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Environmental assessment and macrophytes of the watercourses Bloščica and Cerkniščica

Okoljska ocena in makrofiti vodotokov Bloščice in Cerkniščice

Špela Mechora[1], Urška Kuhar[1], Mateja Germ[1*]

[1]Biotechnical Faculty, Department of Biology, Večna pot 111, 1000 Ljubljana, Slovenia
[*]correspondence: mateja.germ@bf.uni-lj.si

Abstract: The aim of the present work was to determine the abundance and distribution of macrophytes in streams Bloščica and Cerkniščica and to establish the relation between environment characteristics and abundance of macrophytes. The environmental and macrophytes' inventory was made on the whole length of the watercourse. We determined a presence, abundance and growth form of macrophytes and environmental parameters according to modified RCE Inventory. Nineteen taxa were found in the watercourse Bloščica and 20 taxa in the watercourse Cerkniščica. Canonical correspondence analysis revealed that six environmental parameters significantly affected macrophyte community, the most influential being bottom structure, the width of riparian zone, retention devices in a channel and the land use beyond the riparian zone.

Key words: environmental assessment, macrophytes, watercourses

Izvleček: V prispevku podajamo rezultate raziskav pojavljanja, razporeditve in pogostosti makrofitov v vodotokih Bloščica in Cerkniščica ter ugotavljamo povezavo med okoljskimi razmerami in pojavljanjem makrofitov. Makrofite, njihovo pogostost, rastno obliko in stanje širšega vodnega okolja po prirejeni RCE metodi, smo popisali na celotni dolžini izbranih vodotokov. V vodotoku Bloščica smo popisali 19 taksonov, v vodotoku Cerkniščica pa 20 taksonov. Kanonična korespondenčna analiza je pokazala, da šest okoljskih parametrov značilno vpliva na pojavljanje in pogostost makrofitov. Največji vpliv imajo struktura dna, širina obrežnega pasu, zadrževalne strukture v strugi in zaledje.

Ključne besede: okoljska ocena, makrofiti, vodotoki

Introduction

Rivers are diverse and dynamic systems that play an important role in the complexity of the landscape (Chovanec et al. 2000). Macrophytes are fundamental to the structure and functioning of lowland river habitats (Baatrup-Pedersen and Riis 1999). Distribution and abundance of macrophytes are affected by several environmental and antropogenic factors and their interactions (Lacoul and Freedman 2006). Parameters exerting impact on macrophyte's growth and abundance in running waters are the following: climate, hydrology, geomorphology, nutrients and other chemical factors, biological interactions and human activities (Onaindia et al. 1996, Bernez et al. 2004, Hrivnàk et al. 2007). Ecological status of rivers is influenced by human activities that affect the physical properties of the riverbed, riparian vegetation and land beyond the riparian zone (Petersen 1992). These changes worsened the conditions of the river ecosystem and water quality as well as altered communities of aquatic organisms, including macrophytes, which play important roles in energy flow, nutrient cycling and sedimentation processes (Holmes 1999, Gaberščik et al. 2003). Macrophytes improve water quality, both directly through oxygenation and nutrient recycling, and

indirectly by providing surface for water-purifying algae, fungi and bacteria (Holmes 1999). Species composition of macrophytes and their abundance reflect the quality of an ecosystem as a whole. For that reason macrophytes are included in the EU Water Framework Directive (Council of the European Communities 2000), presenting one of the four indispensable biological elements, which determine the ecological status of rivers (Dodkins et al. 2005).

The aims of the present study were to determine the presence, abundance and distribution of macrophytes in watercourses Bloščica and Cerkniščica and to find out the relation between the environmental parameters and the occurrence of macrophytes.

Materials and Methods

Study area

Watercourses Bloščica and Cerkniščica are located in Notranjska region (Slovenia) in karst area. Almost half of the catchment of both watercourses is covered by forest.

The watercourse Bloščica is intermittent watercourse flowing on Bloke plateau being a part of the watershed of the river Ljubljanica. Elevation of its flow ranged from 720 and 750 m. Catchment comprises of small tributaries (Runarščica, Blatni potok, Krajič, Ribjek) covering about 25 km^2. Due to its low slope, the watercourse Bloščica flows slowly and makes many meanders. It flows on dolomites first 6 km of its length. At Velike Bloke it cut its bed into limestone and dolomite and finnaly sinks underground. The upper part of the watercourse Bloščica flows mainly through preserved landscape, while the lower part from Ulake downstreams is more affected by human activity.

Spring of the about 17 km long watercourse Cerkniščica is located in a hilly area of Sveti Vid and Cajnarji. The catchment comprises 50 km^2. It is the biggest surface tributary of the lake Cerknica. The water level changes very quickly in the case of strong rain, so it can be designated as a torrent watercourse. The watercourse Cerkniščica

Table 1: List of taxa, determined in the watercourse Bloščica.
Tabela 1: Seznam vrst, prisotnih v Bloščici.

Taxa	Abbreviation	Growth form
Alisma plantago-aquatica L.	Ali pla	am
Bryophyta	Bryophy	sa
Chara sp.	Cha sp.	sp
Equisetum palustre L.	Equ pal	he
Lythrum salicaria L.	Lyt sal	he
Mentha aquatica L.	Men aqu	am
Mentha longifolia (L.) Hudson	Men lon	am
Menyanthes trifoliata L.	Men tri	he
Myosotis scorpioides L.	Myo sco	am
Myriophyllum spicatum L.	Myr spi	sa
Nasturtium officinale R. Br. In Aiton	Nas off	he
Petasites hybridus (L.) Gaertner	Pet hyb	he
Phragmithes australis (Cav.) Trin ex Steud.	Phr aus	he
Plantago altissima L.	Pla alt	he
Potamogeton lucens L.	Pot luc	sa
Potamogeton nodosus Poir.	Pot nod	fl
Schoenoplectus lacustris (L.) Palla	Sch lac	he
Sparganium erectum L.	Spa ere	he, sa
Typha latifolia L.	Typ lat	he

Legend: ap = plants floating on the water surface, sp = submerged pleustophytes, sa = submerged anchored plants, fl = floating leaf rooted plants, am = amphiphytes, he = helophytes

flows in its upper part in narrow and deep valley. From Cajnarji to Begunje by Cerknica, its bottom becomes wider and steeper, covered by fluvial deposits. At Begunje by Cerknica it flows on karst area. The watercourse Cerkniščica is regulated in the settlements Cerknica and Dolenja vas. It sinks underground at Cerkniško polje.

The catchments of both studied watercourses are part of the Natura 2000 network.

Riparian, Channel, and Environment Inventory (RCE)

Studied watercourses were divided to stretches from 360 to 1030 m long. The start of the new stretch was determined where presence or abundance of macrophytes changed, when we observed changes in land use type, channel characteristics or riparian zone. Every stretch was assessed according to the modified RCE Inventory (Petersen 1992, Germ et al. 2003). RCE Inventory was developed for the assessment of physical condition of the riparian zone and the stream channel in lowland streams, flowing through agricultural landscape. Modified RCE Inventory consisted from 12 parameters, each describing 4 levels of environmental gradient. The parameters include land-use type beyond the riparian zone, characteristics of the riparian zone (width, completeness and vegetation type), and morphology of the stream channel (channel structure, bank structure and undercutting, occurrence of retention structures and sediment accumulation, type of stream bottom and detritus and dynamics of the flow).

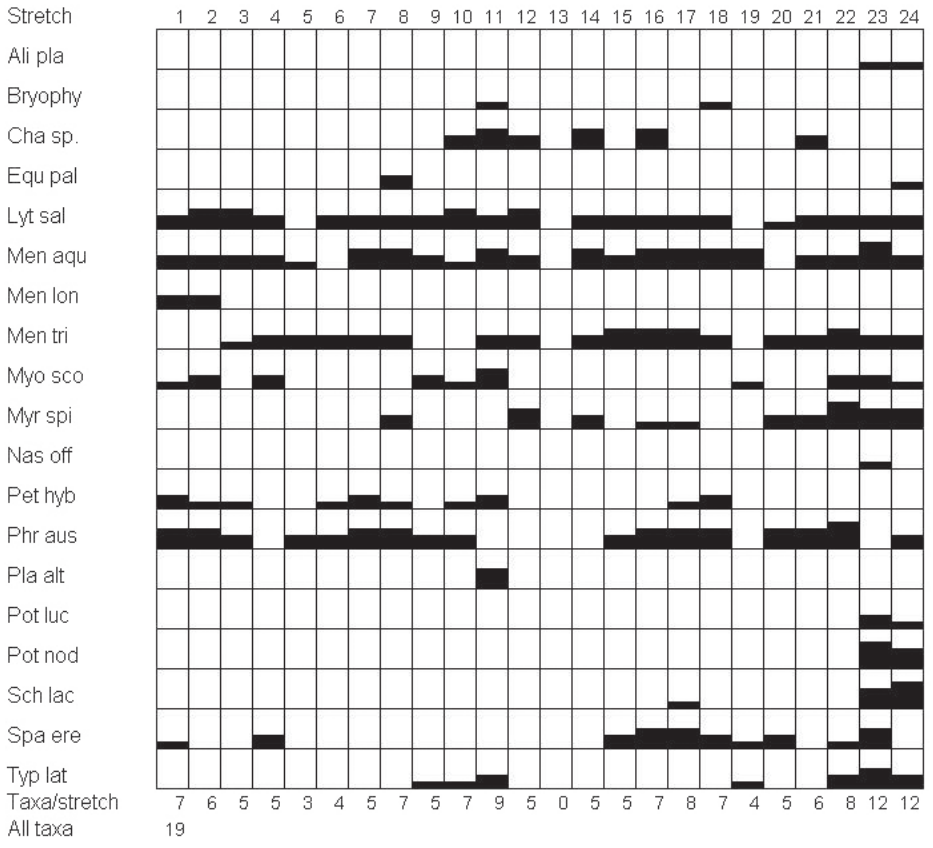

Figure 1: Distribution of macrophytes in the watercourse Bloščica. Stretch 10 was not surveyed.
Slika 1: Razporeditev in pogostost makrofitov v Bloščici. Odsek 10 ni bil pregledan.

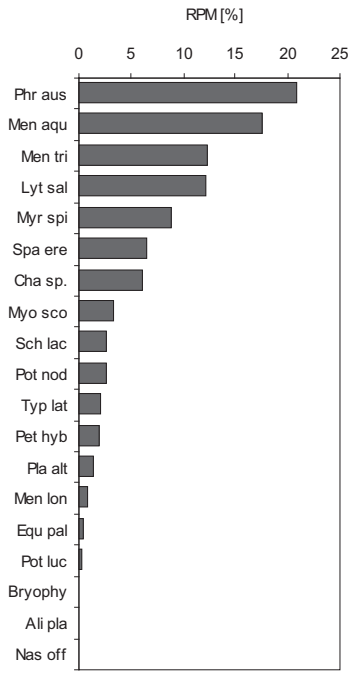

Figure 2: Relative plant mass (RPM) of macrophytes in the watercourse Bloščica.
Slika 2: Relativna rastlinska masa (RPM) makrofitov v Bloščici.

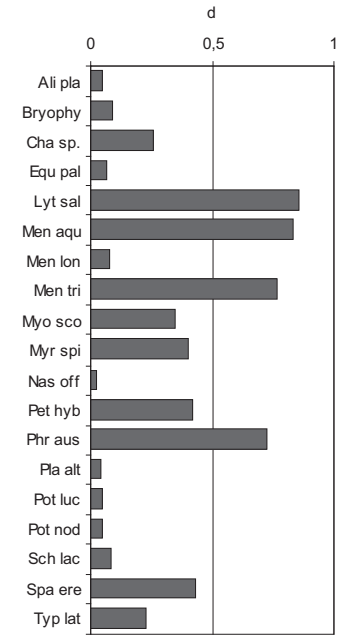

Figure 3: The ratio of the length of the watercourse Bloščica overgrown by certain species of macrophytes »d« value; 0.5 for example means that 50 % of watercourse in owergrown with macrophytes.
Slika 3: Delež dolžine vodotoka, poraslega z določeno vrsto makrofitov »d« vrednost; 0,5 npr. pomeni, da je 50 % vototoka porastlega z določeno vrsto.

Macrophyte survey

The distribution and abundance of macrophytes in studied watercourses were assessed from the source to the outflow, using a boat and a rake with hooks.

The abundance was evaluated using a five degree scale as follows (Kohler and Janauer 1995): 1 = very rare; 2 = infrequent; 3 = common; 4 = frequent; 5 = abundant, predominant. Plants were identified using the keys by Preston (1995), Casper and Krausch (1980) and Martinčič et al. (1999).

Statistical analysis

On the basis of plant abundance, a relative plant mass was calculated (RPM) that is related to true biomass with function x^3 (Pall and Janauer 1995, Kohler and Janauer 1995). Canonical correspondence analysis (CCA) (Canoco for Windows Version 4.5) was used to assess the relationship between the composition and abundance of macrophytes, and environmental parameters. Environmental parameters were coded numerically from 1 (the most modified or degraded condition) to 4 (the natural or near natural condition).

Results

Presence and abundance of macrophytes

In the watercourse Bloščica 19 taxa of macrophytes was detected on the 17.800 m length (Tab. 1 and Fig. 1). Three species found are listed on the Slovenian Red list of Pteridophyta and Spermatophyta (Ur. l. RS 82/2002) as vulnera-

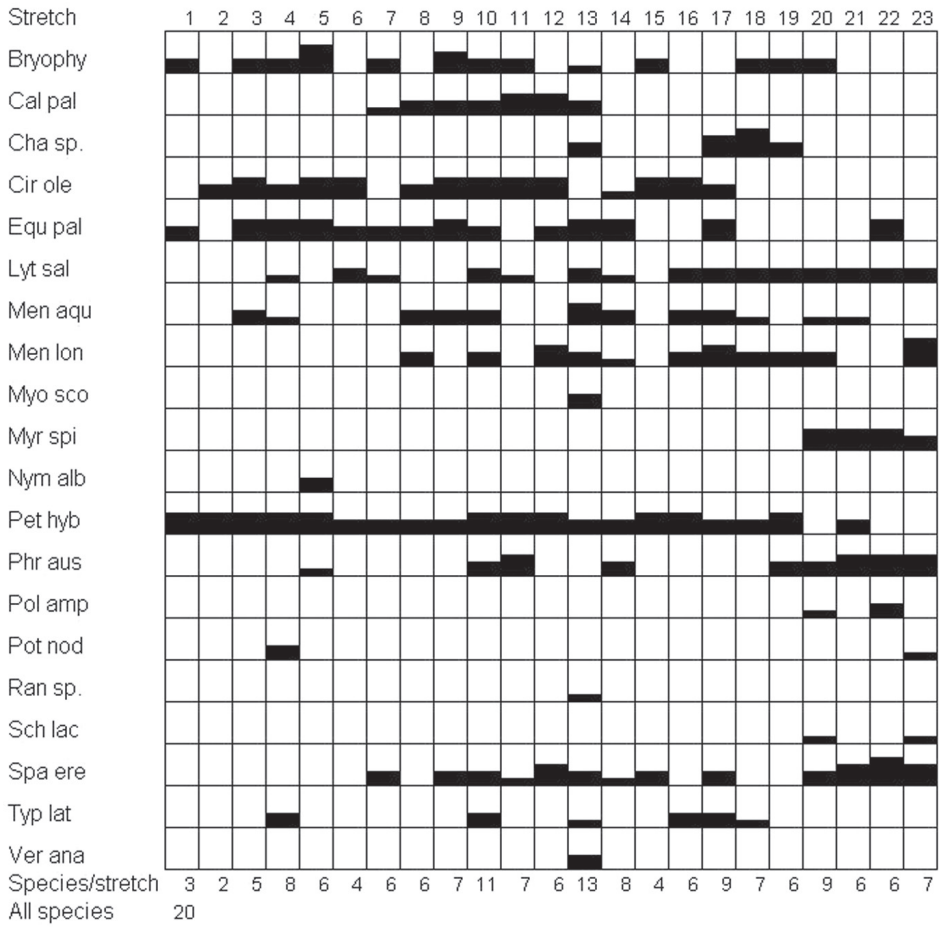

Figure 4: Distribution of macrophytes in the watercourse Cerkniščica.
Slika 4: Razporeditev in pogostost makrofitov v Cerkniščici.

ble (*Menyanthes trifoliata*, *Potamogeton lucens* and *P. nodosus*). The highest number of species was found in the stretches 18 (12) and 19 (12).

The highest RPM reached *Phragmites australis* (20.9 %), followed by *Mentha aquatica* (17.6 %), *Menyanthes trifoliata* (12.4 %) and *Lythrum salicaria* (12.2 %) (Fig. 2). *Lythrum salicaria* and *Mentha aquatica* occured in more than 80 % of the watercourse, followed by *Menyanthes trifoliata* (d = 0.77) and *Phragmithes australis* (d = 0.73) (Fig. 3). The majority of species in the both watercourses had amphibious or helophitic growth form, while submerged species were relatively scarce.

In the watercourse Cerkniščica 20 taxa of macrophytes were found (Tab. 2 and Fig. 4). Three of them are listed on the Slovenian Red list of Pteridophyta and Spermatophyta (Ur. l. RS 82/2002) determined as vulnerable: *Nymphaea alba*, *Potamogeton nodosus* and *Polygonum amphibium*.

The highest RPM reached *Petasites hybridus* (17.5 %), followed by *Cirsium oleraceum* (13.5 %) and *Equisetum palustre* (12.4 %) (Fig. 5). *Petasites hybridus* occured in 85 % of the watercourse, followed by *Lythrum salicaria* (d = 0.67), *Equisetum palustre* and *Cirsium oleraceum* (d = 0.62) (Fig. 6).

Table 2: List of taxa, determined in the watercourse Cerkniščica.
Tabela 2: Seznam vrst, prisotnih v Cerkniščici.

Taxa	Abbreviation	Growth form
Bryophyta	Bryophy	sa
Caltha palustris L.	Cal pal	he
Chara sp.	Cha sp.	sp
Cirsium oleraceum (L.) Scop	Cir ole	he
Equisetum palustre L.	Equ pal	he
Lythrum salicaria L.	Lyt sal	he
Mentha aquatica L.	Men aqu	am
Mentha longifolia (L.) Hudson	Men lon	am
Myosotis scorpioides L.	Myo sco	am
Myriophyllum spicatum L.	Myr spi	sa
Nymphaea alba L.	Nym alb	ap
Petasites hybridus (L.) Gaertner	Pet hyb	he
Phragmithes australis (Cav.) Trin ex Steud.	Phr aus	he
Polygonum amphibium L.	Pol amp	am
Potamogeton nodosus Poir.	Pot nod	fl
Ranunculus sp.	Ran sp.	sa
Schoenoplectus lacustris (L.) Palla	Sch lac	he
Sparganium erectum L.	Spa ere	he, sa
Typha latifolia L.	Typ lat	he
Veronica anagallis-aquatica L.	Ver ana	sa

Legend: ap = plants floating on the water surface, sp = submerged pleustophytes, sa = submerged anchored plants, fl = floating leaf rooted plants, am = amphiphytes, he = helophytes

Environmental parameters and distribution of macrophytes

Canonical correspondence analysis (CCA) (Canoco for Windows Version 4.5) was used to assess the relationship between environmental parameters and the composition and abundance of macrophytes in the watercourses Bloščica and Cerkniščica. Six examined parameters significantly affected the variability within the macrophyte community, the most influential were stream bottom type, width and completeness of the riparian zone, occurrence of retention devices, land use beyond the riparian zone and bank undercutting (Fig. 7).

The stretches are arranged in the ordination diagram according to the characteristics of environmental parameters in individual stretch. The quality of environmental parameters increases in the direction of the arrows. The stretches of Bloščica and streaches of Cerkniščica were present at different parts of the ordination diagram.

Rocky bottom was colonised by taxa *Cirsium oleraceum*, *Equisetum palustre* and *Petasites hibridus*, while the mixture of slime and sand was overgrown by *Menyanthes trifoliata*, *Mentha aquatica* and *Phragmites australis*. The taxon *Ranunculus* sp. and the species *V. anagalis-aquatica* occurred in stretches surrounded by wetland and forests, while the species *S. lacustris*, *P. lucens*, *Alisma plantago-aquatica* and *P. nodosus* preferred open locations.

Discussion

The Riparian, Channel and Environmental (RCE) Inventory has been developed to assess the physical and biological conditions of small, lowland streams in agricultural areas (Petersen 1992). The modified RCE inventory consists of twelve characteristics, which define the structure of the riparian zone, stream channel mor-

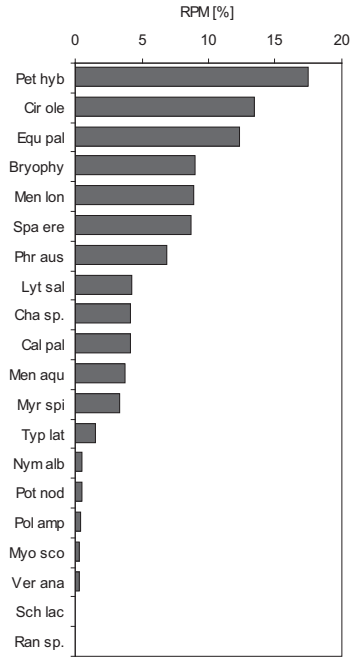

Figure 5: Relative plant mass (RPM) of macrophytes in the watercourse Cerkniščica.
Slika 5: Relativna rastlinska masa (RPM) makrofitov v Cerkniščici.

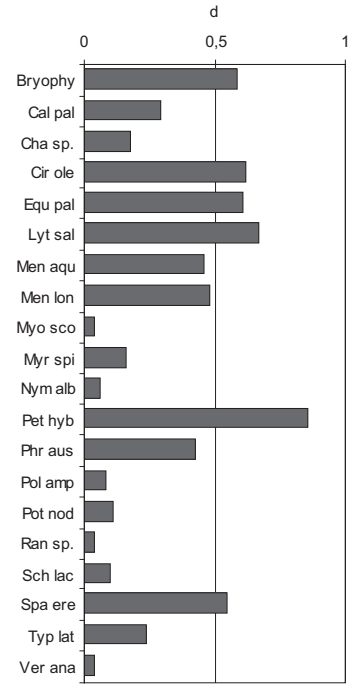

Figure 6: The ratio of the length of the watercourse Cerkniščica overgrown by certain species of macrophytes »d« value; 0.5 for example means that 50 % of watercourse in owergrown with macrophytes.
Slika 6: Delež dolžine vodotoka, poraslega z določeno vrsto makrofitov »d« vrednost; 0,5 npr. pomeni, da je 50 % vototoka porastlega z določeno vrsto.

phology and the biological condition in both habitats.

Numerous agricultural point discharges from field present a serious problem threating a good ecological status of watercourses. Wide and complete riparian vegetation has key role in prevention of erosion and retention of organic and even toxic substances (Johnston et al. 1990). Prevailed land use type of the watercourse Cerkniščica in upper part was forest and wet grassland and in lower parts agricultural and urban areas prevailed. Mosses were frequent, because of shading of the channel due to riparian vegetation and water level fluctuations. The river-bed of the watercourse Cerkniščica was channelized in the settlements Cerknica and Dolenja vas and therefore riparian vegetation was scarce or absent.

The bottom of the watercourse Bloščica consisted from fine, anaerobic sediment. Prevailing land use was wood and wet grassland. Riparian vegetation was removed at certain sites, that increased the vulnerability of the watercourse. This is also confirmed with canonical correspondence analysis that revealed that most influential environmental parameters shaping macrophyte community were bottom structure, width of riparian zone, retention devices in the channel and land use beyond the riparian zone.

Macrophyte species diversity was relatively low in either of the studied watercourses. 19 taxa were detected in the watercourse Bloščica and 20 in the watercourse Cerkniščica. 14 taxa were present in both watercourses. Important parameter, affecting the growth of macrophytes is light (Hut-

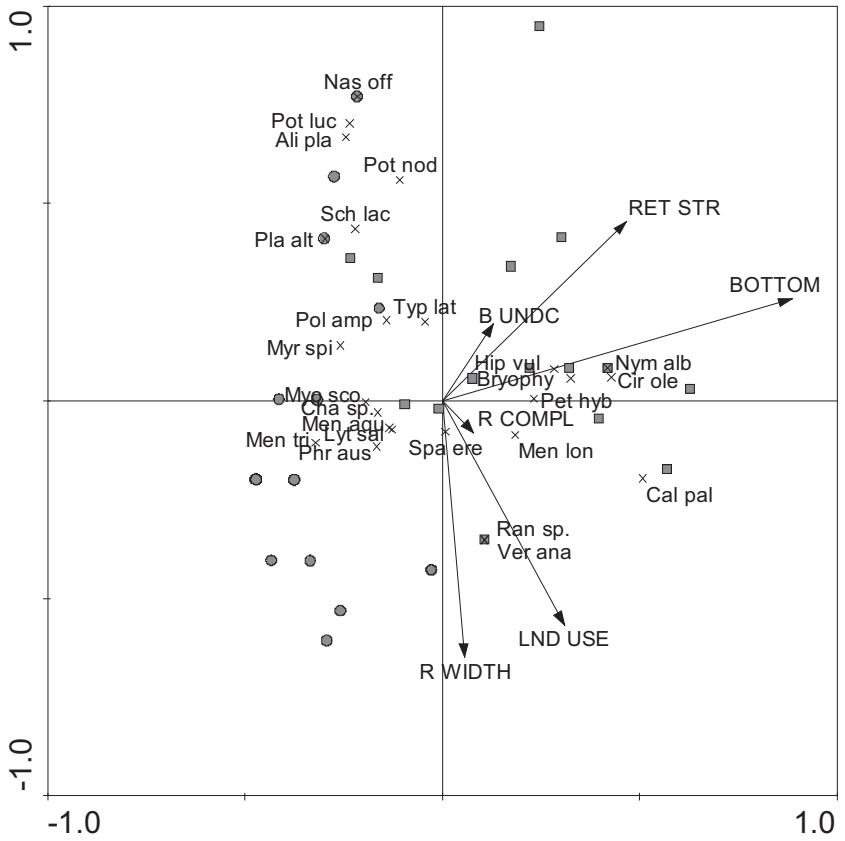

Figure 7: CCA ordination diagram showing the relationship between the macrophytes and environmental parameters. Lnd use - land use pattern beyond the riparian zone; R width - width of riparian zone; R compl - completeness of riparian zone; Ret str - retention structures; B undc - bank undercutting; Bottom - stream bottom; ● - Bloščica; ■ - Cerkniščica. Codes for macrophyte taxa are given in Table 1 and Table 2.

Slika 7: CCA ordinacijski diagram s taksoni makrofitov in spremenljivkami okolja. Lnd use - raba tal v zaledju struge; R width - širina obrežnega pasu; R compl - sklenjenost vegetacije v obrežnem pasu; Ret str - zadrževalne strukture v strugi; B undc - spodjedanje brega; Bottom - dno; ● - Bloščica; ■ - Cerkniščica. Oznake za taksone makrofitov so v Tabeli 1 in Tabeli 2.

cinson 1975). Shaded parts of the watercourses were scarcely colonised with vascular macrophytes. Mosses were dominant group of macrophytes in that stretches. Diversity and distribution of macrophytes in lowland rivers depend on the concentration of nutrients, current velocity and anthropogenic impact (Hrivnàk et al. 2007). Human impact on water ecosystem was less evident in the case of the watercourse Bloščica, where wet grasslands colonising the areas along the watercourse were less appropriate for agricultural use. Similarly, human impact was not prominent in the upper parts of watercourse Cerkniščica, since the area was covered by forests and wet meadows. Six species, listed on the Slovenian Red list (Ur. l. RS 82/2002) as vulnerable, thrive in the sites, where watercourses flow in the natural or little altered landscape with relatively wide riparian zone, and mixed silty and sandy sediment with organic matter as also reveals from previous researches (Kuhar et al. 2009).

The decrease of heterogeneity of habitats induces lower diversity of macrophytes (O'Hare et al. 2006). In the watercourse Bloščica fine mate-

rial and detritus was the prevailing sediment type, banks predominantly consisted from fine inorganic material. Lower number of macrophytes thereafter reflected the homogeneity of the habitat. Relatively homogeneous habitat was found also in the watercourse Cerkniščica. Flow velocity influences the occurrence of macrophytes (Janauer et al. 2010). Upper part of the watercourse Bloščica had higher slope and fast current velocity. Watercourse became wider downstream, current velocity was slower. In that part of the Bloščica, the variety of macrophytes species was higher.

Riis et al. (2000) stated that water chemistry and different tolerance of species to nutrient load determine the distribution of macrophytes. Thus, on the basis on the presence of the certain species of macrophytes, the loading of watercourses with nutrients can be assessed. Acceleration of eutrophication is a consequence of human activity, especially urbanization, agriculture and industry (Germ et al. 2008). *Potamogeton lucens* grows in eutrophic, relatively deep and on calcareous bedrock flowing lowland streams (Preston 1995) as holds true for the last part of the watercourse Bloščica. Genus *Chara* was found in both watercourses only in stretches located far from agricultural areas. Species richness of the genus *Chara* drops when amount of nutrient arises. Bornette and Arens (2002) stated that species in genus *Chara* are pioneer species in habitats, where disturbance appears very often. In the case of both watercourses water-level fluctuations presented the main disturbance. *Myriophillum spicatum* avoids fast flowing and oligotrophic waters (Germ and Gaberščik 1999); it was found in the lower parts of studied watercourses.

Conclusions

1. In the watercourse Bloščica 19 taxa of macrophytes were detected. Three species found are listed on the Slovenian Red list of Pteridophyta and Spermatophyta as vulnerable namely *Menyanthes trifoliata*, *Potamogeton lucens* and *P. nodosus*.
2. In the watercourse Cerkniščica 20 taxa of macrophytes were found. Three of them are listed on the Slovenian Red list of Pteridophyta and Spermatophyta as vulnerable namely *Nymphaea alba*, *Potamogeton nodosus* and *Polygonum amphibium*.
3. The majority of species in the both watercourses had amphibious and helophytic growth form, while submerged species were relatively scarce.
4. Presence and abundance of macrophytes changed along the watercourses mainly due to land use type, width of the riparian zone and bottom properties. Abundance of macrophytes in both watercourses was the highest in unshaded stretches with the middle current velocity.

Povzetek

Namen raziskave je bil ugotoviti pojavljanje, razporeditev in pogostost makrofitov v Bloščici in Cerkniščici. Opisali smo stanje širšega vodnega okolja obeh vodotokov ter povezavo med okoljskimi razmerami in pojavljanjem makrofitov. Vodotoka smo razdelili na odseke (24 odsekov na Bloščici, 23 odsekov na Cerkniščici), v katerih smo popisali makrofite. Hkrati s popisom makrofitov smo ocenili širše okolje s po Petersenu prirejeno RCE metodo (Germ et al. 2003) in habitatne parametre. V obeh vodotokih smo skupno popisali 25 taksonov makrofitov. Večjo pestrost makrofitov smo zasledili na mestih, kjer je vodni tok počasnejši in kjer je vpliv človeka zmanjšan (npr. urbanizirana območja, kmetijske površine). Vodotoka se razlikujeta v habitatnih parametrih in prisotnosti makrofitov. Pomemben je tip sedimenta, saj se rastline lažje ukoreninjajo v bolj trdnem substratu kot v rahlih, finih delcih. V Bloščici se je večinoma pojavljal detrit, v Cerkniščici pa so se ob detritu pojavljali še pesek in skale. Kanonična korespondenčna analiza je pokazala, da šest okoljskih parametrov značilno vpliva na pojavljanje in pogostost makrofitov. Največji vpliv imajo struktura dna, širina obrežnega pasu, zadrževalne strukture v strugi in zaledje.

Acknowledgements

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