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AQUATIC WEEVIL (COLEOPTERA: CURCULIONOIDEA) ASSEMBLY RESPONSE TO THE DIFFERENT ECOLOGICAL CONDITIONS IN ARTIFICIAL LAKES IN CENTRAL SERBIA

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Abstract - Artificial stagnant aquatic ecosystems such as reservoirs, are suitable for monitoring the succession of biocenoses because they are usually formed by rearrangement of the former current river ecosystems. The weevil assembly, as part of such a dynamic biocenose, develops following host macrophytes. In the frame of weevil fauna studies realized during 2001 and 2002 in wet habitats beside four artificial lakes in Central Serbia (Gruža, Grošnica, Šumarice and Bubanj), the aquatic adults from 13 species, divided into two families, Eryrhinidae (*Tanysphyrus lemnae* and *Notaris scirpi*) and Curculionidae (*Bagous bagdatensis*, *B. collignensis, B. lutulentus, Pelenomus canaliculatus*, *P. comari*, *P. waltoni*, *Phytobius leucogaster*, *Rhinoncus castor, R. inconspectus*, *R. pericarpius* and *R. perpendicularis*), were collected. The quantitative and qualitative picture of the studied aquatic weevil assemblies, as well as indices of similarity among them, are given and related to the dimensions and ecological characteristics of studied aquatic systems (particularly the level of eutrophication).

Key words: Weevils, Curculionoidea, aquatic assemblies, artificial lakes, Central Serbia

INTRODUCTION

Artificial aquatic ecosystems, such as reservoirs of water supplies, have particular importance for scientists. They usually represent successive ecosystems with standing water as a biotope, formed in places of previously moving water. Due to the place and manner of their formation, as well as different human impacts and constant evolving, reservoirs are a kind of ecological laboratory, suitable for biological monitoring, i.e. the following of biocenoses development.

Thanks to their most impressive morphological characteristic, a more or less prolonged snout, weevils have two more names in English – long nosed beetles and snout beetles. At the tip of the snout is a mouth apparatus for nibbling.

Represented probably by half a million species in the world, the family Curculionidae is the richest in the animal kingdom, but only one tenth of these species is scientifically described (Hoffmann, 1950; Lyal and King, 1996; Alonso-Zarazaga and Lyal, 1999). The whole superfamily Curculionoidea contains more than 60,000 species described to date (Burrini et al., 1988; Zimmerman, 1991-1993; Caldara and O'Brien, 1995). New weevil species are discovered practically every day somewhere in the world. The number of species that are still unknown to science can only be guessed.

Regarding nutrition, Curculionoidea are phytophages. The chewing mouth apparatus at the apex of the snout contributes to the adult weevil's success in different feeding niches (Holecová, 1992). In respect to the range of food, Holecová (1991) distinguished four groups of weevils: monophagous, narrowly oligophagous, broadly oligophagous, and polyphagous. Weevil larvae mainly feed within different plant organs, but some use moss or fungi. These specialists for feeding on certain plant species can be used as biological control agents to combat weeds, even aquatic (Lekić and Mihajlović, 1970; Buckingham et al., 1980; Bennet and Buckingham, 1991; Cuda and Burke, 1991; Sobhian and Fornasari, 1994; Youssef and Evans, 1994; Sheldon and O'Bryan 1996a, b; Newman et al., 1997; Mazzei et al., 1999; Diop and Hill, 2009a, 2009b; Groves et al., 2010). On the other hand, weevils can produce serious problems in agriculture and forestry (Voroncov, 1982; Holecová, 1993b; Pešić, 2008; Milovac et al., 2010).

Weevils can inhabit all terrestrial environments, from seashores to the mountain tops, from deserts to tropical rain forests (Zimmerman, 1991-1993). During evolution, some weevil species adapted well to life in fresh water habitats, i.e. they possess hygro- or hydrophilous life forms (Holecová, 1993a). These species have great significance as bioindicators of water quality (Sprick and Winkelmann, 1993; Tamayo et al., 2000). A detailed ecological study of the danger to weevil fauna in Germany showed that regarding habitat, aquatic forms are the most threatened (Winkelmann, 1991).

Aquatic and semiaquatic weevils are mainly confined to stagnant or very slowly flowing fresh water ecosystems. They possess many morphological and ethological adaptations to life in water or alongside of it, such as water-repellent glazes, hairiness or specialized setae for plastron formation, and use different swimming techniques: *Rhinoncus* species swim on the surface of the water by moving all three pairs of legs simultaneously; the majority of *Bagous* species and other water weevils swim by "dog-paddling"; certain *Phytobius* species swim by means of alternating movements (Caldara and O'Brien, 1995); propulsion during swimming provided only by the mesothoracic legs makes the swimming of *Lissorhoptrus oryzophilus* Kuschel unique (Hix et al., 2000). The aquatic weevil *Euhrychiopsis lecontei* (Dietz, 1896), a specialist for feeding on *Myriophyllum* sp., is visually attracted to the host, even when the plant is hidden in a vial, or in turbidity conditions (Reeves et al., 2009; Reeves and Lorch, 2009).

Before our studies, aquatic and semiaquatic weevils were never particularly studied in Serbia (Pešić 2000, 2004, 2006, 2007). In previous inventories in the Kragujevac basin, this group of weevils was not completely listed (Pešić, 1997, 1998,). A specialized study of them in Central Serbia started in 2000 (Pešić, 2000). The aim of this study was to register and compare the weevil aquatic assemblies from four water reservoirs in the Kragujevac region.

MATERIALS AND METHODS

Sampling sites

The central part of Serbia, named Šumadija (šuma Serb. = forest), was heavily forested in the last few centuries. Today it is a patchwork of fields, forests, orchards, hedges, villages, etc. that cover the hilly terrain. Among these different ecosystems, near the main city of this region, Kragujevac, four reservoirs were built for different purposes (Fig. 1). They were the objects of our research.

The largest (Fig. 1; Table 2) is Gružansko Lake, formed 25 years ago by dam construction on the small Gruža River, 23 km southwest of Kragujevac. It is approximately 10 km long and 0.15-1.5 km wide, 934 ha in surface, with a 64.6 million m^3 volume. A protective zone of 1450 ha surrounds this reservoir. The maximal depth is 31 m (near the dam), and average depth 6.3 m (Ostojić, 2005). The main problem is that two thirds of the north part of lake's surface are only 2-9 m deep (Milojević et al., 1995), i.e. has a puddle-like character, muddy littoral, many inlets and strong eutrophication, what is bad because this reservoir is the main water supply resource for Kragujevac (Ostojić, 2000; Ćurčić, 2003; Topuzovic and Pavlovic, 2004; Topuzović et al., 2009).

The oldest artificial lake in Serbia is Grošničko (Vodojaža Serb. = dammed water), built 8 km south-southwest from Kragujevac, on the Grošnička River from 1931-1938. This lake was later connected to a small, higher-located mountain reservoir on the Dulenka River. The primary purpose of this reservoir was to supply water to the city of Kragujevac and for

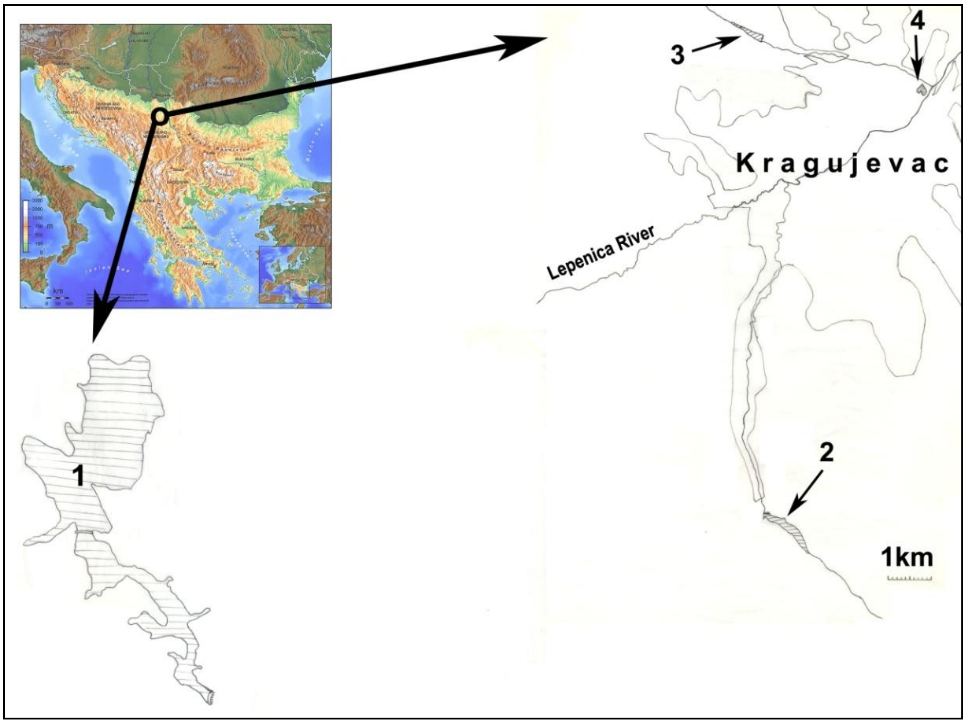

Fig. 1. Balkan Peninsula and investigated localities in real proportions: 1 – Gružansko Lake, 2 – Grošničko Lake, 3 – Šumarice and 4 – Bubanj.

industrial use (Stepanović, 1974). The dam was upgraded twice (by 5.5 m in 1957 and again by 7.3 m in 1962) because of the growth in size of Kragujevac and back filling by erosion. The water chemically belongs to the calcium-bicarbonate type (Janković, 1966). Swimming, fishing and building are prohibited. This reservoir is 1750 m long, with greatest width of 250 m. Its surface comprises 22 ha. The original volume of the reservoir was $2.17x10^6$ m^3, but in 1962 the depth of the lake because of the dam attained 21 m and its capacity grew to $3.53x10^6$ m^3 (Ostojić, 2000).

The reservoir in the Šumarice Memorial Park was formed in 1964-1967 by damming the Sušički Brook, 3 km north-northwest from the center of Kragujevac. Its original purpose (irrigation) was altered due to lack of funds, and the reservoir water is now primarily used for recreation, as well as by the city's fire department, the municipal sanitation department and the park service. This reservoir is 1350 m long and 175 m wide on average. It has a surface area of 14 ha and volume of 950.000 m^3 (Stepanović, 1974).

Bubanj is a lake formed in 1955 in the alluvial plain of the river Lepenica, in the urban zone of the city. It is positioned in a depression from which soil was removed for a brick factory before World War II and up to 1955. It is permanently supplied with water from a subterranean spring, from the drinking fountain "Bubanj", groundwater and rainfall. Its water surface is approx. 2.7 ha, maximal length is 300 m, and width 215 m. The average depth is approximately 1.2 m (max. 1.6 m, min. 0.50 m). It is connected through a drainer with Lepenica River. The summer water temperature reaches up to 29°C, while during the winter almost the whole lake surface is frozen (Stepanović, 1974). From three sides it is surrounded by busy roads. The waterbed is muddy (thickness of sludge is 0.50-0.70 m) and macrophyte vegetation occupies the whole water mass of the lake (11 ml/mg on the average) (Simić et al., 1994).

Weevils collecting and identification

Aquatic weevils are very difficult to collect. They are active during the night. For the most of the day they are concealed underwater on their host plants (floating and immersed) (Caldara and O'Brien, 1995). In China, for example, from approximately 2000 weevil species, only 71 are aquatic or semiaquatic. To illustrate how difficult it is to collect them, an experienced entomological team succeeded in collecting only 28 of these 71 species (Caldara and O'Brien, 1995).

Adult weevils were collected during 2001 and 2002 in wet habitats connected to four reservoirs in Central Serbia (Gruža, Grošnica, Šumarice and Bubanj) as well as in and alongside (50 to 100 m from the shore) the lakes.

The adult weevils were collected in the early morning hours (6:00-10:00 h). Various collecting techniques were used ("mowing" and shaking of plants, rinsing of submersed plants, beating of the branches of trees and bushes, careful examination of the ground beside plants that are potential hosts and manually collecting).

A number of keys were used for species identification: Dieckmann (1972, 1983), Smreczyński (1974), Angelov (1979, 1980), Freude et al. (1981, 1983).

Applied nomenclature is that used by Alonso-Zarazaga and Lyal (1999) and Alonso-Zarazaga (2005).

Similarity indices

For comparison of the faunistic composition of the weevil assemblies on the four researched reservoirs, we used the Sørenson Similarity Index and for the control the Jaccard index (Schwerdtfeger, 1975).

RESULTS AND DISCUSSION

Quantitative and qualitative results, as well as indices of similarity of the registered aquatic weevil assemblies are correspondent to the dimensions and ecological characteristics of the studied aquatic systems.

The collected 260 aquatic adult weevils belong to 13 species from two families, Eryrhinidae (two species) and Curculionidae (Table 1).

The development of weevil assemblies in lakes relates to the composition of host macrophyte association changes. The richest one developed on Gruža reservoir, while the smallest is on Bubanj. It could be concluded that weevil diversity is proportional to lake size (Table 2). The results of Topuzović et al. (2009) on the significance of the morphometric reservoir characteristics for macrophyte associations could be a good support to this conclusion. Many other studies of the diversity and community structure of macrophyte vegetation confirmed the morphometric characteristics of lakes to be more important than any measured chemical parameter (Neiff et al., 2000; Heegaard et al., 2001; Irfanullah and Moss, 2004; Makela et al., 2004). If this is so clear, then it is understandable that weevil assembly diversity is proportional to lake dimensions, because these insects are absolutely dependent. In other words, well-developed macrophyte vegetation means richer weevil settlement.

At first, however, the situation between Grošnica and Šumarice reservoirs shows the opposite: with the smaller reservoir are connected seven weevil species, while with bigger one, only five (Table 2). An explanation could be the richer macrophyte vegetation composition developed in the shallowest parts of the smaller Šumarice lake, while the Grošnica reservoir is placed in a woody gorge and has only a small sunlit surface, i.e. less macrophytes. Apart from this, Grošnica reservoir has steep and rocky banks, and the water is protected from human influences. In other words, the weevils' food base is narrow at Grošnica reservoir. Unfortunately, we did not have a parallel phytocenological analysis for these two reservoirs, but there are comparable results of the hydrophilic flora and its qualitative composition in the Gruža and Grošnica reservoirs. Topuzovic and Pavlovic (2004) registered 64 and

Table 1. Aquatic weevils from the Kragujevac reservoirs: 1 – Gruža, 2 – Grošnica, 3 – Šumarice, and 4 - Bubanj. Characteristic species are signed by shadowed fields.

	TAXA	1	2	3	4
	Erirhinidae Schönherr, 1823				
1.	*Tanysphyrus lemnae* (Fabricius, 1792)		1		
2.	*Notaris scirpi* (Fabricius, 1793)	1			
	Curculionidae Latreille, 1802				
3.	*Bagous bagdatensis* Pic, 1904 (=*wagneri* Dieckmann, 1964)	25		35	1
4.	*Bagous collignensis* (Herbst, 1795) (=*claudicans* Angelov, 1957)	4		1	
5.	*Bagous lutulentus* Gyllenhal, 1813 (=*nigritarsis* Thomson, 1865)		1	1	
6.	*Pelenomus canaliculatus* (Fåhraeus, 1843)			3	
7.	*Pelenomus commari* (Panzer, 1794)		1		2
8.	*Pelenomus waltoni* (Boheman, 1843)			1	
9.	*Phytobius leucogaster* (Marsham, 1802) (=*myriophylli* Gyllenhal, 1813)	1		2	8
10.	*Rhinoncus castor* Fabricius, 1792	33			
11.	*Rhinoncus inconspectus* (Herbst, 1795)	3	13		
12.	*Rhinoncus pericarpius* (Linnaeus, 1758)	31	5		
13.	*Rhinoncus perpendicularis* (Reich, 1797)	94		1	
	TOTAL species	8	5	7	3
	TOTAL specimens	184	21	44	11

Table 2. Proportions among the Kragujevac reservoirs' measures and numbers of aquatic weevil species and specimens.

LAKE	Age	Volume	Depth	Surface	Nr sp.	Nr spcm.
Gruža	26	64.6 milions m^3	6.3 m	934 ha	**8**	**184**
Grošnica	72	3.53 milions m3	max 21 m	22 ha	**5**	**21**
Šumarice	43	950,000 m3	max 24 m	14 ha	**7**	**44**
Bubanj	55	32,400 m3	1.2 m	2.7 ha	**3**	**11**

Table 3. Indices of similarity of aquatic weevil assemblies in Kragujevac reservoirs (S=Sørenson; Cj=Jaccard).

	Gruža		Grošnica		Šumarice	
	S	C_j	S	C_j	S	C_j
Grošnica	30.76	18.18				
Šumarice	53.33	36.36	16.67	9.09		
Bubanj	36.36	22.22	25.00	14.28	40.00	25.00

30 plant species, respectively, and their main conclusion was that the difference between the earlier (Janković, 1965; Veljović et al., 1986) and current state of the hydrophilic flora of the smaller Grošnica reservoir less dramatically and more slowly changed through the time.

After careful comparison of the characteristics of the analyzed reservoirs and their weevil assemblies, we can conclude that age and total size are not as important as the proportion of shallow muddy parts in the relation to the rest of the surface and water volume. In other words, the level of eutrophication is recognized as most important for macrophyte presence and consequently for weevil assemblies.

Eutrophication is caused by nutrient enrichment in aquatic systems. It is a reflection of chemical and biocenotic parameters of an ecosystem.

Among the four reservoirs analyzed in this study (except the smallest, Bubanj, not only because of its size, but because of the permanent water flux from the spring through this pond to the Lepenica river), the process of eutrophication was strongest and accelerated by human activities in the Gruža reservoir (Ostojić, 2000; Ostojić et al., 2005; Topuzović and Pavlovic, 2004; Ranković and Simić, 2005; Topuzović et al., 2009).

The studies of many aquatic systems conducted by Tamayo et al. (2000) showed statistically clear correlations between the abiotic ecological characteristics of water and weevil presence. Center and Dray (2010) experimentally studied the efficiency of different nutrient regimes applied to one floating weed to the fecundity of two specialist weevil species. They confirmed that seasonal nutrient flux from the bottom affects ovarian development of both weevil species. This conclusion is entirely consistent with our results for Gruža reservoir (Pešić, 2006a). The trophical status of the vascular flora of this accumulation from 3.01 in 1985 (Veljović et al., 1986) has grown to 3.32 in 1999-2002 (Topuzović and Pavlović, 2003). The aquatic part of the weevil assembly registered on Gruža in 2001 and 2002 was in absolute accordance with the trophical status of registered flora. It was shown through the comparison of present weevil species and the trophic (nitrophilic) status of their host plants, as well as through the massive presence of *Rhinoncus perpendicularis, R. castor, R. pericarpius* and *Bagous bagdatensis* (Pešić, 2006a). Another confirmation that eutrophication does not disturb, but instead favors weevil assembly richness, is the fact that the muddy bottom and turbid water cannot impair the visual orientation of an aquatic weevil to its host plant (Reeves et al., 2009; Reeves and Lorch, 2009).

Physical differences among the analyzed lakes are reflected to the level of specificity of their weevil assemblies. Gruža and Šumarice reservoirs each have two characteristic species, Grošnica only one, and Bubanj none (Table 1).

Bagous bagdatensis and *Phytobius leucogaster* were present in three of the four analyzed water systems. An explanation for the first species is that it is polyphagous, i.e. its host plant could be *Alisma plantago-aquatica, Butomus umbellatus, Ceratophyllum demersum, Carex* sp., *Myriophyllum spicatum, Lemna minor, Lythrum salicaria, Glyceria* sp. and *Polygonum* sp. (Caldara and O'Brien, 1995; Poiras, 1998). On the other hand, *Phytobius leucogaster* is connected only with *Myriophyllum spicatum* (Buckingham and Bennet, 1981), but this weed is present in all analyzed systems, except Grošnica Reservoir.

Indices of similarity (Sørenson and Jaccard) of the weevil assemblies practically confirmed all our conclusions, since the greatest calculated values were between Gruža and Šumarice (Table 3). The smallest indices, i.e. the biggest differences, were among the weevil assemblies in Grošnica and Šumarice reservoirs. The last two systems, apart from the already mentioned physical and historical characteristics, have obviously different levels of human pressure as the main difference, i.e. absent or strongest, respectively.

Our main conclusion could be that eutrophication is an obviously significant factor for aquatic weevil assembly development.

It would be worthwhile to repeat similar analysis of the same reservoirs from time to time (in five- or ten-year intervals), due to the rapid change in these artificial ecosystems, particularly because of the relatively fast increase in mud at the bottom of all of them and phytocenological changes.

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