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MACROPHYTES OF THE GRLIŠTE RESERVOIR (SERBIA): FIFTEEN YEARS AFTER ITS ESTABLISHMENT

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Abstract — A large number of macrophytes, often in dense populations, have developed on the Grlište Reservoir, Serbia over a period of 15 years. Fast development of vegetation is a consequence of anthropogenic impact in lake management. The methodology used in this research covered 100% of the water body, including all areas with or without aquatic plants. The results indicate that plant communities are still in the early phase of development. This leaves space for future development of competitor macrophyte species (*Najas marina, Eleocharis palustris, Typha latifolia, Typha angustifolia, Phragmites australis*, etc.) capable of endangering stability of the lake, which will tend toward eutrophication.

Key words: Macrophytes, monitoring, Grlište reservoir, competitor species, Serbia

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INTRODUCTION

Water plants in aquatic ecosystems have multiple significance (Janković et al., 1990; Brix, 1993, 1994; Elis et al., 1994; Stojanović et al., 1994; DeBusk et al., 2001). Macrophytes are an integrated part of every aquatic ecosystem. They are primary producers (of biomass and oxygen), constitute structural elements in water bodies, and form small habitats for numerous plant and animal life forms.

Aquatic plants have an important role in biological monitoring of natural habitats because changes in aquatic species composition and abundance are closely linked with water, sediment, and surrounding land quality (Tremp and Kohler, 1995; Pall et al., 1996; Melzer, 1999; Madsen et al., 2001). As determined by biomonitoring, the temporal distribution of macrophytic communities and their structural distribution (species composition, population density) represent important indicators of general ecological parameters that create any water ecosystem (Janauer, 2001).

The Grlište Reservoir was built in 1990 to meet the water supply demands of the city of Zaječar in Serbia and surrounding settlements. Since then, managing of this water body was restricted to monitoring of water physico-chemical parameters and biological quality. The appearance and development of vegetation did not receive any expert attention. Described in this paper, the first detailed surveys of vegetation (especially macrophyte vegetation) were begun in 2003, when the spatial distribution of macrophytes on some parts of the lake surface became dense and therefore obvious. Using modern scientific methods, starting with the European Water Framework Directive (WFD) as a guideline, this paper discusses the taxonomic composition and abundance of macrophytes in the given artificial lake.

MATERIALS AND METHODS

Study area

The Grlište Reservoir is located 10 km from the city of Zaječar, between the villages of Leksovac and

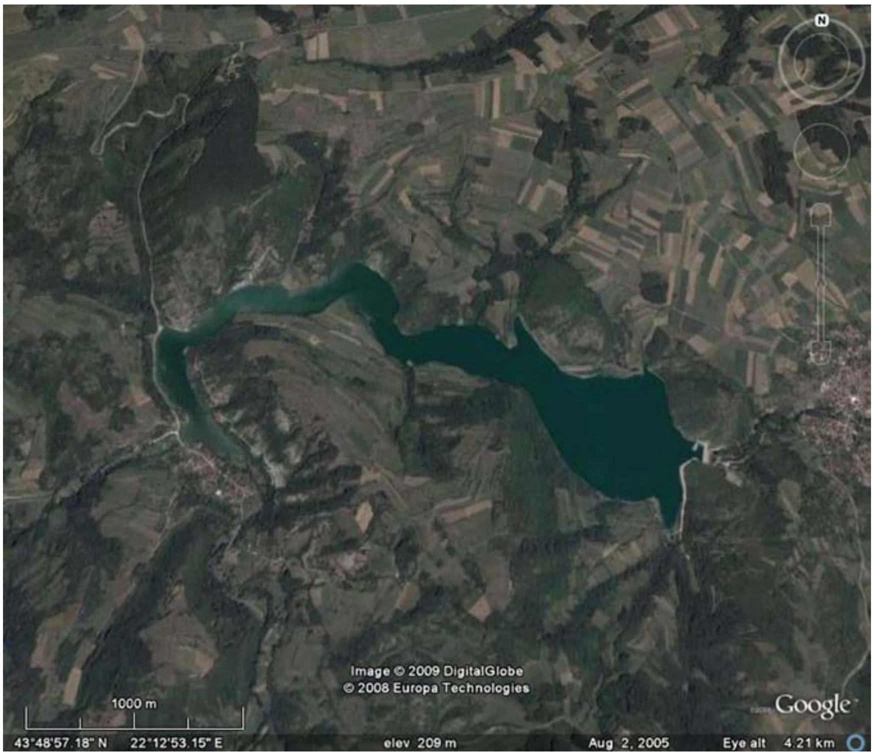

Fig. 1. Lake Grlište - geographical position.

Grlište. The lake lies between 43º 48' and 43º 49' N latitude and between 22º 13' and 22º 15' E longitude, at 187 m above see level (Fig. 1). The reservoir covers a surface of approximately 250 ha (depending on the water level). It is relatively shallow, from 3 to 4 m deep, in most of the lake. Near the dam the depth reaches 20 m. The reservoir is in an area of moderate continental climate.

The lake was created by damming the Grliška Reka River in its gorge, on the north side of Mt. Tupižnica, approximately 1.5 km from the village of Grlište. It flooded mostly meadows and cultivated areas. The lake's water volume is about 12 milion

Table 1. Ten-year average annual flow of the Lasovačka and Lenovačka Rivers measured at the river mouth (m^3/s). (Data provided by the Timok Public Health Institute, Zaječar).

month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Lasovačka River	0.65	1.80	2.38	2.03	1.37	0.76	0.27	0.13	0.17	0.48	0.58	0.58	0.94
Lenovačka River	0.38	0.91	1.37	1.20	0.78	0.44	1.55	0.07	0.10	0.28	0.34	0.54	0.66

Table 2. Plant mass estimates (Kohler, 1971).

MI	descriptive scale	PM
1	rare	1
2	occasional	8
3	frequent	27
4	abundant	64
5	very abundant	125

m^3 with a surface of about 178 km^2. There are no permanent settlements in the immediate vicinity of the lake, except for a few shepherd cottages, which have a seasonal character. The largest part of the area is well covered with young and old deciduous forests, which stabilize some elements of the water regime. The lake is fed by two small rivers, the Lenovačka and the Lasovačka. Both rivers originate from small springs and wells and have a total length of less than 10 km. Considering the small inflow of water (Table 1) compared to the large volume of the reservoir, its water flow is not noticeable and the lake can be classified as stagnant.

The hydroaccumulation is also filled with water from small creeks coming from the nearby hills Bratujevac and Vodanjski Del and by rainwater collecting in the Lesovačka and Lenovačka River catchments.

The water's chemical composition is analyzed on a regular basis by the TIMOK Public Health Institute and Public Water Company in Zaječar. Average pH values were 6.41 in May of 2001 and 8.13 in June. Water transparency in the middle of the lake reaches up to 330 cm (measured in December of 2001), while at the mouths of the Lesovačka and Lenovačka Rivers it is under 50 cm (measured in July of 2001). Such low transparency is the result of shallow water and high sediment turbidity in the area of river mouths, which has been shown to have a strong impact on macrophytes (Madsen et al., 2001).

The water plant in Zaječar delivers 150-300 l/s of drinking water from the Grlište Reservoir, which underlines its importance and the need for continuous monitoring of both physico-chemical and biological parameters.

Mapping and assessment of biomass

Plant material was collected and surveyed during 2003 and 2005. Collected samples were preserved in 4% formalin solution. Species were determinated according to the Water Plant Determination Key of Hungary (Felföldy, 1990), Flora of SR Serbia (Josifović, 1970-1977; Sarić, 1986, 1992), and Flora Europaea (Tutin et al., 1964; Tutin, 1968-1980).

Mapping of macrophytes was conducted by the technique proposed by Kohler et al. (1971), which was later slightly modified (Kohler, 1978; Janauer and Heindl, 1997). This method uses a three-dimensional model for macrophyte abundance assessment and takes into consideration both horizontal and vertical plant development. In this context, abundance is understood as "Pflanzenmenge", which in rough translation means "plant mass" (PM). This is not identical with biomass (kg/m^2), but is equivalent to the "3-D-amount" or bio-volume of a plant stand in a general sense. The scale follows a third power function: $f_{(x)} = x^3$ (Melzer et al., 1986; Janauer et al., 1993; Janauer and Heindl, 1997) (Table 2).

Plant mass was estimated using a five-level descriptive scale (Kohler et al., 1971), where "MI" stands for "mass index" (Table 2).

Mapping was carried out on shoreline sections of variable breadth. The boundaries of each section were determined by uniformity of vegetation. As this changed, a new section was designated.

Based on the PM estimates, relative plant mass (RPM) values, mean mass indexes (MMT and MMO), and the distribution coefficient (d) were calculated (Janauer et al., 1993; Kohler and Janauer, 1995; Pall and Janauer, 1995).

Some relative ecological indicator values and social behavior types according to Borhidi (1993) are used in the discussion.

RESULTS

Macrophytes of the Grlište Reservoir

Surveys of the Grlište Reservoir were conducted during 2003 and 2005. A total of 26 species of vascular water plants and one of algae (Charophyta) were recorded.

During the 2003 survey, Lake Grlište was divided into 17 specific mapping sections (survey units). The presence of 21 species was established. Most recorded species were helophytes (11), followed by submersed anchored species (6). Two amphiphytes, one floating rooted form, and one floating non-root-

Table 3. Aquatic macrophytes of Lake Grlište.

No	Species	Growth form	Abbrev	2003	2005	
1	*Eleocharis palustris*	he	Ele pal	■	■	Emerged
2	*Bolboshoenus maritimus*	he	Bol mar		■	
3	*Carex pseudocyperus*	he	Car pse	■	■	
4	*Iris pseudoacorus*	he	Iri pse	■	■	
5	*Echinochloa crus-galli*	he	Ech cru	■		
6	*Typha latifolia*	he	Typ lat	■	■	
7	*Lycopus europaeus*	he	Lyc eur	■	■	
8	*Typha angustifolia*	he	Typ ang	■	■	
9	*Juncus inflexus*	he	Jun inf		■	
10	*Scirpus lacustris*	he	Sci lac	■	■	
11	*Rumex hydrolapathum*	he	Rum hyd	■	■	
12	*Lytrum salicaria*	he	Lyt sal	■	■	
13	*Sparganium erectum*	he	Spa ere	■	■	
14	*Mentha aquatica*	am	Men aqu		■	
15	*Alisma plantago-aquatica*	am	Ali pla	■	■	
16	*Polygonum amphibium*	am	Pol amp	■	■	
17	*Potamogeton gramineus*	fl	Pot gra		■	Floating
18	*Potamogeton fluitans*	fl	Pot flu	■	■	
19	*Lemna minor*	ap	Lem min	■	■	
20	*Najas marina*	sa	Naj mar	■	■	Submerged
21	*Najas minor*	sa	Naj min	■	■	
22	*Potamogeton pectinatus*	sa	Pot pec	■		
23	*Potamogeton lucens*	sa	Pot luc	■		
24	*Potamogeton crispus*	sa	Pot cri		■	
25	*Elodea canadensis*	sa	Elo can	■		
26	*Chara* sp.	sa	Cha sp.		■	
27	*Vallisneria spiralis*	sa	Val spi	■	■	

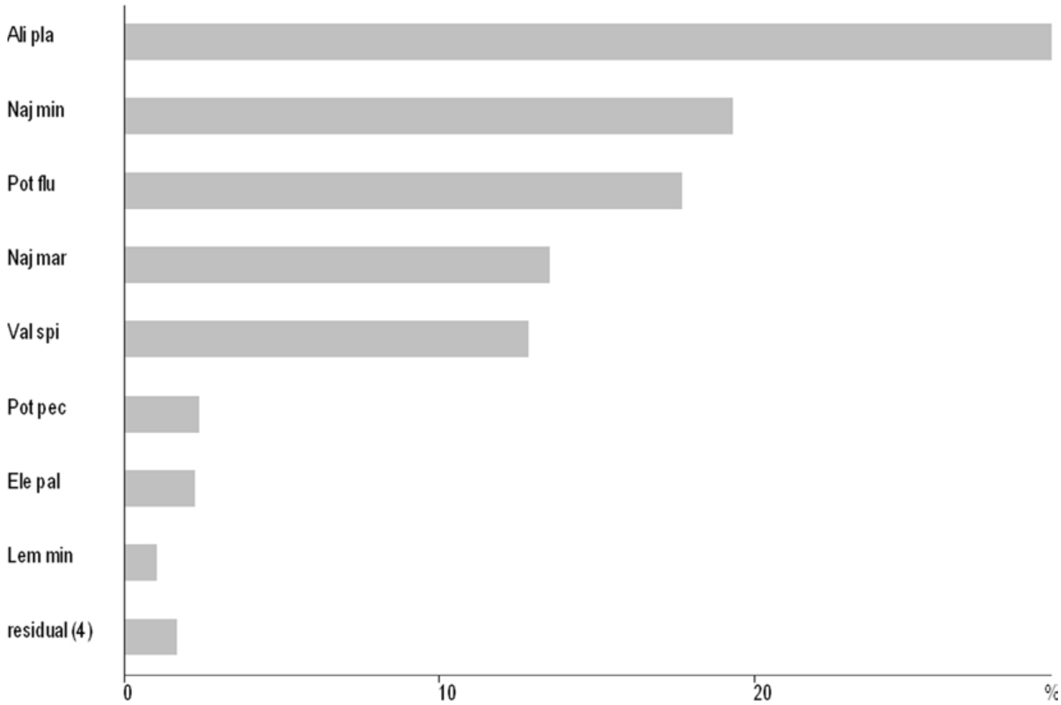

Fig. 2. Relative plant mass of macrophytes in 2003 (%).

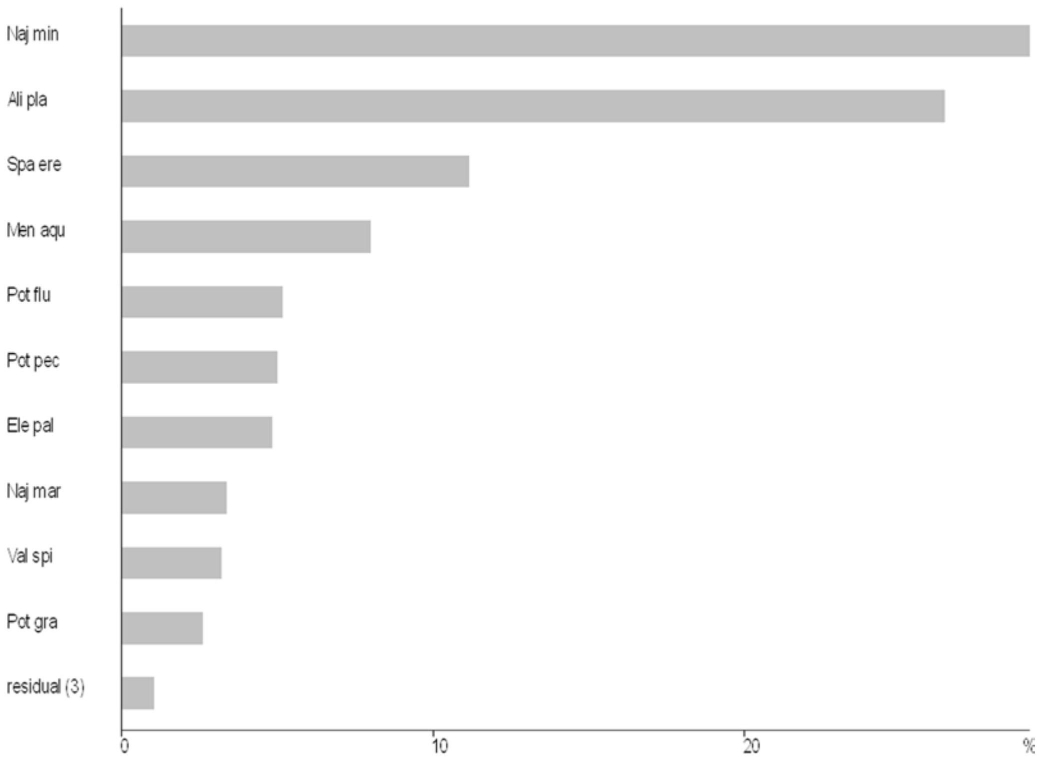

Fig. 3. Relative plant mass of macrophytes in 2005 (%).

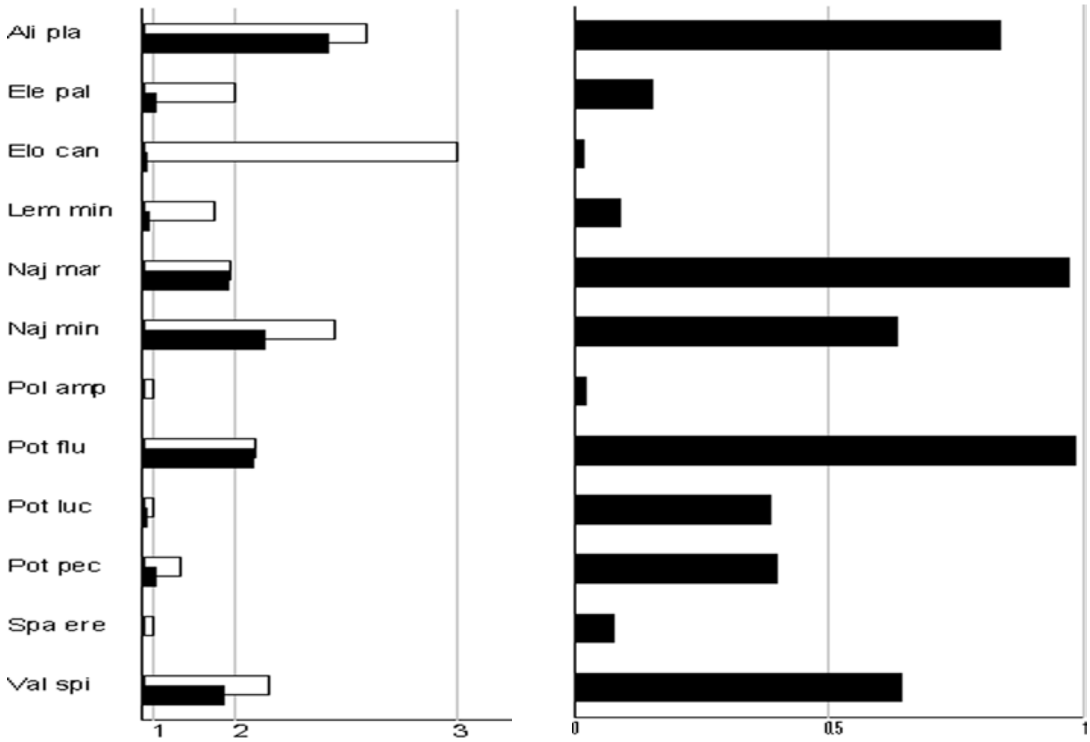

Fig. 4. A - MMT and MMO values in 2003; B - d values in 2003.

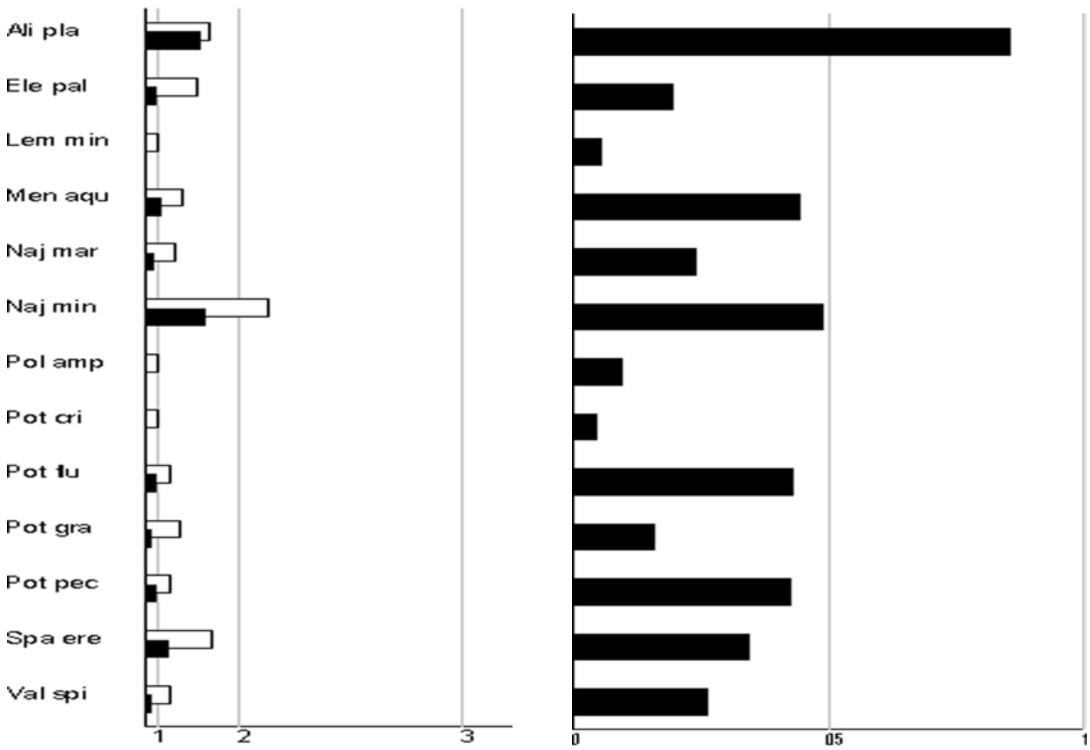

Fig. 5. A - MMT and MMO values in 2005; B - d values in 2005.

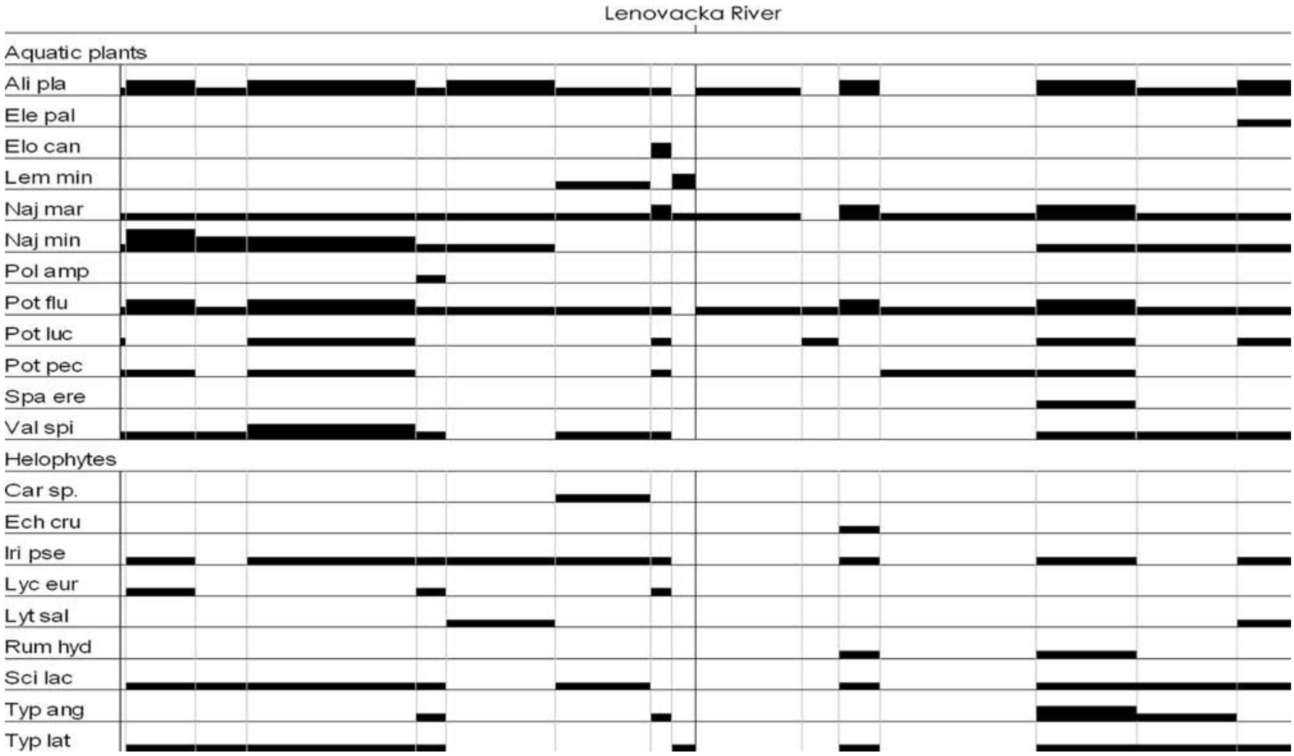

Fig. 6. Distribution diagram of macrophyte populations in 2003.

ed (acro-pleustophyte) species were also recorded (Table 3). During 2005, the lake was divided into 22 survey units and a total of 23 species were registered. Again, most of them were helophytes (12), followed by submersed anchored species (6), two amphiphytes, two floating non-rooted forms, and one floating rooted species (Table 3).

Relative plant mass – RPM

Relative plant mass is the percentage share of the biovolume of each plant species in overall plant mass of the surveyed locality (Pall and Janauer, 1995). In 2003, five hydrophytic macrophyte species were dominant on the Grlište Reservoir: *Alisma plantago-aquatica* (RPM = 29.4%), *Najas minor* (RPM = 19.31%), *Potamogeton fluitans* (RPM = 17.68%), *Najas marina* (RPM = 13.5%), and *Vallisneria spiralis* (RPM = 12.8%) (Fig. 2). These five species were followed by *Potamogeton pectinatus* (RPM = 2.37%), *Eleocharis palustris* (RPM = 2.23%), and *Lemna minor* (RPM = 1.02%). The rest of the hydrophytes are displayed together as a residual bar (RPM = 1.68%).

Except for *Alisma plantago-aquatica* (an amphiphyte), the dominant species belong to the submersed anchored growth form. This is a warning signal indicating possible organic residue accumulation in the lake's sediment.

During 2005, two species were dominant with RPM values over 20%, viz., *Najas minor* (RPM = 29.13%) and *Alisma plantago-aquatica* (RPM = 26.42%). They were followed by *Sparganium erectum* (RPM = 11.17%), *Metha aquatica* (RPM = 8.00%), *Potamogeton fluitans* (RPM = 5.16%), *Potamogeton pectinatus* (RPM = 5.0%), *Eleocharis palustris* (RPM = 4.84%), *Najas marina* (RPM = 3.36%), *Vallisneria spiralis* (RPM = 3.22%), and *Potamogeton gramineus* (RPM = 2.63%), and remainder with a „residual" bar of 1.06% (Fig. 3).

Since 2003, *Najas minor* had a significant increase in RPM (ΔRPM = 9.81%). This indicates a potential danger of stimulation of eutrophic processes. During the years of the survey, it was evident that the given species covered large underwater sur-

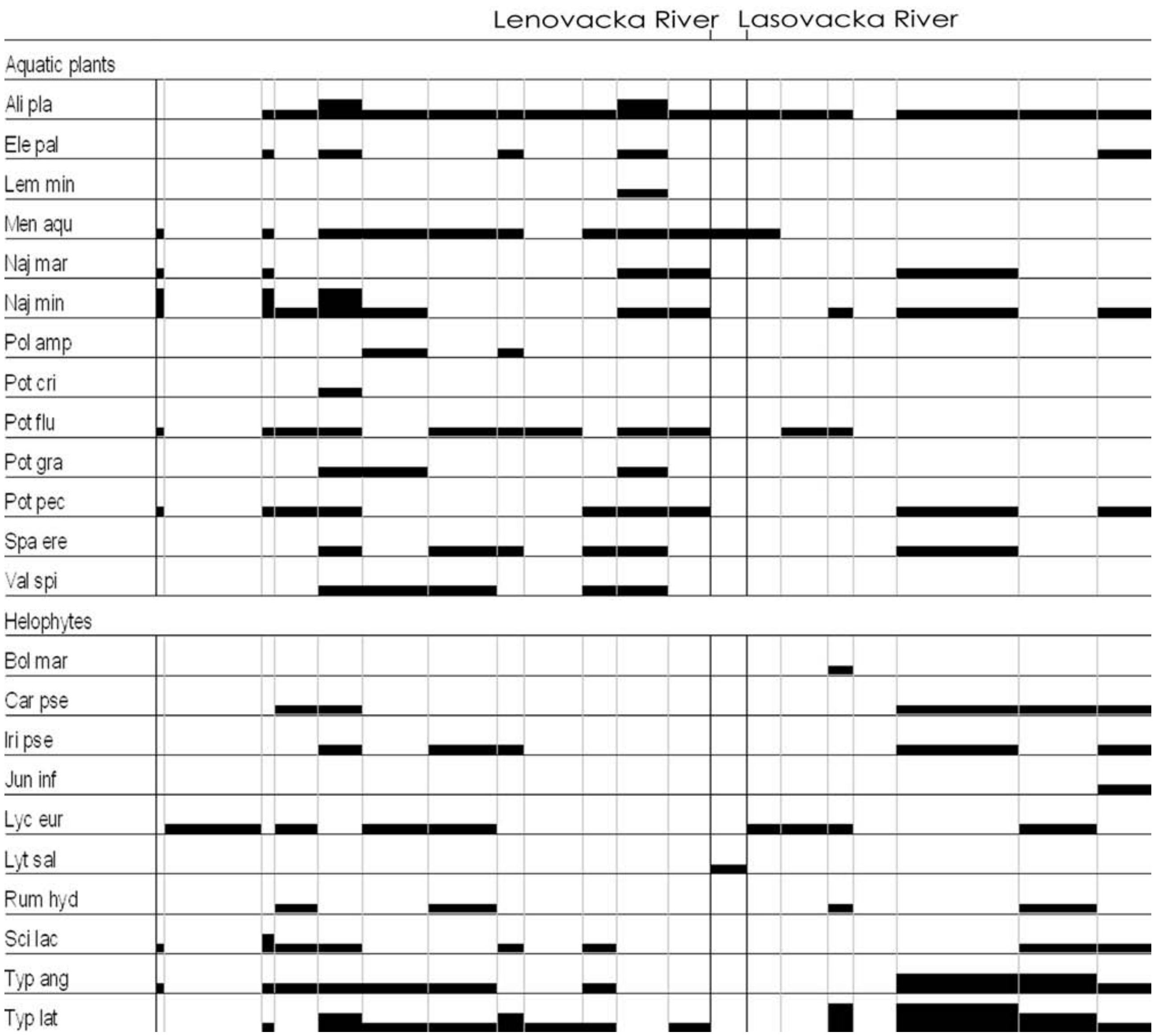

Fig. 7. Distribution diagram of macrophyte populations in 2005.

faces as a dominant form in most parts of the lake with shallow water.

Mean mass indexes (MMT, MMO) and distribution coefficient (d)

Mean mass indexes are metric values for the average abundance of each species calculated according to Janauer et al. (1993). The first of them (MMT) is a mean mass index of one species in all survey units, while the second (MMO) is a mean mass index of one species only in survey units where the species occurs. The distribution coefficient (**d**) is the MMT/MMO ratio, which describes distribution continuity (Janauer et al., 1993). If d = 1, the species is present in all survey sections; if d < 0.5, the species is present in a small number of survey units (a heterogeneous distribution pattern). If populations are rare but with high abundance where present, this distribution type has high MMO values, but low MMT values.

Analyses of MMT and MMO (Fig. 4) during 2003 (MMT values are marked as black bars, MMO values as white bars) showed that *Alisma plantago-aquatica* had the highest MMT value, indicating high bio-volume in most of the survey units. *Elodea canadensis* had very low MMT, but the highest MMO value, indicating that it was present in a small number of survey units, but with high abundance. Dense populations of this species were found in only one survey unit. A heterogeneous distribution pattern is clearly displayed as a small **d** value for *Elodea canadensis* (Fig. 4). A similar pattern is evident for *Eleocharis palustris* and *Lemna minor*, although with significantly smaller bio-volume in their own survey units (low MMO values). *Potamogeton fluitans* had low equal values of MMT and MMO, indicating that it was present in large number of survey units (d is almost 1 and the highest compared to other species) with small abundance. A homogeneous distribution was also established for *Najas marina* and *Alisma plantago-aquatica*. The lowest d values – registered for *Elodea canadensis* and *Polygonum amphibium* – indicate a heterogeneous presence.

Najas minor had the highest MMT in 2005 (Fig. 5) and was closely followed by *Alisma plantago-aquatica*, although *Najas minor* had a significantly higher MMO value, indicating high biomass in survey units where the species was present and a heterogeneous distribution, in contrast to *Alisma plantago-aquatica*. The lowest MMT and MMO values were determined for *Lemna minor*, *Poligonum amphibius*, and *Potamogeton crispus*. These species also had a low d value.

Since each survey section is marked by means of GPS, a detailed distribution diagram can be constructed (Figs. 6 and 7). The length of each shoreline survey unit is proportional to length of each column of the diagram. Abundance of each species is displayed with three diagram black bar heights, the lowest for PM estimates of 1 and 2, medium for a PM estimate of 3, and the highest for PM estimates of 4 and 5. Survey units start from the dam of the lake, extend counterclockwise toward the Lenovačka and Lasovačka Rivers, and then return again. This diagram is a descriptive map of the surveyed water body. Helophytes are displayed on a separate part of the diagram, since they are mostly present on the shoreline and therefore were not included in the figures showing RPM, MMT, and MMO values.

With respect to aquatic plants, conclusions drawn on the basis of RPM, MMT, and MMO analyses are joined in this diagram. Helophytes have a very heterogeneous distribution, and only *Typha angustifolia* is present with a mass index above 2 in one survey unit.

In 2005, it was evident that some helophyte species had an increase in PM and distribution cover. In addition to *Typha angustifolia*, higher PM estimates were also established for *Typha latifolia* and for *Scirpus lacustris* in one survey unit.

DISCUSSION

The aim of the Water Framework Directive in the long term is to achieve a good ecological state of water bodies in Europe (European Union, 2000). In order to derive information about the state of the waters based on their macrophytic vegetation, it is essential to obtain an overall view. This includes all macrophytes as biological indicators. Since there are no well-defined biological reference data, several attempts have been made recently to develop an appropriate method for conducting scientifically-based, practical surveys of the macrophyte stands in larger water bodies (Melzer, 1999; Jäger et al., 2002, 2004; Scott et al., 2002; Søndergard et al., 2005; Stelzer et al., 2005). The methodology used in this research is designed for aquatic plants only, and its main advantage is that it covers 100% of the water body and takes into consideration even areas with the smallest abundance of plants. Since it is georeferenced, the result is a precise map of the lake or river surveyed. This is very suitable for monitoring of vegetation dynamics in the long term.

On Lake Grlište, a large number of macrophytes, often in dense populations, have developed over a period of 15 years. The possible reasons for fast development of vegetation are mostly of an anthropogenic nature, since the lake has frequently been used as a fish pond from the start of its existence. Plant species were probably introduced together with fish from other reservoirs in Serbia. Two species from the group with highest RPM values (*Najas minor*, *Potamogeton x fluitans*) belong to the category of natural pioneers (Borhidi, 1993), indicating that plant communities are still in the early state of development. It is therefore highly probable that competitor macrophyte species (*Najas marina*, *Eleocharis palustris*, *Typha latifolia*, *Typha angustifolia*, *Phragmites australis*, etc.) will develop more in the future. Future development of vegetation will of course depend on abiotic elements. For instance, *Najas* species are often indicators of alkaline waters, which is in accordance with measurements made in June of 2001 (pH = 8.13). In the shallow part of the lake (sections near the Lasovačka River), the transparency is very low (under 50 cm), resulting in decreased diversity and abundance of plant species. Nutritional parameters are of highest significance to macrophyte development, while some other factors (e. g., light, epiphytes, inter- and intraspecific competition, herbivores, etc.) have uneven effects on macrophytes (Melzer, 1999; Seele et al., 2000). It is certain that the course of succession on Lake Grlište will tend toward eutrofication in the years to come, demanding expert attention and monitoring.

If continuous monitoring employs the same methodology as in this research, it can indicate tendencies of population dynamics. In this way, the direction of negative changes can be predicted and possibly suppressed or avoided. In order to establish and confirm the indicative potential of this type of data, it is necessary to pursue continuous monitoring on all types of water bodies over longer time periods. It is especially important to conduct such monitoring on younger water bodies (like the one studied here), so that the complete evolution of these reservoirs is documented and understood on a scientific basis. This will reduce the confusion that arises in cases where multiple indicators are used for assessment of a water body and point to different ecological states of the environment. The obtained data about Lake Grlište can serve as a database for long-term monitoring and eutrophication control.

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МАКРОФИТЕ ХИДРОАКУМУЛАЦИЈЕ ГРЛИШТЕ (СРБИЈА) ПЕТНАЕСТ ГОДИНА ПОСЛЕ ЊЕНОГ ОТВАРАЊА

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Велики број врста водених васкуларних биљака, често у густим популацијама, развио се на хидроакумулацији Грлиште у периоду од 15 година. Брз развој водене вегетације у највећој мери је последица антропогеног утицаја у управљању језером. Методологија употребљена у овом истраживању покрила је 100 % површине воденог огледала, укључујући делове са малим бројем врста и

делове без водених биљака. Резултати указују да су биљне заједнице још увек у раној фази развоја. У будућности се може очекивати већи развој компетиторских врста макрофита (*Najas marina*, *Eleocharis palustris*, *Typha latifolia*, *Typha angustifolia*, *Phragmites australis*, итд.), који би довео до убрзаног померања еколошке стабилности хидроакумулације Грлиште у правцу убрзане еутрофизације.