Arch. Biol. Sci., Belgrade, 61 (2), 289-296, 2009 DOI:10.2298/ABS0902289T

TEMPORAL AND SPATIAL DISTRIBUTION OF MACROPHYTES IN THE GRUŽA RESERVOIR (SERBIA)

MARINA TOPUZOVIĆ, DRAGANA PAVLOVIĆ, and A. OSTOJIĆ

Institute of Biology and Ecology, Faculty of Science, 34000 Kragujevac, Serbia

Abstract — A survey of aquatic macrophytes in the Gruža Reservoir (Serbia) was conducted during the period 2007-2008. Detailed data on the actual condition of macrophytes were established and compared between four parts of the reservoir. The distributions of most aquatic macrophytes of the Gruža Reservoir are heterogeneous, with different values of the MMT and MMO indices and low values of the distribution ratio. Quantitative analysis indicates that the greatest diversity and abundance of species can be found in those parts of the reservoir with the shallowest water and greatest indentation of the shoreline.

Key words: Macrophytes, distribution, relative plant mass, mean mass indices, Gruža Reservoir, Serbia

UDC 575.4:58(497.11)

INTRODUCTION

Macrophytes as primary producers have an important role in maintaining the stability of dynamic equilibrium, nutrient cycling, sedimentation processes, and biofiltration in aquatic ecosystems (Wetzel, 1983). They are also valuable as indicators of water quality.

Although their presence is regulated by water quality, water depth, and substrate characteristics, morphometric characteristics of reservoirs on the whole show better correlations with vegetation structure than any measured chemical parameters (Heegaard et al., 2001; Mäkelä et al., 2004). Favorable morphometrical conditions make quick colonization possible in still water (Neiff, 2000). A high level of macrophyte development and especially overgrowth of emerged plants cause eutrophication of reservoirs (Wetzel, 1983; Moss, 1990).

We investigated macrophytes in a lowland eutrophic reservoir, one whose water quality supports development of this vegetation, but whose different habitat characteristics along the shoreline cause different distribution of macrophytes. Knowledge of the diversity, composition, abundance, and habitat preference of macrophytes provides important information about the ecological status of this aquatic ecosystem and makes it possible to predict possible changes in ecosystem quality.

MATERIAL AND METHODS

The Gruža Reservoir was formed in 1985, in the central region in Serbia, at an elevation of 238 m above sea level. The flooded area had a well-developed pedological substrate and represented one of the most fertile regions of Serbia. The lake is 10 km long and 0.2-1.5 km wide, with surface area of 934 ha. Oscillations of the water level comprise 3-5 m. Maximum depth of the water is 31 m near the dam, whereas two thirds of the reservoir are shallow (3-9 m).

Field work was carried bimonthly from September to July during the period 2007-2008. Macrophytes were surveyed in four parts of variable length (A, B, C, and D in Fig. 1), depending on vegetation distribution patterns, morphometric characteristics of the reservoir, water depth, and human impact. Part A of the shoreline is 1 km and lies next to both sides of the dam. Its banks are steep, unindentend, naked, and rocky, with great depths occur-

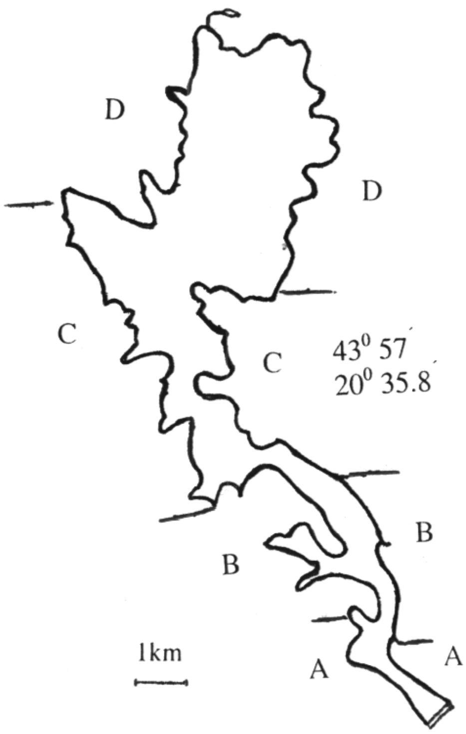

Fig. 6. Distribution diagram of macrophyte populations in 2003.

ring just off shore. The maximum depth is 31 m. Part B has a somewhat more indented and less steep shoreline, and the water is less deep. The maximum depth here is 21 m. In part C, the shoreline is shallow, muddy, and indented, with maximum depth of 9 m. Part D has a shallow muddy shoreline surrounded by agricultural fields, with a very gently-sloping littoral and maximum depth of 3.5 m.

Every homogeneous shoreline stretch with macrophyte colonization was investigated by the transect method. Plants growing on the shore and in water to a depth of 5 m were collected (with a grapple) and determinated according to Javorka and Shapody (1979).

Because several phytocenological areas are covered by the transect method, this paper gives a synthetic view of the presence of species of aquatic macrophytes during the period of investigations. The relative abundance was evaluated using a five-point scale (Kohler and Schneider, 2003) as follows: 1 - very rare, 2 - infrequent, 3 - common, 4 - frequent, and 5 - abundant, predominant. The obtained data form the base for a mathematical model with: relative plant mass (RPM) for each species; cumulative RPM for growth forms; mean mass indices for all macrophytes in total stretches (MMT); mean mass indices for stretches with their occurrence (MMO); and the distribution ratio (d) (Pall and Janauer, 1995). These data sets are used to describe quantitative relationships of aquatic macrophyte vegetation.

The Sørenson similarity index S (Schwerdtfeger, 1975) was used to calculate the degree of similarity between populations of macrophytes today and at the time of earlier investigations, based on the results of Veljović et al. (1986).

RESULTS

The main physical, chemical (Table 1), biological (chlorophyll a, zooplankton), and microbiological parameters (Ostojić et al., 2005) indicated that the reservoir's water belongs to the eutrophic category.

Table 1. Average annual values of some physical and chemical water characteristics of Gruža Reservoir, Serbia (Ostojić et al. 2005).

Water characteristics	
Temperature (C^0)	14,2
Disolved oxygen (mg l^{-1})	4,99
Conductivity (μS cm^{-1})	363
pH	7,84
$KMnO_4$ consump. (mg l^{-1})	23,53
Total P (μg l^{-1})	0,06
Nitrates (μg l^{-1})	0,51
Nitrites (μg l^{-1})	0,01
NH_4^+ (μg l^{-1})	0,22
Ca^{2+} (mg l^{-1})	51,5
Mg^{2+} (mg l^{-1})	27,3
Saturation %	44,5
Secchi depth (m)	1,1

Table 2. Floristic composition of the macrophytes in the four parts of the Gruža Reservoir. For A, B, C and D – see Material and Methods.

Plant species	Abbrevation	year	Parts of Reservoir			
			A	B	C	D
Submerged						
Ceratophyllum demersum L.	Cer dem	2008	+	+	+	+
		1986	-	-	-	-
C. submersum L.	Cer sub	2008	+	+	+	+
		1986	-	-	-	-
Myriophyllum spicatum L	Myr spi	2008	+	+	+	+
		1986	-	-	-	-
M. verticillatum L.	Myr ver	2008	+	+	+	+
		1986	-	-	-	-
Najas marina L.	Naj mar	2008	+	+	-	-
		1986	-	-	-	-
Potamogeton crispus L.	Pot cri	2008	-	+	+	+
		1986	-	-	+	+
P. pusillus L.	Pot pus	2008	-	-	+	+
		1986	-	-	+	-
Veronica anagallis-aquatica L.	Ver ana	2008	-	+	+	+
		1986	-	-	-	-
Veronica beccabunga L.	Ver bec	2008	-	-	+	+
		1986	-	-	+	+
Floating						
Lemna gibba L.	Lem gib	2008	-	-	+	+
		1986	-	-	+	+
Lemna minor L.	Lem min	2008	-	-	+	+
		1986	-	-	+	+
Polygonum amphibium L.	Pol amp	2008	-	+	+	+
		1986	-	-	-	-
Potamogeton fluitans L.	Pot flu	2008	-	-	+	+
		1986	-	-	+	+
Emerged						
Alisma plantago- aquatica L	Ali pla	2008	-	+	+	+
		1986	-	-	+	+
Butomus umbellatus L.	But umb	2008	-	-	+	+
		1986	-	-	-	-
Glyceria fluitans (L.) R. Br.	Gly flu	2008	-	-	+	+
		1986	-	-	-	-
Heleocharis palustris (L.) R.Br	Hel pal	2008	-	+	+	+
		1986	-	-	+	+
Iris pseudacorus L.	Iri pse	2008	-	+	+	+
		1986	-	-	-	-
Lycopus europaeus L	Lyc eur	2008	-	+	+	+
		1986	-	+	+	-
Lycopus exaltatus L.	Lyc exa	2008	-	+	+	+
		1986	-	-	-	-
Lythrum salicaria L.	Lyt sal	2008	-	+	+	+
		1986	-	-	+	-
Mentha aquatica L.	Men aqu	2008	-	+	+	+
		1986	-	-	-	-
Mentha spicata tomentosa Urv.	Men spi	2008	-	+	+	+
		1986	-	-	-	-
Oenanthe aquatica (L.) Poir	Oen aqu	2008	-	+	+	+
		1986	-	-	-	-
Phragmites australis Trin.	Phr aus	2008	-	-	+	+
		1986	-	-	-	-
Scirpus silvaticus L.	Sci sil	2008	-	-	+	+
		1986	-	-	+	-
Shoenoplectus palustris L.	Sho pal	2008	-	-	-	-
		1986	-	-	+	+
Typha angustifolia L	Typ ang	2008	-	-	+	+
		1986	-	-	+	-
Typha latifolia L.	Typ lat	2008	-	-	+	+
		1986	-	-	+	-
Sørenson index for parts of Reservoir in %				11,1	63,4	45,7
Sørenson index for whole Reservoir in %			61,91			

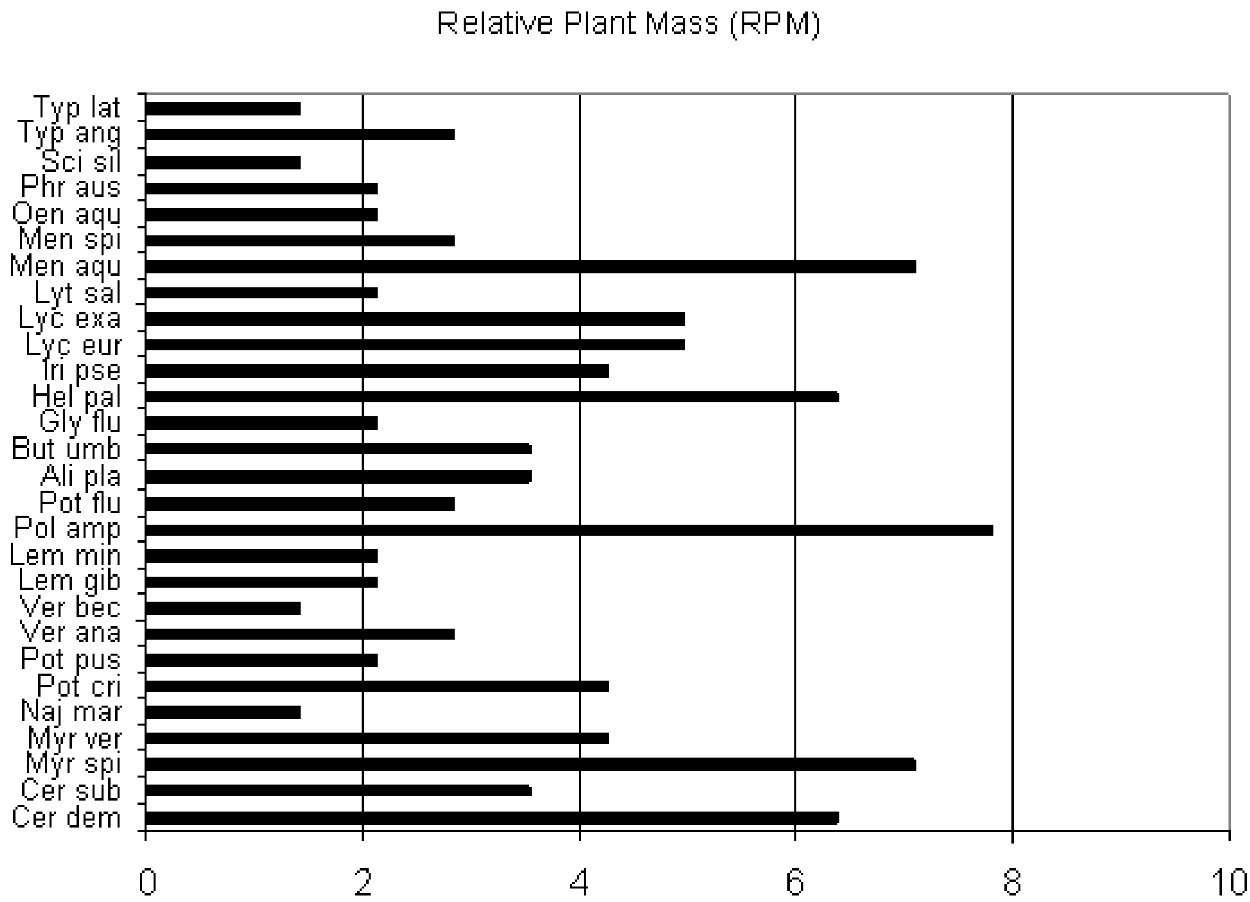

Fig. 2. Relative plant Mass (RPM) of aquatic macrophytes in the Gruža Reservoir as a fraction of all macrophytes.

The indicated status of the reservoir is reflected in the presence and composition of macrophytic vegetation. In accordance with the eutrophic status of the reservoir, eutrophic species are dominant. Macrophytes such as *Potamogeton crispus*, *Phragmites australis*, *Ceratophyllum demersum*, and *C. submersum* belong to a set of species which indicate highly eutrophic waters (Kohler and Schneider, 2003).

Data on the actual condition of aquatic macrophytes were established and compared between four parts of the reservoir (Table 2).

Thus, in part A next to the dam (Fig. 1, Table 2) – where banks are steep, unindented, and naked and where great depth occurs just off shore – submerged species are represented by few species, while floating and emerged species are not present. In this part, macrophytes were not recorded in 1986 (Veljović et al., 1986).

Part B (Fig. 1, Table 2) – whose shoreline is somewhat more indented and less steep, and where the water is less deep – has more recorded species, but still small coverage. *Ceratopyllum demersum* and *Polygonum amphibium* are dominant here. In 1986 there existed very poor macrophyte vegetation. Low values of the Sørenson similarity index indicate that there are great differences between the earlier and current state of macrophytes, which over 22 years settled this unfavorable area.

In the zone of submerged vegetation in the next part of the reservoir (part C in Table 2 and Fig. 1), *Myriophyllum spicatum* (which builds underwater

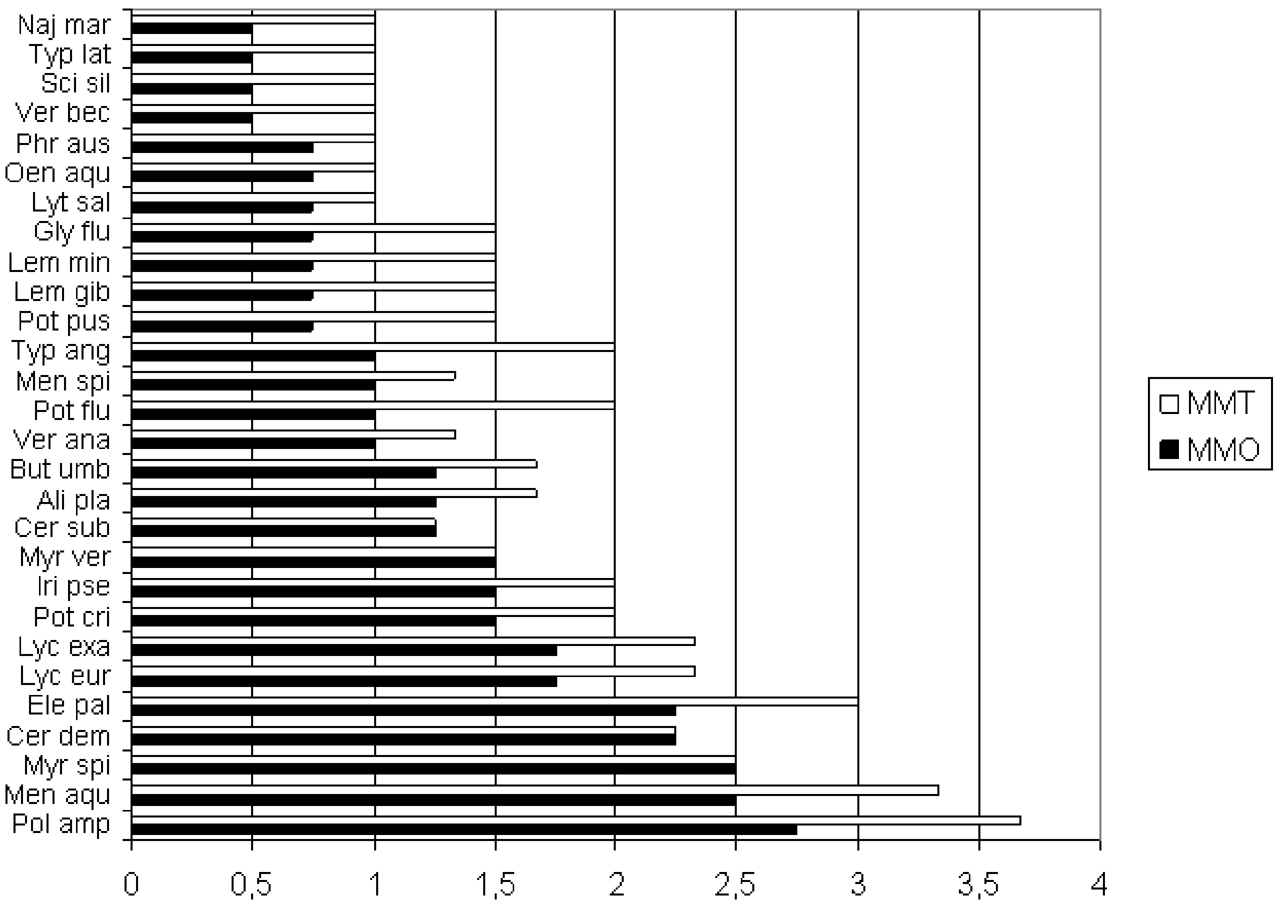

Fig. 3. Mean mass indices (MMT, MMO) calculated for all aquatic macrophytes in stretches with their occurrence (MMT, empty column) and total stretches (MMO, dark column) in the Gruža Reservoir.

meadows here to a depth of 4 m) is the dominant species, followed by *Ceratophyllum demersum* and *Potamogeton crispus.* This part has an indented, shallow, and muddy shoreline. The zone of floating plants contains *Polygonum amphibium* as a dominant species. The zone of emerged plants is the richest in species. The most dominant is *Mentha aquatica* in shallow parts. Values of the Sørenson similarity index (Table 2) show a high degree of similarity between the two times of analysis.

Part D (Fig. 1, Table 2) – whose shoreline is shallow, muddy, indented, and surrounded by agricultural fields, with a very gently-sloping littoral – is rich in species and coverage, both at the present time and in the past, and values of the Sørenson similarity index indicate that there are small differences between the earlier and current state of macrophytes.

Myriophyllum spicatum is the most common submerged species and together with *M. verticillatum* builds underwater meadows. Less frequently and in the deep water other submerged species are also present, but shallow water does not permit massive development of these species. Floating vegetation is represented by the dominant species *Polygonum amphibium. Heleocharis palustris*, *Mentha aquatica*, and *Lycopus exaltatus* are the most common emerged species. Values of the Sørenson similarity index (Table 2) indicate that there are small differences between the earlier and current state of macrophytes.

Our survey showed that the highest percentage of RPM was recorded for *Polygonum amphibium*, *Myriophyllum spicatum*, *Ceratophyllum demersum*, and *Heleocharis palustris* (Fig. 2). The cumulative RPM is 51.77% for emerged species, 33.33% for sub-

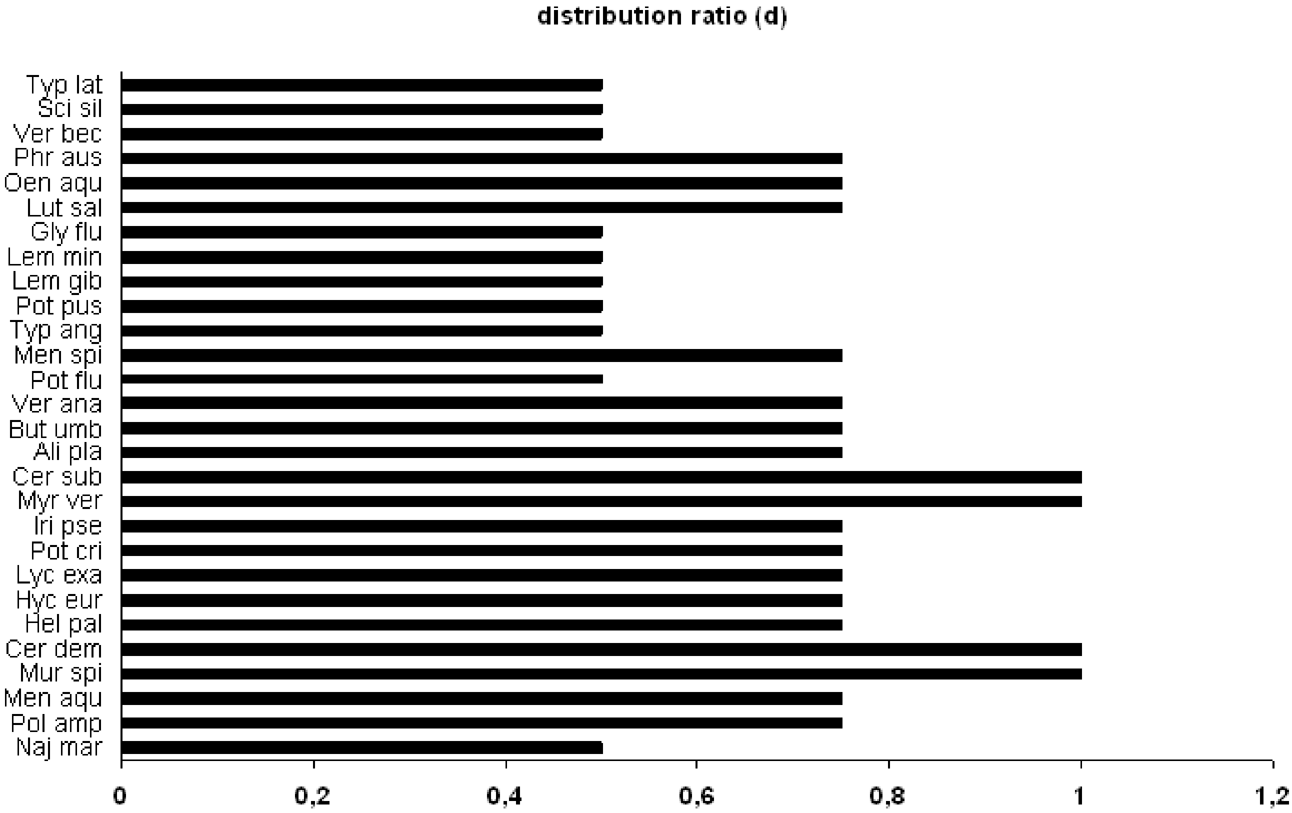

Fig. 4. Distribution ratio (d) of aquatic macrophytes in the Gruža Reservoir.

merged species, and 14.90% for floating species.

The MMT and MMO values are low for most plant species, indicating that the species occur in small populations (Fig. 3). The MMT and MMO values are levelled and low for the species *Ceratophyllum demersum*, *C. submersum*, *Myriophyllum spicatum*, and *M. verticillatum* because these species are present with low plant masses in all surveyed sections (a homogeneous distribution pattern).

In this case, the distribution ratio (d) in Fig. 4 has a value of 1. For the Gruža Reservoir as a whole, the distributions of most aquatic macrophytes at the present time are heterogeneous, with different MMT and MMO values and a low value of the distribution ratio (Figs. 3 and 4).

DISCUSSION

Although prior to formation of the Gruža Reservoir the terrain lacked swamp vegetation, macrophytes there developed very quickly after the reservoir's creation. Already in the first year after its formation, the entire shallow and muddy littoral was overgrown with macrophyte vegetation, most extensively in the inlets (Veljović et al., 1986).

The quickness and manner of this colonization corresponded to data published for the Kis-Balaton Reservoir (Herodek, 2001) and for the Yacireta Reservoir (Neiff et al., 2000) and show that the first changes in the flora occurred very quickly, while in recent years changes in vegetation structure seem to be much slower. Because of this, the high value of the Sørenson similarity index for the Gruža Reservoir as a whole (Table 2) shows a high degree of similarity between the two times of analysis. Comparison with results from the period 1999-2002 (Topuzović and Pavlović, 2004) shows that there are no differences in species diversity.

It is known that eutrophic conditions support the growth of vascular aquatic plants (Carbinier et al., 1990). The high species diversity of macrophytes in the Gruža Reservoir is also a consequence of the diversity of habitats on the banks of the reservoir, mainly morphometric characteristics of the shoreline, its slope, water depth, and pollution by nutrients (Wetzel, 1983; Heegaard et al., 2001; Irfanullah and Moss, 2004). There is a pronounced poverty of species with small coverage in the part of the lake next to the dam, which has the form of a gorge with steep rocky banks that are virtually naked and where great depth occurs just off shore and poor physical conditions rather than water quality might be responsible for restricting biodiversity. The greatest diversity and RPM of species can be found in parts of the lake with the shallowest water and greatest indentation of the shoreline, where nutrients are constantly leached into it.

Our results on the significance of morphometric characteristics of the reservoir for macrophyte development correspond to the data of Neiff et al. (2000), Heegaard et al. (2001), and Irfanullah and Moss (2004). Mäkelä et al. (2004) came to the conclusion (based on investigation of the diversity and community structure of macrophyte vegetation in 50 lakes in Finland) that morphometric characteristics of lakes on the whole show better correlations with vegetation structure than any measured chemical parameters.

Although today increased numbers of species are present in the Gruža Reservoir as a whole, no significant increase of abundance and mass is discernible because frequent fluctuations of the water level limit their development (Tarver, 1980; Hellsten and Riihimäki, 1996). This is especially important for emerged plants, which are richest in diversity and whose death followed by accumulation of difficultly soluble lignin and cellulose leads to creation of anaerobic conditions in the sludge, thereby contributing to the process of eutrophication. Because of this, the presence of macrophytes is not excessive, and they are still a desirable component of the reservoir for regulation of the development of phytoplankton and Cyanobacteria, competition with algae for nutrients, and biofiltration of the large influx of allochthonous nutrients. The macrophytes accumulate nutrients, excluding them from the biogeochemical cycle for a certain period, during which they can be removed from the system by harvesting. Macrophyte harvesting provides the best possibility for the removal of nutrients (Engel, 1990; Moss, 1990; Heegaard et al., 2001). This is important and advisable for the Gruža Reservoir, 2/3 of which are surrounded by cultivated fields.

Together with other measures, monitoring of further development of macrophytes and their regulation are needed for conservation of the Gruža Reservoir. This is very important primarily because of the reservoir's significance as a source of water supply for settlements.

Acknowledgment — This research was supported by grant No. 22001 from the Ministry of Science of Serbia (Project: Development and Implementation of a SeLaR Information System on Lakes and Reservoirs in Serbia).

REFERENCES

Carbiener, R., Trémolières, M., Mercier J. L., and *A. Ortscheit* (1990). Aquatic macrophyte communities as bioindicators of eutrophication in calcareous oligosaprobe stream waters (Upper Rhine plain, Alsace). *Vegetatio* **86**, 71-88.

Engel, S. (1990). Ecological impacts of harvesting macrophytes in Halverson Lake, Wisconsin. *J. Aquat. Plant Management* **28**, 41-45.

Heegaard, E., Birks, H. H., Gibson, C. E., Smith, S., and *S. Wolfe-Murphy* (2001). Species-environmental relationships of aquatic macrophytes in Northern Ireland. *Aquat. Bot.* **70**, 175-223.

Hellsten, S., and *J. Riihimäki* (1996). Effects of lake water level regulation on the dynamics of littoral vegetation in Northern Finland. *Hydrobiologia* **340**, 85-92.

Herodek, S. (2001). Watershed development and eutrophication control of Lake Balaton. In: *Partnerships for Sustainable Life in Lake Environments: Making Global Freshwater Mandates Work*, Conference Proceedings, 9th International Conference on the Conservation and Management of Lakes, Biwako (Japan), 2001, 3C/D-P60 (3D-O06), pp. 489-492.

Irfanullah, H., and *B. Moss* (2004). Factors influencing the return of submerged plants to a clear-water, shallow temperate lake. *Aquat. Bot.* **80**, 177-191.

Javorka, S., and *V. Scapody* (1979). *Ikönographie der Flora des südostlichen Mitteleuropa*, 704 pp. Gustav Fischer Verlag, Stuttgart.

Kohler, A., and *S. Schneider* (2003). Macrophytes as bioindicators. In: *Macrophyte Inventory of the River Danube: a Pilot Study* (Eds. G. A. Janauer, P. Hale, and R. Sweeting), *Arch. Hydrobiol. Suppl.* **147 (1-2),** 17-31.

Mäkelä, S., Huitu, E., and *L. Arvola* (2004). Spatial patterns in aquatic vegetation composition and environmental covariates along chains of lakes in the Kokemäenjoki watershed (S. Finland). *Aquat. Bot.* **80 (4),** 253-269.

Moss, B. (1990). Engineering and biological approaches to the restoration from eutrophication of shallow lakes in which aquatic plant communities are important components. *Hydrobiologia* **200-201**, 367-377.

Neiff, J. J., Poi de Neiff, A. S. G., Patino, C. A. E., and *I. Basterra de Chiozzi* (2000). Prediction of colonization by macrophytes in the Yaciretá Reservoir of the Paraná River (Argentina and Paraguay). *Rev. Bras. Biol.* **60 (4),** 1-19.

Ostojić, A., Ćurčić, S., Čomić, Lj., and *M. Topuzović* (2005). Estimate of the eutrophication process in the Gruža Reservoir (Serbia and Montenegro). *Acta Hydrochim. Hydrobiol.* **33 (6),** 605-613.

Pall, K., and *G. A. Janauer* (1995). Die Makrophytenvegetation von Fluβstanten am Beispiel der Donau zwischen Fluβ-km 2552,0 und 2511,8 in der Bundesrepublik Deutschland. *Arch. Hydrobiol. Suppl.* **101,** *Large Rivers* **9,** 91-109.

Schwerdtfeger, F. (1975). *Ökologie der Tiere. B*and *3: Synökologie*, 678 pp. Paul Parey Verlag, Hamburg-Berlin.

Tarver, D. P. (1980). Water fluctuation and the aquatic flora of Lake Miccosukee. *J. Aquat. Plant Management* **18,** 19-23.

Topuzović, M., and *D. Pavlović* (2004). Physical organization of two reservoirs in Serbia as a crucial factor in development of their hydrophilic flora: a comparative study. *Hydrobiologia* **525,** 239-243.

Veljović, V., Marković, A., and *V. Vukomanović* (1986). Dijagnostički značaj pojave makrofitske flore i vegetacije u novoformiranim akumulacionim jezerima. Konferencija "Zaštita voda 86", Zbornik radova, 82-86.

Wetzel, R. G. (1983). *Limnology*, 767 pp. W. B. Saunders Co., Philadelphia, PA.

ВРЕМЕНСКА И ПРОСТОРНА ДИСТРИБУЦИЈА МАКРОФИТА АКУМУЛАЦИЈЕ ГРУЖА (СРБИЈА)

МАРИНА ТОПУЗОВИЋ, ДРАГАНА ПАВЛОВИЋ и А. ОСТОЈИЋ

Институт за биологију и екологију, Природно-математички факултет, 34000 Крагујевац, Србија

У раду су презентовани резултати истраживања просторне и временске дистрибуције акватичних макрофита у еутрофној акумулацији Гружа, вршених током 2007. и 2008. године. Детаљни подаци проучавања односа између дистрибуције, диверзитета и масе макрофита и еколошких услова средине (пре свега морфометријских карактеристика обале, дубине воде и утицаја полутаната), вршених дуж четири различита дела акумулације, упоређени су са ранијим истраживањима (Veljović et al., 1986), а Sørenson-ов индекс сличности је коришћен за одређивање степена сличности између популација макрофита. Дистрибуција већине макрофита акумулације Гружа је хетерогена, са средњим масеним индексима ММТ и ММО различитих вредности и ниским вредностима односа дистрибуције. Део акумулације уз брану карактерише се стеновитом и стрмом обалом, великом дубином, малим упливом полутаната и малим диверзитетом макрофита. Највећи диверзитет и бројност врста налази се у деловима са плитком водом, разуђеном обалом са доста рукаваца и сталним дотоком нутријената са околних поља.