Quality of aquatic environment and macrophytes in Slovenian watercourses

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Keywords: environment quality, macrophytes, Slovenia, watercourses

Introduction

Slovenia is characterised by heterogeneous geomorphology with carbonate rocks presenting over 40 % of its surface. The same holds true for climate ranging from Mediterranean to continental, resulting in the gradient of precipitation rate. About 57 % of Slovenian territory is covered by forest, while agriculture developed mainly in lowlands beside the rivers. These properties along with anthropogenic activity determine the properties of different watersheds and consequently the quality of the environment in watercourses.

The aims of this study were to examine the quality of the physical environment of different watercourses in Slovenia by assessing the properties of riverbed, riparian zone and land use beyond the riparian zone, to establish the distribution and abundance of macrophytes in watercourses and to get an insight into the relationship between the quality of environment and macrophyte presence and abundance.

Material and Methods

Site description: Twenty-nine watercourses in Slovenia were studied. In the Dolenjska region the Kolpa, Sotla, Krka, Temenica and Rinža rivers were examined. In the Notranjska region, we surveyed seven streams characterised by intermittent water regime. In the Dravsko polje region and Središko polje region along the Drava river, we surveyed seven and four lowland streams, respectively. In the Ljubljansko barje region, six watercourses were examined.

Environment assessment: The watercourses were divided into subsequent reaches. The environmental condition of watercourses was assessed using the modified Riparian, Channel and Environmental (RCE) Inventory proposed by PETERSEN (1992). We assessed twelve environmental parameters that describe land use beyond the riparian zone, the structure of riparian zone (width, completeness, and type of vegetation) and stream channel morphology (bank structure and undercutting, channel structure, the dynamics of river flow, the type of bottom and detritus, occurrence of retention structures and the accumulation of sediments). Each parameter includes four categories comprising the quality gradient, from the most natural to the most modified status of physical environment.

Macrophyte survey: The distribution and abundance of macrophytes were assessed from the bank or using a boat. The relative abundance was evaluated using a five-degree scale: 1 = very rare; 2 = infrequent; 3 = common; 4 = frequent; 5 = abundant, predominant (KOHLER & JANAUER, 1995; European Standard EN 14184, 2003). Plants were identified using the following keys: CASPER & KRAUSCH (1980), PRESTON (1995) and MARTINČIČ et al. (1999).

Statistical analysis: Canonical correspondence analysis (CCA) was used to assess the relationship between the presence and abundance of macrophytes, and environmental

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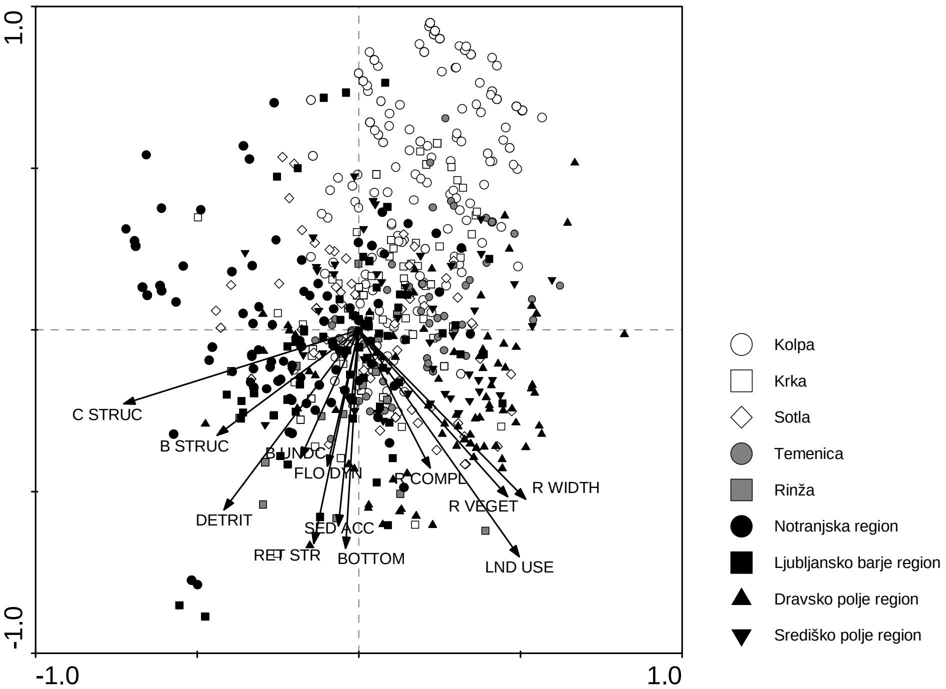
parameters. Categories of environmental parameters were coded numerically from 1 to 4. The statistical significance of environmental parameters was tested by the Monte Carlo permutation test. Analyses were performed using Canoco for Windows Version 4.5.

Results and Discussion

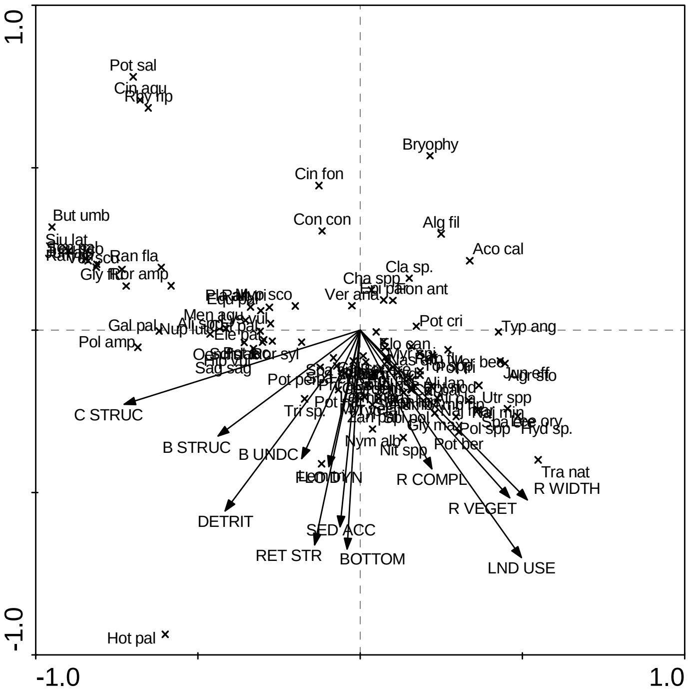
The studies of macrophytes in Slovenia have been performed systematically only in a few water bodies (SELIŠKAR, 1993; GERM et al., 2000; GERM et al., 2003). Recently, it becomes evident that the knowledge of the macrophyte species composition and abundance reveals important information about the aquatic ecosystem. According to EU Water Framework Directive macrophytes are among the three biological elements needed for the determination of ecological status of running waters (DODKINS et al., 2005).

Table 1. The list of the species found in the watercourses examined

Acorus calamus L.	Aco cal	*Nitella* spp.	Nit spp
Agrostis stolonifera L.	Agr sto	*Nuphar luteum* (L.) Sibth. & Sm.	Nup lut
Algae filamentosae	Alg fil	*Nymphaea alba* L.	Nym alb
Alisma lanceolatum With.	Ali lan	*Oenanthe fistulosa* L.	Oen fis
Alisma plantago-aquatica L.	Ali pla	*Phalaris arundinacea* L.	Pha aru
Alisma spp.	Ali spp	*Phragmites australis* (Cav.) Trin. ex Steud.	Phr aus
Amblystegium riparium (Hedw.) Schimp.	Amb rip	*Plantago altissima* L.	Pla alt
Berula erecta (Huds.) Coville	Ber ere	*Polygonum amphibium* L.	Pol amp
Bryophyta	Bryophy	*Polygonum* spp.	Pol spp
Butomus umbellatus L.	But umb	*Potamogeton berchtoldii* Fieber	Pot ber
Callitriche palustris L.	Cal pal	*Potamogeton crispus* L.	Pot cri
Callitriche spp.	Cal spp	*Potamogeton filiformis* Pers.	Pot fil
Caltha palustris L.	Cat pal	*Potamogeton lucens* L.	Pot luc
Ceratophyllum demersum L.	Cer dem	*Potamogeton natans* L.	Pot nat
Chara spp.	Cha spp	*Potamogeton nodosus* Poir	Pot nod
Cinclidotus aquaticus (Hedw.) B. & S.	Cin aqu	*Potamogeton pectinatus* L.	Pot pec
Cinclidotus fontinaloides (Hedw.) P. Beauv.	Cin fon	*Potamogeton perfoliatus* L.	Pot per
Conocephalum conicum (L.) Underw.	Con con	*Potamogeton x salicifolius* Wolfg.	Pot sal
Cladophora sp.	Cla sp.	*Potamogeton trichoides* Cham. et Schld	Pot tri
Eleocharis palustris (L.) Roem. et. Schult.	Ele pal	*Ranunculus circinatus* Sibth.	Ran cir
Elodea canadensis L. C. Rich.	Elo can	*Ranunculus flammula* L.	Ran fla
Epilobium hirsutum L.	Epi hir	*Ranunculus fluitans* Lam.	Ran flu
Epilobium parviflorum Schreber	Epi par	*Ranunculus lingua* L.	Ran lin
Equisetum palustre L.	Equ pal	*Ranunculus trichophyllus* Chaix	Ran tri
Fontinalis antipyretica Hedw.	Fon ant	*Rhynchostegium riparioides* (Hedw.) Card.	Rhy rip
Galium palustre L.	Gal pal	*Rorippa amphibia* (L.) Besser	Ror amp
Glyceria fluitans (L.) R. Br.	Gly flu	*Rorippa sylvestris* (L.) Besser	Ror syl
Glyceria maxima (Hartm.) Holmb.	Gly max	*Rumex hydrolapathum* Hudson	Rum hyd
Hippuris vulgaris L.	Hip vul	*Sagittaria sagittifolia* L.	Sag sag
Hottonia palustris L.	Hot pal	*Schoenoplectus lacustris* (L.) Palla	Sch lac
Hydrodictyon reticulatum (L.) Lagerh.	Hyd ret	*Scrophularia umbrosa* Dumort.	Scr umb
Iris pseudacorus L.	Iri pse	*Senecio paludosus* L.	Sen pal
Juncus alpino-articulatus Chaix	Jun alp	*Sium latifolium* L.	Siu lat
Juncus effusus L.	Jun eff	*Sparganium emersum* Rehmann	Spa eme
Leersia oryzoides (L.) Sw.	Lee ory	*Sparganium erectum* L.	Spa ere
Lemna minor L.	Lem min	*Sparganium* spp.	Spa spp
Lemna trisulca L.	Lem tri	*Spirodela polyrhiza* (L.) Schleid.	Spi pol
Lycopus europaeus L.	Lyc eur	*Teucrium scordium* L.	Teu sco
Lysimachia vulgaris L.	Lys vul	*Tolypella* spp.	Tol spp
Lythrum salicaria L.	Lyt sal	*Trapa natans* L.	Tra nat
Mentha aquatica L.	Men aqu	*Tribonema* sp.	Tri sp.
Mentha longifolia (L.) Hudson	Men lon	*Typha angustifolia* L.	Typ ang
Myosotis scorpioides L.	Myo sco	*Typha latifolia* L.	Typ lat
Myriophyllum spicatum L.	Myr spi	*Utricularia* spp.	Utr spp
Myriophyllum verticillatum L.	Myr ver	*Veronica anagallis-aquatica* L.	Ver ana
Najas marina L.	Naj mar	*Veronica beccabunga* L.	Ver bec
Najas minor All.	Naj min	*Veronica scutellata* L.	Ver scu
Nasturtium officinale R. Br. in Aiton	Nas off	*Zannichellia palustris* L.	Zan pal



(a)



(b)

Figure 1. CCA ordination diagram showing the relationship between environmental parameters (Lnd use - land use pattern beyond riparian zone, R width - width of riparian zone, R compl - completeness of riparian zone, R veget - vegetation of riparian zone, Ret str - retention structures, C struc - channel structure, Sed acc - accumulation of sediments, B struc - bank structure, B undc - bank undercutting, Bottom - stream bottom, Flo dyn - flow dynamics, Detrit - detritus) and the macrophyte presence and abundance in the watercourses examined. (a) Environmental parameters and reaches of watercourses. (b) Environmental parameters and the abundance of macrophytes. Codes for macrophytes are given in Table 1.

In our research 96 different species were found on the length of about 600 km of watercourses (Table 1). The relationship between the composition of macrophyte communities and environmental parameters was identified using CCA. We surveyed 12 parameters of the RCE inventory, namely, land use beyond the riparian zone, width, completeness and vegetation type of the riparian zone, presence of retention structures in the channel, channel structure, sediments accumulation, bank structure and undercutting, stream bottom and detritus type, and flow dynamics (the presence of riffles and pools, or meanders). All environmental parameters were taken into account for CCA ($P=0.001$). They explain only 11.9 % of the variance in the composition of macrophyte community. This is probably due to the fact that some other parameters i.e. geological features, stream size and nutrient status might be more influential. The influence of single surveyed parameter was rather low. Channel structure and land use beyond the riparian zone were the most important parameters explaining 2.3 % and 1.8 % of the variance, respectively. The biplot of the first two canonical axes (eigenvalues 0.30 and 0.19, respectively) is shown in Figure 1. The quality of environmental parameters decreases in the direction of the arrows. The origin of arrows presents the middle of the quality gradient of the environmental parameter, while the best quality of environmental parameter opposes the end of the arrow. According to the RCE inventory good environmental conditions are characteristic of the Kolpa river and upper flow of the Krka river and some other watercourses. Moderate conditions were observed in the lower flow of the Krka river, the majority of reaches of Rinža and Temenica rivers and partly in streams of the Ljubljansko barje region, the Središko polje region and the Dravsko polje region. The reaches of the Sotla river are scattered in the lower part of the biplot indicating moderate to bad environmental conditions. The reaches of the Notranjska region watercourses are also scattered in the biplot even though that this watercourses flow through relatively natural landscape, since the intermittent water regime prevents human impacts such as agriculture, industry, infrastructure, and settlements, as well as the melioration measures aimed to mitigate floods or droughts. The intermittent water regime also influences macrophyte community favouring plant species with amphibious character.

The heterogeneous environment of rivers results in dynamic and non-uniform distribution of macrophyte species as it was also established by some other authors (Bornette et al., 1994; Baatrup-Pedersen & Riis, 1999). The distribution of macrophytes in the biplot shows that the bulk of macrophyte species is concentrated in the area marked by moderately disturbed environment. Separate group of species is correlated to the intermittent watercourses of the Notranjska region. More natural environment is indicated mainly by different species of mosses, since the conditions, namely water velocity and substrate structure are not suitable for colonisation with higher plants.

Summary

The environmental condition of watercourses was assessed using a modified Riparian, Channel and Environmental (RCE) Inventory proposed by Petersen (1992). The survey of macrophytes was performed following the methodology of Kohler & Janauer (1995) and European Standard EN 14184.

In whole about 600 km of watercourses was examined. The highest macrophyte diversity was estimated in intermittent streams of the Notranjska region, probably due to variable water regime. Great variety of habitats also supported high plant diversity in the Krka river. The Kolpa river exhibited good status of environment, but macrophyte diversity was rather low. The results revealed worse environment condition and lower macrophyte diversity in watercourses flowing through the landscape with intense anthropogenic activity, and with heavily modified riverbeds, as was the case of the Sotla river.

Acknowledgements

This research was financed by the Slovenian Ministry of Higher Education, Science and Technology through programs "Biology of plants" and "Young researchers". Additional support was given by Austrian Ministry of Education, Science and Arts through the project "Multifunctional Integrated Study Danube. Corridor and Catchment" (MIDCC). The financial support is gratefully acknowledged.

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