ESTIMATE OF CONTROL MEASURES FOR AQUATIC MACROPHYTES IN BEČEJ-BOGOJEVO CHANNEL (SERBIA)

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Abstract
From June to August 2016, a field survey of the distribution of aquatic macrophytes was performed along Bečej-Bogojevo channel, survey mark 0+250-1+600km. In this research taxonomy and vegetation of macrophytes are given. Dominant aquatic macrophytes were identified as well as their morphological and biological characteristics. Based on results at 10 locations of the Bečej-Bogojevo channel 16 weed species were determined. The main aquatic macrophytes occurring in study area are *Ceratophyllum demersum* L., *Trapa natans* L., and *Salvinia natans* L.All. Mechanical control measures were effective on all identified species except *Salvinia natans* (L). All. which is restores from fragments, while from biological measures in our country only the introduction of the grass carp species is applied (*Ctenopharyngodon idella* Valenciennes in Cuvier & Valenciennes, 1844).

Introduction
Aquatic macrophyte species are important parts of natural aquatic systems because they produce oxygen and perform a water-purification function by binding heavy metals and removing nutrient loads [1]. Macrophytes serve as habitats for a wide diversity of organisms, they promote sediment deposition, increase water clarity and quality and have an influence on fish productivity [2]. Problems with aquatic plants have increased in the last two centuries, so they disturb the flow of water in irrigation canals and drainage channels. Deep-rooted submerged weeds cause a reduction in oxygen levels and present gas exchange with water resulting in unfavorable fish production, and provide ideal habitat for the mosquito development, and serve as vectors for disease [3]. The most widespread macrophytes in the Danube-Tisa-Danube channel are *Ceratophyllum demersum* L., *Trapa natans* L., *Typha latifolia* L., *Salvinia natans* L. All., *Hydrocharis morsus ranae* L., *Potamogeton lucens* L., *Lemna minor* L., *Nymphea alba* L. [4]. The Danube-Tisa-Danube (DTD) hydro-system is a multivalent water system connecting waters of Bačka and Banat regions in Serbia. The Bečej-Bogojevo canal is 90km long and it starts from the Tisa river at Bečej lock. The canal weed control is a complex task demanding knowledge of aquatic plants. Mechanical control is expensive and requires access to waterways, while chemical control is easier, quick and usually cheaper when compared to mechanical methods [5], but herbicides are often toxic that the water cannot be used often for fish culture or human consumption. The species which has been most widely used in biological control is the grass carp, *Ctenopharyngodon idella*. The aim of this paper was to review the most frequent aquatic weeds of the canal DTD and to provide recommendations for their mechanical, chemical and biological control.

Experimental
In this paper, during the vegetation period in 2016, the presence of aquatic weed species was examined on the Bečej-Bogojevo channel (survey mark 0+250-1+600km) in Serbia. Collected plant material was identified by ,,Flora of SR Serbia I-IX,, [6], ,,Flora of Serbia X,, [7], ,,Flora of Serbia I,, [8], ,,Flora Europeae I-V,, [9] i Iconographie der Flora des Sudostlichen Mitteleuropa,, [10]. The standard phytocenological methods of the Swiss-French school were

used to record vegetation [11]. Biological and morphological properties of aquatic macrophytes are also shown. The assessment of measures has been compared with the literature data, where both the advantages and disadvantages for all measures individually by species suppressed are given.

Results and discussion

Phytocenological analysis was performed on the Bečej-Bogojevo channel at 10 localities by Braun-Blanquet method. The results and available weeds in the selected area are given in Table 1-3 with their scientific names. During the floristic research different types of species were found in the study area on the Bečej-Bogojevo channel. In that area, 16 weed species were identified.

Analyzing higher taxonomic categories, of the 16 constant species, 4 species belong to the class Magnoliopsida (*Ceratophyllum demersum* L., *Trapa natans* L. (agg.), *Rumex lapatifolium* L., *Rumex hydrolaphatum* (Huds), 11 species to the class Liliopsida (*Typha latifolia* L., *Hydrocharis morsus-ranae* L., *Typha angustifolia* L., *Phragmites communis* L. Trin., *Lemna minor* L., *Potamogeton pectinatus* L., *Glyceria maxima* (Hartm) Holm, *Potamogeton crispus* L., *Butomus umbellatus* L., *Vallisneria spiralis* L., *Najas marina* L.) and 1 species belong to the classes Polypodiopsida (*Salvinia natans* L. All.). The flora is divided into 11 families, of which the representatives of the families *Poaceae*, *Polygonaceae*, *Hydrochariaceae*, *Typhaceae*, *Potamogetonaceae* are presented with 2 representatives for each family, while the families *Lemnaceae*, *Najadaceae*, *Ceratophylaceae*, *Salviniaceae*, *Trapaceae*, *Butomaceae* are presented with only one.

Table 1. Phytocoenological recordings, June 2016

Surface size (m^2)	25	25	25	25	25	25	25	25	25	25	The level of presence	Cover value
General coverage	70	80	95	70	100	95	95	100	100	100		
Number of plant species	3	4	9	7	6	3	6	5	3	5		
Plant species	1	2	3	4	5	6	7	8	9	10		
Ceratophyllum demersum L.	1.1	2.2	3.3	4.4	3.3	3.3	2.2	1.1	3.3	1.1	V	2625
Trapa natans L.(agg.)	-	1.1	-	2.2	3.3	-	-	+.1	+.1	3.3	IV	985
Typha latifolia L.	-	-	2.2	-	-	-	-	3.3	-	4.4	II	1175
Salvinia natans L. Alli.	-	-	-	-	-	-	-	-	-	-	-	-
Hydrocharis morsus-ranae L.	-	-	-	-	-	-	-	-	-	-	-	-
Typha angustifolia L.	-	-	-	-	3.3	-	-	-	3.3	-	I	750
Phragmites communis Trin.	-	4.4	-	-	2.2	-	-	4.4	-	-	II	1425
Lemna minor L.	-	-	-	-	-	-	-	-	-	-	-	-
Rumex lapatifolium L.	-	-	1.1	1.1	-	-	1.1	-	-	-	II	150
Potamogeton pectinatus L.	-	-	+.1	+.1	-	-	-	+.1	-	+.1	II	20
Glyceria maxime (Hartm) Holm	1.1	-	2.2	-	1.1	-	1.1	-	-	1.1	III	375

Potamogeton crispus L.	-	-	+.1	+.1	+.1	-	-	-	-	-	I	15
Butomus umbellatus L.	-	-	+.1	+.1	-	+.1	+.1	-	-	-	II	20
Vallisneria spiralis L.	2.2	+.1	+.1	-	-	-	+.1	-	-	-	II	190
Rumex hydrolaphatum (Huds)	-	-	+.1	+.1	-	+.1	+.1	-	-	-	II	20
Najas marina L.	-	-	-	-	-	-	-	-	-	-	-	-

During June 2016, at the tested localities, dominant species were *Ceratophyllum demersum* L., *Phragmites communis* Trin., and *Typha latifolia* L., of which *C. demersum* had the highest cover value, with the level of presence V. *Ceratophyllum demersum* is a submerged, perennial plant with no roots, attached to the lake bottom by modified leaves. Mechanical measures had good effects in some more temperate areas. Engel (1990) [12] states that the best results were obtained if suppression was carried out during July. In Serbia, herbicides diquat and 2,4-D have been registered for this species. It is successfully suppressed using the fish *Ctenopharyngodon idella*, as a biological control measure.

Table 2. Phytocoenological recordings, July 2016

Surface size (m^2)	25	25	25	25	25	25	25	25	25	25	The level of presence	Cover value
General coverage	70	80	95	70	100	95	95	100	100	100		
Number of plant species	5	8	12	9	5	3	8	4	4	6		
Plant species	1	2	3	4	5	6	7	8	9	10		
Ceratophyllum demersum L.	1.1	2.2	3.3	4.4	3.3	2.2	2.2	1.1	3.3	1.1	V	2425
Trapa natans L.(agg.)	1.1	1.1	2.2	2.2	2.2	-	1.1	-	2.2	2.2	IV	1025
Typha latifolia L.	-	-	2.2	-	-	-	-	3.3	-	4.4	I	1175
Salvinia natans L. Alli.	-	-	-	-	-	-	-	-	-	-	-	-
Hydrocharis morsus-ranae L.	-	2.2	2.2	+.1	-	-	+.1	-	1.1	2.2	III	585
Typha angustifolia L.	-	-	-	-	3.3	-	-	-	3.3	-	I	750
Phragmites communis L. Trin.	-	4.4	-	-	2.2	-	-	4.4	-	-	II	1425
Lemna minor L.	1.1	1.1	2.2	2.2	-	-	1.1	-	-	1.1	III	550
Rumex lapatifolium L.	-	-	1.1	1.1	-	-	1.1	-	-	-	II	150
Potamogeton pectinatus L.	-	-	1.1	1.1	-	-	-	+.1	-	+.1	II	110
Glyceria maxime (Hartm) Holm	+.1	-	+.1	-	+.1	-	+.1	-	-	-	II	20
Potamogeton crispus L.	-	+.1	+.1	+.1	-	-	-	-	-	-	I	15
Butomus umbellatus L.	-	+.1	+.1	-	-	-	-	-	-	-	I	10

Vallisneria spiralis L.	+.1	+.1	+.1	+.1	-	-	+.1	-	-	-	III	25
Rumex hydrolaphatum (Huds)	-	-	+.1	+.1	-	+.1	+.1	-	-	-	II	20
Najas marina L.	-	-	-	-	-	+.1	-	-	-	-	I	5

In submerged vegetation during the July, the dominant role had the species *Ceratophyllum demersum* L., whose level of presence was V. When it comes to flotant plants, *Trapa natans* L. was most dominant, with a cover value of 1025 and the level of presence IV. In addition to these two species, *Phragmites communis* L. Trin and *Typha latifolia* were also dominant. *Trapa natans* L. is a floating herb, that colonizes areas of freshwater lakes and ponds where it forms floating vegetation, causing problems for boaters and swimmers. Early detection of introductions and rapid control response are key to preventing high impact infestations. Herbicides that are effective on *T. natans* are glyphosate, triclopyr, and 2,4-D. The most promising biocontrol species appears to be the leaf beetle *Galerucella birmanica.*

Table 3. Phytocoenological recordings, August 2016

Surface size (m^2)	25	25	25	25	25	25	25	25	25	25	The level of presence	Cover value
General coverage	70	95	95	80	100	90	95	100	100	100		
Number of plant species	5	7	9	5	6	5	8	5	5	6		
Plant species	1	2	3	4	5	6	7	8	9	10		
Ceratophyllum demersum L.	2.2	2.2	2.2	3.3	2.2	2.2	2.2	1.1	2.2	1.1	V	1700
Trapa natans L.(agg.)	+.1	+.1	1.1	1.1	2.2	-	1.1	-	1.1	+.1	IV	390
Typha latifolia L.	-	-	4.4	-	-	-	-	3.3	-	4.4	II	1625
Salvinia natans L. Alli.	1.1	2.2	3.3	2.2	2.2	1.1	-	3.3	3.3	3.3	IV	1950
Hydrocharis morsus-ranae L.	-	3.3	2.2	2.2	+.1	1.1	+.1	-	1.1	-	IV	835
Typha angustifolia L.	-	-	-	-	-	-	-	-	3.3	-	I	375
Phragmites communis L. Trin.	-	3.3	-	-	3.3	-	-	3.3	-	-	II	1125
Lemna minor L.	-	-	+.1	-	-	-	1.1	-	-	+.1	II	60
Rumex lapatifolium L.	-	-	-	-	-	-	1.1	-	-	-	I	50
Potamogeton pectinatus L.	-	-	+.1	1.1	+.1	-	-	+.1	-	+.1	III	70
Glyceria maxime (Hartm) Holm	+.1	-	+.1	-	-	-	+.1	-	-	-	II	15
Potamogeton crispus L.	-	+.1	+.1	-	-	-	-	-	-	-	I	10
Butomus umbellatus L.	-	+.1	-	-	-		-	-	-	-	I	5
Vallisneria spiralis L.	3.3	-	-	-	-	+.1	+.1	-	-	-	I	375
Rumex hydrolaphatum	-	-	-	-	-	-	+.1	-	-	-	I	5

(Huds)												
Najas marina L.	-	-	-	-	-	+.1	-	-	-	-	I	5

The dominant aquatic macrophytes in August 2016, were *Salvinia natens*, with the level of presence IV, then *Ceratophyllum demersum* L., and *Typha latifolia* L. Many endangered plant species are found in aquatic ecosystems. Some of these species are *Najans marina* L., *Hidrocharis morsus-ranae* L., *Ceratophyllum demersum* L., *Trapa natan*s L., *Butomus umbellatus* L., *Vallisneria spirali*s L., which deserves special attention because their protection contributes to the conservation of ecosystem diversity.

Conclusion

Based on the number and coverage, 16 aquatic weeds species were identified at 10 localities of the Bečej-Bogojevo canal in the period June-August 2016. The most common are the representatives of the family *Poaceae*, *Polygonaceae*, *Hydrochariaceae*, *Typhaceae*, *Potamogetonaceae.* The predominant aquatic macrophytes at the investigated localities in June was *Ceratophyllum demersum* L., in July *Trapa natans* L. and in August month *Salvinia natans* L.All. During the vegetation period, in June and July 2016, it is recommended that mechanical suppression need to be repeated based on the dominant aquatic flora. In the case of the introduction of grass carp into the Bečej-Bogojevo canal, as a form of biological control, the application of mechanical suppression would be reduced.

References

[1] L. Moeller, A. Bauer, H. Wedwitschka, W. Stinner, A. Zehnsdorf, Crop Characteristics of Aquatic Macrophytes for Use as a Substrate in Anaerobic Digestion Plants—A Study from Germany. *Energies*, (2018), 11, p. 3016.

[2] H. Yu, W. Qi, C. Liu, L. Yang, L. Wang, T. Lv, J. Peng, Different Stages of Aquatic Vegetation Succession Driven by Environmental Disturbance in the Last 38 Years. Water, 11(7), (2019), p.1412.

[3] M. Salwa Abou El Ellaand, A. Tarek El Samman. Review: Egyptian Experience in Controlling Aquatic Weeds. J Am Sci, (2016), pp. 104-115.

[4] B. Konstantinović, M. Meseldžija, S. Maletin, Mogućnost primene herbicida i biljojedih riba u uklanjanju korovske vegetacije iz kanalske mreže. U: Održive melioracije, Belić, S. (ed.), Univerzitet u Novom Sadu Poljoprivredni, Novi Sad, (2007).

[5] S. Datta, Aquatic Weeds and Their Management for Fisheries, Aquatic Weeds and Their Management for Fisheries, (2009), pp. 1-22.

[6] M. Josifović, (ed.). Flora SR Serbia, I-IX, SANU, Belgrade, (1970-1977).

[7] Sarić, M. (ed.). Flora of Serbia X, SANU, Belgrade, (1986).

[8] Sarić, M. (ed.). Flora of Serbia 1. SANU, Belgrade, (1992).

[9] G. Tutin, V.H. Heywood, N.A. Burges, D.H. Valentine, S.M. Walters, D.A. Webb, (ed.) Flora Europaea I, Cambridge University press, Cambridge, England, (1964).

[10] S. Jávorka, V. Csapody, Icanographie der Flora des Südostlichen Mitteleuropa. Akademiai Kiado, Budapest, (1975).

[11] J. Braun-Blanquet, Pflanzesociologie, Grundzuge der Vegetations Kunde. 3rd ed. Springer Verlag, Wien-New York, (1964).

[12] S. Engel, Ecological impacts of harvesting macrophytes in Halverson lake, Wisconsin. Journal of Aquatic Plant Management, (1990), pp. 41-45.