CONTRIBUTION TO THE STUDY OF THE MACROZOOBENTHOS OF THE IZVORU MUNTELUI – BICAZ RESERVOIR (ROMANIA)

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Abstract. The community structure and distribution of macrozoobenthos has been examined monthly, from March to November 2005, at depths from 0.5 to 1.5, 35 to 45 and 70 to 82 m, in Izvoru Muntelui – Bicaz reservoir. A total of 23 species were identified. Species richness in sampled areas ranged from 20 in shore zone, with abundances dominated by Tubificidae (*Limnodrilus hoffmeisteri* - 35.7 %; *Tubifex tubifex* - 9.8%) and Chironomidae (*Procladius choreus* - 18.8%, *Polypedilum nubeculosum* - 18.5% and *Chironomus* spp. - 9.3%) to 6 in 35-45 m depth area, with abundances dominated by *L. hoffmeisteri* - 66.3% and *T. tubifex* - 30.2%, and to 4 species in 70-82 m profound area, with abundances dominated by *T. tubifex* - 98.2%. Five species of invertebrates were firstly described in the lake in 2005 in restricted shallow benthic locations; they may be considered accidentally or occasionally, except *Asellus aquaticus* (Isopoda) frequent and abundant in the summer and autumn samples. The population density ranged from 762 ± 183 individuals in the shallow sites to 2899 ± 976 in 35-40 m depth sites, and to 11595 ± 1421 individuals/m^2 in the 70-92 m profound sites. The biomass values were approximate equally in shallow and 35-45 m sublittoral sites (4.21 ± 1.11 respective 4.45 ± 0.89) and reached a maximum of 10.52 ± 2.01 mg wet weight /m^2 in profound sites. A historically comparison between present community structure and previous data shows a continuous reduction of species richness and biomass values in 1965-1998 time interval and an increase in 2005, nearly two times higher compared with 1998's situation. The trophic status of the reservoir in 2005 was considered oligotrophic in 35–82 m deep areas and showed several signs of mesotrophy in shallow 0.5-1.5 m benthic areas.

Keywords: dam reservoir, macrozoobenthos, structure, distribution, abundance.

Rezumat. Contribuţie la studiul macrozoobentosului din lacul Izvoru Muntelui – Bicaz (România). Structura şi distribuţia comunităţilor macrozoobentice a fost analizată lunar, din martie până în noiembrie 2005, la adâncimi de 0,5-1,5, 35-45 şi 70-82 m în lacul de acumulare Izvoru Muntelui – Bicaz. În urma analizei a fost identificat un total de 23 de specii. Bogăţia în specii în zonele investigate variază de la 20 în zona litorală, în care predomină tubificidele (*Limnodrilus hoffmeisteri* - 35,7 %; *Tubifex tubifex* - 9,8%) şi chironomidele (*Procladius choreus* - 18,8%, *Polypedilum nubeculosum* - 18,5% şi *Chironomus* spp. - 9,3%) la 6 în zona de adâncime de 35-45 m, unde predomină *L. hoffmeisteri* în proporţie de 66,3% şi *T. tubifex* în proporţie de 30,2%, şi la 4 specii în zona profundală de 70-82 m, unde predomină *T. tubifex* - 98,2%. Cinci specii de nevertebrate semnalate pentru prima dată în Lacul Bicaz au fost descrise în 2005 în zona strict litorală, ele putând fi considerate accidentale sau întâmplătoare, cu excepţia lui *Asellus aquaticus* (Isopoda) frecvent şi abundent în probele din vară şi toamnă. Densitatea populaţiilor variază de la 762 ± 183 în staţiile litorale la 2899 ± 976 în staţiile de la 35-40 m adâncime, şi la 11595 ± 1421 indivizi/m^2 în staţiile profundale de 70-92 m adâncime. Valorile biomasei au fost aproximativ egale în staţiile din zona litorală şi sublitorală, de 35-45 m (4,21 ± 1,11 respectiv 4,45 ± 0,89) şi a înregistrat un maximum de 10,52 ± 2,01 mg greutate umedă/m^2 în staţiile profundale. O comparaţie în timp între structura comunităţii actuale şi datele anterioare arată o reducere continuă a bogăţiei specifice şi a valorilor biomasei în perioada 1965-1998 şi o creştere în 2005, aproape de două ori mai mult comparativ cu situaţia din 1998. În ceea ce priveşte statutul trofic al lacului, în 2005 era considerat oligotrof în zona de adâncime 35-82 m şi prezenta câteva semne de mezotrofie în zona litorală de 0,5-1,5 m.

Cuvinte cheie: lac de acumulare, macrozoobentos, structura, distribuţie, abundenţă.

Introduction

Izvoru Muntelui – Bicaz Reservoir is described as a large dimictic oligotrophic to mesotrophic lake, which has been impounded for hydro-electrical purposes, in 1960, on the Bistrita River, Carpathian Mountain, Romania (N 47°9', E 26°11'). Its surface area,

lenght, width, depth, storage volume and retention time at maximum filing level (517 a. s. l.) are 3300 ha, 35 Km, 0.2 km min – 2.0 km max, 46 m mean – 89 m max, 1230 mill. m^3 and cca.1.2 year, being extremely strong exposed to annually water level fluctuations – 16 to 25 m. The lake watershead area has been well studied for a variety of limnological purposes before its impoundment (Motaș & Anghelescu, 1944; Botnariuc & Cure, 1954; Miron, 1960), and the general limnology of the lake was detailed in a monography (Miron *et al*., 1983). The previous macrobenthos studies (Cure, 1962, 1967; Miron, 1968; Miron & Botea, 1968; Simalcsik, 1973) have shown a high reduction of diversity of rheophilus species in first six years after the impoundment, and dominance of two taxonomical groups: Tubificidae in the profoundal and Chironomidae in the shore zones of the lake. This paper aims to reveal the changes which have occurred in macrozoobenthic communities of the Izvoru Muntelui – Bicaz reservoir after 45 years of its existence comparing with the results of other studies.

Materials and Methods

Macrozoobenthos sampling took place monthly during from March to November 2005 at eight sites situated in shore, sublittoral and profoundal zones of the lake. The shore zone is characterized by a long denudation period during from November to March. The bottom substrate of the examined sites consists on gravel and sand with detritus and coars particulated organic matter. There is no macropyta and periphyton vegetation here. The sublittoral zone is submerged all year. The sediment consists in sand and silt. The profoundal zone represents approximately 75% of the total bottom area, and bottom substrate consists of slack mud with fine granulated organic matter resulting by sedimentation of the seston. The variability of the physical and chemical environment at the benthic area of the lake was described by Miron *et al.* (1983). The major characteristics of environmental factors are represented in Table 1 including the data given by Apetroaie (1991), and the results of monthly in–situ measurements, pH and temperature values.

Table 1. Environmental factors characterizing the benthic habitats in Izvoru Muntelui – Bicaz Reservoir.

Parameter	zone		
	shore	sublittoral	profundal
1. Surface water			
Water depth in sampled area (m)	0.5 – 1.5	35 – 45	70 – 82
Secchi depth (m)	0.5 – 1.5	0.3 – 0.9	0.5 – 1.7
Ph	5.5 – 7.5	6 – 7.5	6.5 – 7.5
Temperature (^oC)	1 – 25	2.5 – 16	4 – 6
2. Sediment – water interface			
pH	5.8 – 6.5	6.1 – 6.5	5.9 – 6.3
Temperature (^oC)	2.1 – 23.4	2.4 – 15.5	3.7 – 5.7
O_2 (mg/l)	5.5 – 11.2	4.6 – 7.2	0.0 – 2.5
3. Sediment granulometry (%)			
Gravel (>2mm)	18	7	0
Sand (<2 mm>0.06 mm)	59	21	12
Silt (<0.06 mm>0.004 mm)	17	46	23
Shale (<0.004 mm)	6	26	65
4. Sediment interstitial water chemistry			
105^oC humidity (%)	53.7	57.9	61.7
Total dissolved salts (mg/100g)	530.1	602.3	1065.7
Dissolved organic matter (%)	4.4	3.1	2.8

*by Apetroaie (1991)

On each site and each sampling occasion six replicate samples were taken with a modified Petersen grab (170.5 cm^2). In the laboratory macroinvertebrates were sorted and identified to species level, counted and weighed (formalin wet weight) for determination of densities (individuals/m^2) and biomass (g/m^2) values. Differences in mean total abundances and densities from each site were analyzed using two–way analyses of variance (ANOVA) by log_{10} transformed data. An index of ecological significance (Dzuba) is also calculated by mean percentage of annually frequency and the numerical dominance data using the formula: W= (F*d*100) / 10000, F=the frequency of species A, D= the dominance of species A. The index values ranging from W= < 0.1 corresponding to the accidental species to W= >10 corresponding to the euconstant species.

Results and Discussion

In the sampled benthic areas overall 23 macroinvertebrate taxa were identified. The most diverse group was Oligochaeta (39.1 %) and Chironomidae (34.7 % of the total number of taxa). The pattern of faunal richness distribution shows highest values: 20 taxa in the shore sites, and proportionally reduction by increases of water depth: 6 taxa in sublittoral and 4 taxa in the profoundal sites. Two species of Tubificidae: *Tubifex tubifex* and *Limnodrilus hoffmeisteri*, and same Chironomidae: *Procladius choreus* and *Polypedilum nubeculosum* were ubiquists. Five macroinvertebrates species were firstly described in the lake: *Haplotaxis gordioides, Eseniella tetraedra* (Oligochaeta) and *Valvata naticina* (Gasteropoda) in the restricted areas situated in the shore zone; *Lumbriculus variegates* (Oligochaeta) in the sublittoral and *Asellus aquaticus* (Isopoda) both in shore and sublittoral zones. During the end of summer stratification, in October, a very high Cyclopids (*Cyclops* sp.) aggregation (over 2500 individuals per 170.5 cm^2 sample) was observed in the depth water sediments.

Changes in density, biomass, diversity (H') and eveness (E') at each of the investigated benthic zones are presented in the Table 2. Average densities (individuals/m^2) showed a progressive increase from the shore zone to the profound zone. The respective biomass values (g wet weight/m^2) were low in the shore and sublittoral zones and increase by ca. 2.0 times in the profound zones. Sannon's diversity (H') and eveness (E') values decreased with increasing of the water depth.

Table 2. Average macroinvertebrate density, biomass ($\bar{x} \pm$ s.e.) diversity index (H') and eveness (E') in the sampled benthic zones (Sh.- shore; Sl.- sublittoral and Pr.- profundal).

	Sh.	Sl.	Pr.
Density (ind/m^2)	762 ± 183	11595±1421	2899±976
Biomass (g/m^2)	4.21±1.11	10.56±2.01	4.45±0.89
Diversity (H')	1.70	0.77	0.34
Eveness (E')	0.71	0.39	0.24

The numerically dominant two Tubificidae species (*Limnodrilus hoffmeisteri* and *Tubifex tubifex*) contributed 45.9-99.8 % to total density values in all benthic areas. In the upper half of the lake the zoobenthos was dominated by *Limnodrilus hoffmeisteri* and in the lower half by *Tubifex tubifex*. Chironomids were dominant only in the shore zone, where collectively represented 51.5 % by the total number of the individuals. In the sublittoral, chironomids may be considered subdominants (3.2 %) and in the profoundal were represented by an insignificant number of individuals (0.2 %) by the total macroinvertebrates density. In the shore and sublittoral zones two species: *Asellus aquaticus* and *Pisidium casertatum* constituted together from 1.0–1.3 % of the zoobenthic community (Table 3).

Table 3. Percentage contribution of characteristic macroinvertebrates species to the total average abundance in the shore, sublittoral and profoundal zones.

Shore	%	Sublittoral	%	Profoundal	%
Limnodrilus hoffmeisteri	35.7	*Limnodrilus hoffmeisteri*	66.3	*Tubifex tubifex*	98.7
Tubifex tubifex	9.8	*Tubifex tubifex*	30.2	*Limnodrilus hoffmeisteri*	1.1
Polypedilum nubeculosum	18.8	*Procladius choreus*	1.7	*Procladius choreus*	0.1
Procladius choreus	18.5	*Polypedilum nubeculosum*	0.8	*Polypedilum nubeculosum*	0.1
Chironomus spp.	9.3	*Pisidium casertatum*	0.5	Other taxa	0.0
Prodiamesa olivaceea	1.6	*Asellus aquaticus*	0.2		
Cryptochironomus defectus	1.1				
Cladotanytarsus mancus	0.7				
Asellus aquaticus	0.6				
Pisidium casertatum	0.4				
Other taxa	1.7				

The evaluation of an ecological significance index (Dzuba) indicated two euconstant ($w \geq 10$) species *Tubifex tubifex* and *Limnodrilus hoffmeisteri* in the all sampled sites. *Procladius choreus, Chironomus plumosus* and *Polypedilum nubeculosum*, were euconstant in the shore sites, *Asellus aquaticus* was constant ($w \geq 1 < 5$) in the investigated parts of the sublittoral. Other four chironomids: *Prodiamesa olivaceea, Cryptochironomus defectus, Chironomus gr. semireductus* and *Cladotanitarsus mancus* may be considered constant in the shore sites. The remaining species occurred occasionally ($w = 0.1 – 1.0$) or accidentally ($w \leq 0.1$) in the samples.

Two way ANOVA analysis indicated significant differences in the zoobenthic overall abundance between sites ($P=0.001$) and between dates ($P=0.007$). The difference in the Tubificidae abundance between sublittoral and profoundal are not statistically significant ($P=0.05$). The comparison between sampled benthic areas from a community ecology point of view using the Sorensen's (1948) formula has shown maximum similarity ($QS=0.54$) between shore and sublittoral and lowest similarity ($QS=0.32$) between shore and profound zones.

The majority of numerical dominant species (representing over 90% by the total macrozoobenthic densities) are considered tolerant and useful bioindicators for most severe water quality degradation caused by organic and inorganic pollutants (Nalepa & Thomas 1976, Seather 1979, Lenat 1993, Breiting & Tümpling, 1982, Frederich, 1990). The Izvoru Muntelui – Bicaz reservoir is not polluted, consequently the severe sediment conditions are determined by intrinsic limnological and biological conditions: oligotrophic morphometry, high water level fluctuations, degree of stratification, hypolimnic oxygen levels, food supply and others.

In the shallow well oxygenated shore areas, the community structure is determinate primarily by diurnally and seasonally water level fluctuations, causing a certain amount of transportation and dislocation of superficial sediment stratum with negative consequences on macrophyta and fixed algae colonization. In these conditions, the absence of phitophilus grazers and shredders is obvious. Burrower detritovorus tubificids (*L. hoffmeisteri* and *T. tubifex*) and filter feeders chironomids larvae (*Chironomus spp.*) were the almost totally dominating bottom inhabitants. However, the free swimmer predators *Pr. choreus, P. nubeculosum* (Chironomidae), *E. tetraedra* (Lumbricidae) may be also dominants or well represented.

The distribution of chironomids in the deep benthos may be limited of the oxygen depletition of the hypolimnion layer after the onset of the summer thermal stratification and by absence of the optimal food conditions.

In profoundal, total dominance of tubificids may be a consequence of them tolerance to anoxia, and a function of nutritional preferences. Wavre & Brinkhurst (1971) and other works shown the role of microorganisms in the diet of tubificids living in the absence of another food resources. In the Izvoru Muntelui – Bicaz reservoir the deep benthos food resources is limited by the phyto- and zooplankton sedimentation, rapidly decomposed in water column and the resulting nutrients serves as medium for bacterial communities.

The penetration of cyclopids in shallow eutrophic lake sediments is well known and interpreted as a hibernation strategy (Elgmork, 1959, Milbrink, 1973). The presence of a high number of *Cyclops viccinus* in the 70 – 82 m deep areas are firstly described in this paper.

The appearance of *Asellus aquaticus* in some sites can indicate a diffuse anthropogenic impact resulted from intensively riverside agro-turism and cage aquaculture activities. Stancovic *et al.* (1971) explain the increases of Isopoda densities in ancient Lake Ohrid by increasing of pollution degree in profoundal (over 130 m) areas after 1950.

Distribution pattern of species richness, dominance and average densities suggest the presence of two distinct benthic areas: 1) shore area, characterized by the instability of the environment events – high seasonally and diurnally water level fluctuations, high sedimentation rates, exogenous food supply from affluent drift and shore levigation, where the benthic community exhibited highest diversity and lowest density (controlled by fish predation) associated with considerable temporarily and spontaneous variations in species composition; 2) profound area, with low variations of environmental factors: constant low O_2 and temperature values, and only indigenous food resources from bioseston sedimentation where the benthic communities structure are nearly monospecific (*Tubifex tubifex*) developing highest densities in the reservoir. The sublittoral area is not distinguished clearly and has a restricted area in several locations in the upper quarter of the reservoir.

Historically, prior to impoundment 222 macrozoobenthic taxa were described in the starch of Bistrita River system situated in the reservoir area (Table 4). Litoreophilus and phitoreophilus insects accounted for the majority of the diversity, with Chironomidae contributing with more taxa (83 species) than any other insects or non insects groups (Miron, 1960; Cure, 1962). In the beginning of post-impoundment phases chironomids diversity depressed to 31 species in the first year and to 11 species in the sixth year (Cure, 1967). The overall macrozoobenthos species richness showed a continuous depressing trend from 47 taxa described in 1961-1968 period (Miron *et al.*, 1983), to 31 in 1970-1972 period (Simalcsik, 1973) and to 11 after thirty-eight years before impoundment (Toderaş *et al.*, 1999). Dominant species in the first year were represented by *Chironomus gr. plumosus, Polypedilum nubeculosum* and *Lauterbornia* Kieff in the 0.1-11 m water depth areas, in the deepest areas only few *Chironomus plumosus* and *Limnophies gr. transcaucasicus* were present in association with of the dominant Tubificids unidentified to genus or species level (Cure, 1967). After six years *Limnodrilus hoffmeisteri* became dominant species in shore zone and in the sublittoral zone and *Tubifex tubifex* in the profound zone (Miron, 1968; Miron & Botea, 1968). Chironomidae were well represented in the shore zone, especially by *Chironomus semireductus, Ch. thumi, Cladotanytarsus mancus* and *Cryptochironomus defectus*, and severely declined in the profound zone (Miron *et al.*, 1983; Simalcsik, 1973).

Table 4. Historical comparison of the macrozoobenthos species richness and diversity H' in Izvoru Muntelui – Bicaz Reservoir area between pre-impoundment and post-impoundment phases. Data for pre-impoundment phases (before 1960) have been taken from Cure (1962) and Miron (1960), and for post-impoundment phases from Cure (1967), Simalcsik (1973), Miron *et al.* (1983) and Toderaş *et al.* (2001). The number of new species occurred only in reference year period is given between parenthesis.

Taxonomical group	No. of taxa per year or period				
	Before 1960	1960-1968	1970-1972	1998	2005
Chironomidae	88	33 (6)	21 (4)	9 (1)	8 (0)
Oligochaeta	-	6 (3)	7 (3)	2 (0)	9 (3)
Other taxa	134	8 (0)	3 (0)	-	6 (2)
Total number of taxa	222	47 (9)	31 (7)	11 (1)	23 (5)

Average biomass values showed a continuous decreasing trend during from 1965 to 1998, especially in the shore zone and a substantially increases in 2005 of all benthic areas in contrast with 1998's values (Fig. 1).

The present picture of macrozoobenthos spatial distribution and community structure not differs essentially by the situation observed in first 5-6 years after impoundment. Changes in species composition in shore zone are not relevant, because both, the disappeared and new species exhibited very low densities and frequencies, without an important ecological signification.

The trophic status of Izvoru Muntelui – Bicaz reservoir is described as oligo-mesotrophic (Miron *et al.*, 1988; Toderaş *et al.*, 1999). This affirmation is not confirmed by the profoundal macrozoobenthos characteristics. The low number of species and the high dominance of only a small number of very tolerant Tubificidae species contrasting to relative low densities, suggest very severe benthic food regime constituted by a moderately algal production, consequently the trophic status in the deep benthic area is oligotrophic and only in the shore areas, where some indicative taxa (*Chironomus* spp., *Procladius choreus, Pisidium casertatum*) may be dominants, the trophic status having an incipient oligo-mesotrophic trend.

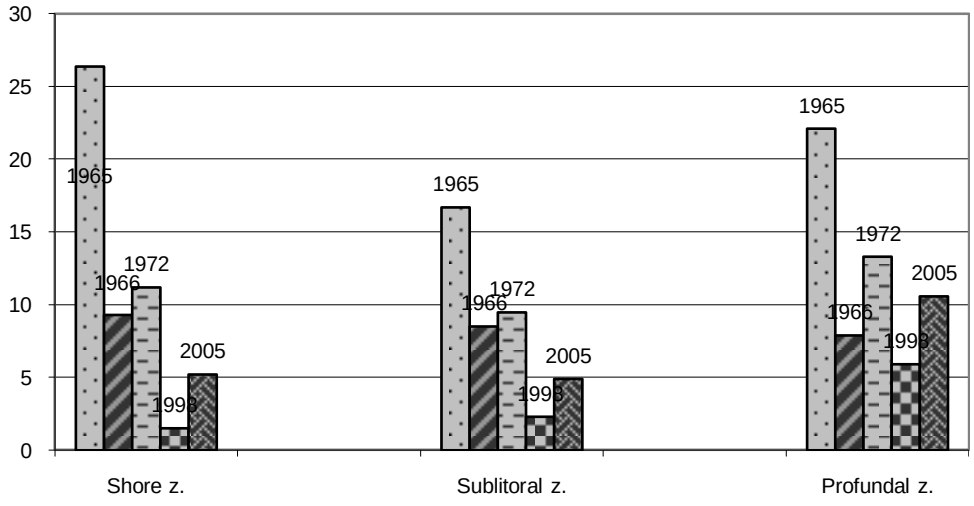

Figure 1. Distribution pattern of annual biomass mean (g/m^2 wet weight) of macrozoobenthos from Izvoru Muntelui – Bicaz Reservoir for 1965, 1966, 1972, 1998 and 2005.

Conclusions

1. Two way ANOVA analysis indicated significant differences in the zoobenthic overall abundance between sites (P = 0.001) and between dates (P = 0.007).

2. The difference in the Tubificidae abundance between sublittoral and profoundal is not statistically significant (P = 0.05).

3. The Chironomidae were well represented in the shore zone, especially by *Chironomus semireductus, Ch. thumi, Cladotanytarsus mancus* and *Cryptochironomus defectus*, and severely declined in the profound zone.

4. The appearance of *Asellus aquaticus* in some sites can indicate a diffuse anthropogenic impact resulted from intensively riverside agro-tourism and cage aquaculture activities.

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