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Ecological Status of Shallow Lakes in the Bulgarian Danube River Floodplain According to the ECOFRAME Approach: Testing a System for Integrated Ecological Quality Assessment

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Abstract: In this study four shallow lakes, situated in the Bulgarian Danube River floodplains were tested for the assessment of their ecological status. According to the Bulgarian legislation, the ecological classification of lakes and reservoirs is based mainly on physical parameters and on two biological quality elements, and namely phytoplankton and macrophytes. The other three widely used biological quality elements, macrozoobenthos, fish and zooplankton communities, are not adopted yet. An integrated method designed for the ecological assessment of shallow lakes called ECOFRAME approach was tested. This system had been developed for the implementation of the Water Framework Directive and included the application of other biotic variables. Our investigation was conducted in the summer of 2012. Most of the samples were collected and processed as described in the ECOFRAME methodology, or by the state-of-the-art methods. According to the analysed biotic variables, only the Srebarna Lake was assessed as a lake with Moderate ecological quality, while the other three sites were assessed as with Poor ecological quality. The ecological assessment based on abiotc variables determined Poor ecological quality for all of the studied lakes and it was accepted as being the final assessment of the ecological status. The results obtained suggest that the ECOFRAME method for ecological assessment needs further verification for the specific conditions in the shallow oxbow lakes on the Lower Danube River floodplain.

Keywords: Oxbow lakes, ecological status, ecological quality indices, Lower Danube River floodplain.

Introduction

The ecological assessment of lakes and water reservoirs according to the current Bulgarian legislation is based mainly on physical and chemical parameters, as well as on two biological quality elements, such as phytoplankton and macrophytes (Ordinance H-4/2013). Including more biological quality elements should give more precise ecological assessment.

The ECOFRAME system was developed by Moss *et al*. (2003) for the assessment of the ecological status of shallow lakes and for the implementation of the EU Water Framework Directive 2000/60/EC. It included easy measurable biotic and abiotic variables.

The present study intended to verify the applicability of zooplankton, macroinvertebrate and fish communities as reliable biological quality elements for the ecological assessment of shallow lakes, as suggested by the ECOFRAME system. Such an attempt for similar type of lakes has already been carried out during 2007 (Török *et al.* 2008). The authors tested the ECOFRAME assessment system on the lakes in the Danube River Delta region.

Moreover, an attempt for ecological assessment using standardised biological quality elements was made by Varadinova *et al.* (2012). Different indices, based on the macroinvertebrate community parameters, showed controversial results. For instance, the percentage of Oligochaeta, showed Good ecological quality while the ITC - Index of Trophic Completeness (Pavluk *et al.* 2000) defined Bad ecological quality. One of the well investigated Bulgarian lakes in terms of biological quality elements as zooplankton (Pehlivanov *et al*. 2006), macroinvertebrates (Varadinova *et al.* 2009) and fish communities (Pehlivanov 2000, Pehlivanov *et al.* 2005) is the Srebarna Lake.

Material and Methods

A method for an ecological quality assessment was tested using the ECOFRAME system in four selected shallow lakes, situated along the Bulgarian section of the Lower Danube River: Srebarna Lake, Malak Preslavets Lake, Plundogiri (or Prundogire) Oxbow and Torfata Marsh (Fig. 1). The Srebarna Lake is an oxbow lake in its origin. But since a Danube embankment in 1948, the lake was isolated from the river and reconnected again through a canal in 1994-1995. Currently its flooding regime is strongly regulated. The Malak Preslavets Lake was transformed into a reservoir and isolated from the Danube River by a dam in 1960s. The water level raised and the direction of the water flow remained one-way: from the lake to the river and overflowing the dam. The Plundogiri (or Prundugire) Oxbow is situated onto the island of Kozloduy. It has natural surface and underground hydrological connection with the Danube River. During high waters the whole area is flooded and the oxbow becomes a part of a side arm that divides the island into two parts. The Torfata Marsh is artificially excavated peat pit, located within the Orsoya Marshland and is naturally flooded by groundwater during spring flood periods. The floodplain of Orsoya is embanked and the surface hydrological connection with the Danube River is restricted.

Sampling was carried out in July and August 2012. The number of sampling points depended on the lake area size and the characteristics of the hydromorphology of each lake. About 30 variables were processed and analyzed: 10 biotic and 20 abiotic. Most of the samples were collected as described in the ECOFRAME methodology, or following ISO/EN methods. The obtained results of the measured parameters at the different sampling points were expressed as average values for the specific water body. Water temperature, conductivity, oxygen content, pH and salinity were measured using WTW multi1960i set. Google Earth history images were used for calculation of the water surface area. Instead of total phosphorous and total nitrogen (as described in the ECOFRAME system), the dissolved inorganic forms $P\text{-}PO_4^{-3}$ and total inorganic nitrogen TIN were measured.

Two statistics based on macroinvertebrates were calculated: the percentage of predators to the total number of macroinvertebrates and the percentage of Oligochaeta to Chironomidae. Hand-net sampling with accordance to the Standard EN 27828:1994 was used for collecting macroinvertebrates from the vegetation, while soft-bottom macroinvertebrate samples were collected using Ekman-Birge sampler (Standard EN ISO 9391: 1995). For the fish sampling gillnet of NORDICA type was used and left for two to eight hours overnight. No distinct zooplanktivorous fish species were found in Srebarna Lake (Pehlivanov, Pavlova 2012), neither in the Torfata and Malak Preslavets (Pavlova, Pehlivanov 2012). Therefore, the ratio of piscivorous to non-piscivorous fishes,

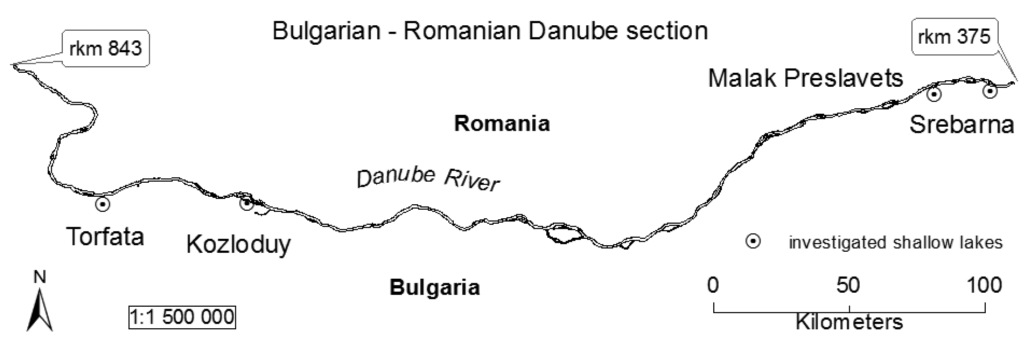

Fig. 1. Position of the investigated shallow lakes

calculated using fish biomass, was used instead of the index piscivores to zooplanktivores, as suggested in the original ECOFRAME methodology.

Two ecological estimates (based on the biotic, and then based on the biotic and abiotic variables together) were applied according to the used methodology. Each biotic variable was assessed and assigned a single ecological quality class (High, Good, Moderate, Poor or Bad). The estimate for the group of the biotic variables was assigned the class, which included more than 80% of the total biotic variables in ascending order. For the second assessment the same operation was repeated with the whole list of variables (biotic and abiotic). The final result was obtained through assigning the overall poorer ecological quality class to the shallow lakes.

Results and Discussion

All of the studied water bodies were small, with water surface area less than 100 km^2 (Table 1). The average water temperatures, registered in July and August were higher than 25^{o}C (Table 1). Since the ice cover lasts usually more than two months during the winter, Torfata, Malak Preslavets and Srebarna lakes were classified as cool shallow lakes. On the island of Kozloduy the ice cover is often melted by the winter flow, thus the oxbow of Plundogiri acquires characteristics of a lotic ecosystem. That is why the latter was referred as to a warm shallow lake. According to the geomorphological features the Srebarna Lake and the Malak Preslavets Lake were referred to the Ecotype 8 and the Plundogiri – to the Ecotype 20 as it is situated on rocky sediments, while Torfata Marshland was referred to the Ecotype 11, based on the underlying peat soil deposits.

The surface water flow connectivity (Table 2) in the Orsoya Marshland occurs only when the water level of the Danube River reaches extremely high values. Such conditions were observed during the winter-spring period of 2010, accompanied by a destruction of the embankment integrity. In general, the water retention time was shortened to a minimum because of the drainage canal system, constructed within the marshland. During 2012 no surface flooding occurred in the marshland. Malak Preslavets Lake has not been flooded by the Danube River after the construction of the dam, because the embankment is situated higher than the maximum recorded water level in the Danube River. The outflow from the Srebarna Lake is highly regulated by the management authorities with the intention to maintain the water level as high as possible. Overall, the water flow connection and the retention time in these three water bodies are strongly modified.

The only water body which is not modified, with regard to the water flow connection and water retention time, is Plundogiri on the island of Kozloduy. No human impact that could disturb the groundwater supply of the shallow lake or could cause groundwater depletion and significant depth variation was identified. Moreover, no human activities were found which could cause a substrate abstraction, change of the salinity concentration or influence the temperature in as defined in the ECOFRAME assessment system.

Oxygen conditions were slightly modified, *i.e.* there was a higher fluctuation of the oxygen concentration caused by the algae blooms in Srebarna Lake and macrophyte development in the Torfata Marshland. These conditions were triggered probably by the nutrients influent from the adjacent vil-

Table 1. Categorisation of the shallow lakes according to the ECOFRAME geomorphology

Variable/ Lake	**Torfata**		**Plundogiri**		**Malak Preslavets**		**Srebarna**	
River kilometer (rkm)	765		699		413		393	
Catchment geology	Peat		Rock		Rock		Rock	
Conductivity (µS.cm^{-2})	507	100-800	303	100-800	765	100-800	388	100-800
Average temperature (C^o) in the warmest month	25.9	>25	29.3	>25	27.2	>25	29.8	>25
Ice cover (months)	2.5	>2	1.5	<2	2.5	>2	2.5	>2
Water surface area (km^2)	0.03	<100	0.09	<100	0.36	<100	1.06	<100
Number of stations	4		4		4		6	
Ecotype No.	11		20		8		8	
Lake type	Small cool		Small warm		Small cool		Small cool	

Table 2. Descriptive abiotic variables. Legend**:** Abiotic variables (AV) values: N-Normal, M-Modified, SM-Strongly Modified; U-Undisturbed, MD-Moderately Disturbed, D-Disturbed, SD-Severely Disturbed; Ecological Quality (EQ) responding to the variable: H-High, G-Good, M-Moderate, P-Poor, B-Bad

Lake / Variable	Torfata		Plundogiri		Malak Preslavets		Srebarna	
	AV	EQ	AV	EQ	AV	EQ	AV	EQ
Water flow connection	SM	P	N	H	SM	P	SM	P
Water residence time	SM	P	N	H	SM	P	SM	P
Groundwater connection	N	H	N	H	N	H	N	H
Depth variation	U	H	U	H	U	H	U	H
Substrate	U	H	U	H	U	H	U	H
Temperature	U	H	U	H	U	H	U	H
Oxygen	MD	G	U	H	MD	G	MD	G
Salinity	U	H	U	H	U	H	U	H

Table 3. Measured abiotic variables (AV) and Ecological Quality signage (EQ) is the same as in Table 2

Lake / Variable	Torfata		Plundogiri		Malak Preslavets		Srebarna	
	AV	EQ	AV	EQ	AV	EQ	AV	EQ
pH (log units)	7.84	M	7.97	M	8.17	M	9.21	P
Transparency (m)	1.17	M	0.52	B	0.71	B	0.24	B
Chlorophyll-a (μg/l)	9.30	H	5.84	H	39.12	P	65.89	B
$P-PO_4$ (mg/l)	0.16	B	0.13	B	0.08	B	0.17	B
Total inorganic nitrogen (mg/l)	0.35	G	0.44	G	0.38	G	0.32	G
Total hardness GH/Ca (mg/l)	94.3		93		145.5		57.4	

lages and fertilizer influx from the surrounding croplands.

The high values of pH define the Poor quality status of the Srebarna Lake, corresponding also to higher concentration of chlorophyll-a and reciprocal lower water transparency (Table 3). Severe algal blooms were observed as a confirmation of the values of chlorophyll-a. The high fluctuation of the pH in the Srebarna Lake probably depended on the low buffer capacity of the water, determined by the low values of the total water hardness (Table 3). The pH values in the Torfata, Plundogiri and Malak Preslavets water bodies corresponded to Moderate conditions. These water bodies were characterised by more stable condition and higher total hardness of the water. The higher water transparency in Torfata Marsh was associated with the high abundance of submerged plants (Table 4). The submerged plants are competing and suppressing the algal development, which results in lower chlorophyll-a concentration (Table 3). In the Malak Preslavets Lake the water transparency was determined directly by the algal development, expressed by high values of chlorophyll-a, while in the case of Plundogiri Oxbow we recorded high turbidity (Table 3).

Inorganic phosphorous was measured and extremely high values were found (Table 3). The values of total phosphorous (from the literature) usually exceed ten times the values of the inorganic phosphorous. Therefore, the measured values were used, since it was accepted that the values of the total phosphorus would exceed the limit for Bad ecological status.

During the assessment of the biotic variables the predominant macrophyte communities in all of the investigated lakes were identified as a „CanNym" community (Moss *et al*. 2003), since the communities were composed mainly by poorly rooted vascular plants like *Ceratophyllum sp.*, *Myriophyllum sp.* and *Nymphaea sp.*. The macrophytes occupied the biggest volume in the Torfata Marsh, where over 90% of the area was overgrown during the period of the investigation (Table 4). On the other hand, the lowest abundance and diversity of macrophytes were recorded in Plundogiri Oxbow, while the highest diversity of macrophyte species per area was established at Malak Preslavets Lake (Table 4).

The highest percentage of predators among the macroinvertebrates to the total number of individu-

Table 4. Assessed Biotic variables. Ecological Quality signage (EQ) is the same as in Table 2

Legend: Ecological Quality (EQ) as in Table 2; CanNY – Extensive communities of nymphaeids and/or canopy forming poorly rooted vascular plants as *Ceratophyllum demersum* and *Lemna trisulca* (acc. Moss *et al.* 2003); Pi - present piscivorous fish.

Variables / Lake	Torfata		Plundogiri		Malak Preslavets		Srebarna	
	AV	EQ	AV	EQ	AV	EQ	AV	EQ
Plant community	CanNY	M	CanNY	M	CanNY	M	CanNY	M
Plant diversity (ident.sp. No)	4	M	2	P	8	M	5	M
Plant abundance	3	M	1	P	2	G	2	G
No. large/ No. total Cladocera	0.1	P	0.95	G	0.16	P	0.5	G
Zoopl/Chl-a (mg/µg)	15.33	P	63.47	M	113.87	G	10.17	P
Predators/total invertebrates (%)	10.62	M	8.19	P	35.88	H	16.07	G
Oligo/Chiro (ratio by No)	5.73	B	9.35	B	4.58	B	0.44	G
Fish community	Pi	M	Pi	M	Pi	M	Pi	M
Fish biomass CPUE ($g/m^2/h$)	24.36	M	32.87	M	n/a		14.03	G
Pi/non-Pi fish (ratio by biomass)	0,43	P	0,34	P	n/a		0,27	P

Table 5. Final assessment. Ecological Quality signage (EQ) is the same as in Table 2

Variables / Lake	Torfata		Plundogiri		Malak Preslavets		Srebarna	
	AV	EQ	AV	EQ	AV	EQ	AV	EQ
Biotic variables %/status	90	P	90	P	88	P	80	M
Total variables %/status	91	P	83	P	86	P	87	P
Lesser of the two estimates		P		P		P		P

als was recorded in Malak Preslavets Lake, while the lowest one was found in Plundogiri Oxbow (Table 4). In most of the cases the ratio of Oligochaeta to Chironomidae showed higher predominance for the abundance of Oligochaeta with comparison to the abundance of Chironomidae, indicating Bad ecological quality. Only for the Srebarna Lake this proportion indicated Good quality status.

The two zooplankton variables were recorded with values that could be interpreted ambiguously (Table 4). The values of the ratio of large to total Cladocera defined Poor ecological quality in the Torfata and Malak Preslavets lakes but Good ecological quality in the Plundogiri and Srebarna lakes. At the same time the values of the ratio of zooplankton to chlorophyll-a varied from Poor ecological quality, in the Torfata and Srebarna lakes, to Moderate, in the Plundogiri Oxbow and even Good ecological status in the Malak Preslavets Lake.

In all of the investigated shallow lakes "native piscivorous" fish species, as well as "introduced aggressive" (as defined by ECOFRAME) fish species were recorded (Table 4). This finding assigned them the Moderate ecological quality status. The assessement of the fish biomass indicated a Moderate status of the Torfata and Plundogiri marshes, while the registered catches in the Srebarna Lake referred it to Good quality status. Piscivorous to non-piscivorous fish ratio defined Poor classes for all of the water bodies.

The sum of the biotic variables (Table 5) that included over 80 %, defined for the Srebarna Lake Moderate and for the Torfata, Malak Preslavets and Plundogiri – Poor ecological quality. The sum of the total variables gathering 80 % of the classes defined Poor ecological quality for all of the investigated shallow lakes. Therefore, the final ecological quality assessment, based on the lower estimates obtained from the biotic or total variables defined Poor ecological status for all of the water bodies.

Conclusions

The overall ecological quality of the studied water bodies, based on biotic and abiotic variables, was assessed as Poor using the indexes from the ECOFRAME system. The obtained results suggest that, in order to meet the specific features of the aquatic ecosystems of wetlands on the floodplains of the Lower Danube River, the ECOFRAME system needs further testing and adapting with regards to the indicative values of the variables and the borders between different ecological quality classes.

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