstrøm, E.A. (1983). Influence of current velocity on periphyton distribution. In: Wetzel, R.G. (Ed.), *Periphyton of Freshwater Ecosystems.* Dr W. Junk Publishers, 97–99.

Naslovi avtorjev – Authors' Addresses

asist. dr. Nataša Smolar - Žvanut
LIMNOS d.o.o. – LIMNOS Ltd.
Podlimbarskega 31, SI-1000 Ljubljana, Slovenia
E-mail: natasa@limnos.si
&
Inštitut za vode Republike Slovenije – Institute for Waters of the Republic of Slovenia
Hajdrihova 28, SI-1000 Ljubljana, Slovenia
E-mail: natasa.smolar@guest.arnes.si

prof. dr. Matjaž MIKOŠ
Fakulteta za gradbeništvo in geodezijo – Faculty of Civil and Geodetic Engineering
Univerza v Ljubljani – University of Ljubljana
Jamova 2, SI-1000 Ljubljana, Slovenia
E-mail: matjaz.mikos@fgg.uni-lj.si

dr. Barbara BREZNIK
LIMNOS d.o.o. – LIMNOS Ltd.
Podlimbarskega 31, SI-1000 Ljubljana, Slovenia
E-mail: barbara@limnos.si