FISH-BASED ASSESSMENT OF THE ECOLOGICAL STATUS OF THE KIS-BALATON–BALATON RESERVOIR–LAKE SYSTEM, HUNGARY

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ABSTRACT

In Europe, the implementation of the WFD requires the use of fish-based tools to assess the ecological status of all lentic water bodies, including reservoirs with an area of over 50 ha. The first multimetric, fish-based index developed by Karr has been mostly adapted to lotic systems; much less emphasis has been put on similar assessment of ecological conditions of lentic systems, especially reservoirs. In our study, a spatial analysis was done to assess the ecological status of three different, but geographically connected, water bodies: two reservoirs of the Kis-Balaton Water Protection System (KBWPS) and the western basin of Lake Balaton. The KBWPS was designed to function as a natural filter zone and to protect the water quality of Lake Balaton. The main aim of our study was to lay out the framework for assessing the ecological status of the Kis-Balaton Water Protection System and Lake Balaton and to present a preliminary approach to investigate what are the most applicable attributes and metrics which can be used later on in a more detailed study.

Keywords: ecological status, fish-based index, Kis-Balaton Water Protection System, Lake Balaton, Water Framework Directive.

1 INTRODUCTION

Lake Balaton is the largest shallow freshwater lake in Central Europe [1]. It is located in West Hungary, with an area of 596 km^2, and a mean depth of 3.25 m. At present it consists of four basins, but originally the Kis-Balaton ('Kis' means small or little in Hungarian) belonged to the lake, forming its most western, fifth basin. The transition of the Kis-Balaton from a shallow lake to a wetland is discussed by Korponai *et al*. [2]. Actually it has been called Kis-Balaton from the beginning of the 19th century. River Zala flushed over the wetland which functioned as a natural filter zone, retaining nutrients and suspended solids. In the 19th century the water level of Lake Balaton was artificially modified and lowered which resulted in the partial desiccation of the wetland. Only two parts escaped, being situated in the area of the second reservoir.

Disappearance of this filter, in parallel with the increase of nutrient load carried by River Zala, was the main reason of the serious eutrophication of Lake Balaton by the 1960s. This river supplies 45% of the lake's water and 35–40% of its nutrient input [3].

In order to restore the filtering zone, a huge wetland restoration or rather reconstruction project was initiated in 1982. The Kis-Balaton Water Protection System was built of two reservoirs: the first (Lake Hídvégi) was finished in 1985; the second (Lake Fenéki) was partially completed in 1992, as only 16 km^2 of the originally planned area was inundated (Fig.1).

The first reservoir is an open-water habitat, whilst the second is a marshland with 95% macrophyte coverage, primarily reed [4]. It should be noted that during the construction of the first reservoir a meadow was inundated, in the area of the second reservoir some parts of the original Kis-Balaton Wetland have survived, providing refugee for protected and rare species such as *Umbra krameri* (Walbaum, 1792) and *Misgurnus fossilis* (Linnaeus, 1758). The whole Kis-Balaton Water Protection System is under the de-jure protection of the Ramsar Convention.

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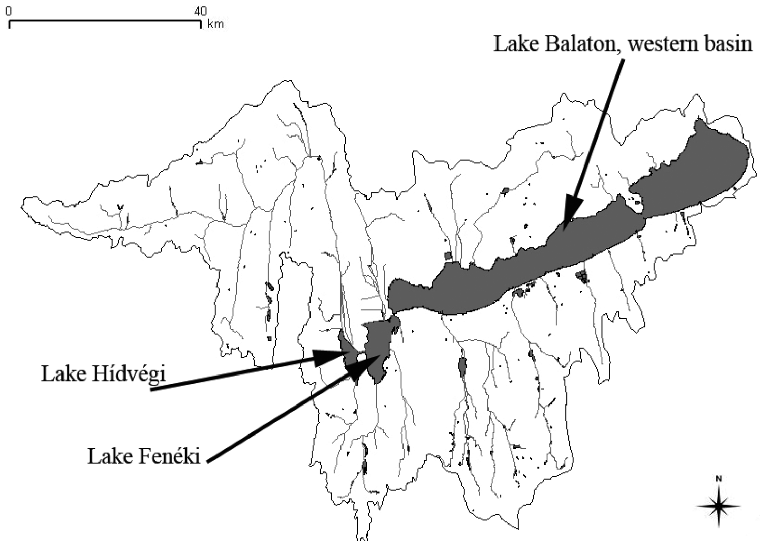

Figure 1: Schematic map of the Kis-Balaton water protection system and Lake Balaton.

In Europe, the implementation of the Water Framework Directive (WFD), which entered into force in 2000, requires the use of fish-based tools to assess the ecological status of all lentic water bodies, including reservoirs with the area over 50 ha.

The first fish-based multimetric index, called Index of Biotic Integrity (IBI) was developed by Karr [5]. 'Integrity' has been defined as the ability of the ecosystem to support and maintain 'a balanced integrated, adaptive community of organisms having a species composition, diversity and functional organisms comparable to that of a natural biota of the region' [6]. 'Good ecological quality' defined by the WFD may have the same meaning.

Karr's original index was used on lotic systems, on the Midwestern streams of the US. It is still mostly used for assessing the ecological status of rivers, streams, etc., but fish-based indices are available for lentic systems such as lakes [7] or wetlands [8]. Still, reservoirs have been only scarcely addressed. They are considered as an intermediate between lentic and lotic systems, especially due to high exchange rates [9, 10]. Petesse *et al.* [11] even considered the term biotic integrity inappropriate due to the artificial nature of reservoirs and used the term Reservoir Fish Assemblage Index (RFAI) instead. In Europe, Launois *et al.* [12, 13] developed a fish-based index (FBI) of biotic integrity for both natural and artificial French lakes.

Although the metrics included in a fish-based index and the way in which those metrics are scored may depend on the habitat type and geographical region [14, 15], the structure of the indices is very similar. They incorporate important ecosystem attributes such as taxonomic richness, trophic guild composition, individual health and abundance. These attributes are characterized by metrics which in turn are rated and scored.

The main aim of our study was to lay out the framework for assessing the ecological status of the Kis-Balaton Water Protection System and Lake Balaton. In fact, this is a preliminary approach to investigate what are the most applicable attributes and metrics which can be used later on in a more detailed study.

2 MATERIALS AND METHODS

2.1 Sampling

Samples were taken in June 2011 in three locations, in Lake Hídvégi, Lake Fenéki and the western basin of Lake Balaton (see Fig.1). Samples were collected by electrofishing, using a 12V battery-powered AGK-Kronawitter IG-200/2 (300–600V) electric fishing device. Samplings were carried out in the morning hours, one hour in each site three times.

2.2 Candidate metrics

Including abundance 18 metrics were selected. Species richness and composition were described by the following metrics: total number of fish species [6], total number of non-native species [10], % abundance of non-native fish [16], % tolerant individuals [17] and total number of intolerant species [8]. Five metrics were related to trophic guilds: % omnivorous, % piscivorous, % invertivorous, % herbivorous and % planktivorous [12].

Presence of tolerants, non-natives, as well as metrics related to trophic guilds were also expressed as % biomass, such as % non-native, % tolerant, % omnivorous, % piscivorous, % invertivorous, % herbivorous and % planktivorous [18].

2.3 Statistical analysis

We used Spearman rank correlations to search relations among biomass and abundance-based metrices.

3 RESULTS AND DISCUSSION

Relative abundance and biomass of species as well as their characterization are given in Tables 1 and 2, respectively. Both data series are given as a cumulative value of 3×1 hour sampling. Assignment into trophic guilds was done based on literature data [12, 19] and on expert judgment. The calculated values for the metrics are summarized in Table 3.

The first main point is to evaluate if the variables selected are informative enough to characterize the ecological condition of the reservoir-lake system. Also, values derived based on abundance of a given guild should be compared with those derived from biomass of the same guild. Occurrence of non-native species is considered as a disturbance factor [18]. While the ratio of non-native species was approximately the same in all three water bodies (3/15 in the first reservoir, 4/16 in the second and 3/15 again in Lake Balaton), abundance vs. biomass-based data show completely different tendency. Percentage of non-native individuals is considerably higher in the second reservoir (21.97%) than in the first one or in Lake Balaton (5.71 and 1.59%, respectively). On the contrary, total biomass of non-natives falls in the same range in all three water bodies (3.57, 5.20 and 5.54%). Based on the high abundance of non-natives, the second reservoir shows the highest disturbance.

Tolerant species are able to accommodate to a variety of environmental conditions, including stress factors such as physical disturbance, low water quality or even toxic stress [20]. Abundance of tolerant individuals fell in app. the same range in all water bodies, being somewhat lower in the second reservoir with 80.65%. Biomass-based values showed much more marked differences, with 73.39% in the first reservoir, 23.23% in the second and a high value again, 88.04% in Lake Balaton. Lower ratio of tolerants in the second reservoir might indicate a lower level of environmental disturbance (apart from non-natives, as discussed earlier).

Table 1: Biomass of species in the three water bodies (g).

	1st reservoir	2nd reservoir	Lake Balaton
Abramis brama (T, Omni)	16,459	1527	3160
Alburnus alburnus (T, Plankti)	819	693	2229
Aspius aspius (T, Pisci)	264	8110	4200
Blicca bjoerkna (T, Omni)	1150	415	500
Cyprinus carpio (T, Omni)	71,600	69,405	119,000
Esox lucius (Pisci)		46	900
Gymnocephalus cernuus (Inverti)	1		
Perca fluviatilis (T, Inverti)	82	15	459
Rutilus rutilus (T, Omni)	6747	984	6856
Sander lucioperca (Pisci)	240	173	3215
Scardinius erythrophthalmus (Omni)	101	50	3841
Silurus glanis (Pisci)	37,400	344,900	12,000
Tinca tinca (T, Omni)	2000		1295
Rhodeus sericeus (Intol, Inverti)		8	
Anguilla anguilla (NN, T, Inverti)			650
Carassius gibelio (NN, T, Omni)	5056	23,261	8587
Lepomis gibbosus (NN, T, Inverti)	12	94	10
Neogobius fluviatilis (NN, T, Inverti)		23	
Pseudorasbora parva (NN, T, Plankti)	12	11	

NN: non-native; T: tolerant; Intol: intolerant; Omni: omnivorous; Inverti: invertivorous; Pisci: piscivorous; Plankti: planktivorous; Herbi: herbivorous.

Table 2: Relative abundance of species in the three water bodies.

	1st reservoir	2nd reservoir	Lake Balaton
Abramis brama (T, Omni)	17	8	6
Alburnus alburnus (T, Plankti)	131	101	438
Aspius aspius (T, Pisci)	15	8	3
Blicca bjoerkna (T, Omni)	19	9	5
Cyprinus carpio (T, Omni)	17	14	29
Esox lucius (Pisci)		2	3
Gymnocephalus cernuus (Inverti)	1		
Perca fluviatilis (T, Inverti)	36	7	33
Rutilus rutilus (T, Omni)	480	144	181
Sander lucioperca (Pisci)	14	59	7
Scardinius erythrophthalmus (Omni)	5	4	34
Silurus glanis (Pisci)	6	27	1
Tinca tinca (T, Omni)	2		3

Continued

Table 2: *Continued*.

Rhodeus sericeus (Intol, Inverti)		4	
Anguilla anguilla (NN, T, Inverti)			1
Carassius gibelio (NN, T, Omni)	42	89	10
Lepomis gibbosus (NN, T, Inverti)	1	14	1
Neogobius fluviatilis (NN, T, Inverti)		2	
Pseudorasbora parva (NN, T, Plankti)	2	4	

NN: non-native; T: tolerant; Intol: intolerant; Omni: omnivorous; Inverti: invertivorous; Pisci: piscivorous; Plankti: planktivorous; Herbi: herbivorous.

Table 3: Calculated values of metrics selected.

	1st reservoir	2nd reservoir	Lake Balaton
Total number of species	15	16	15
Total number of non-natives	3	4	3
% of non-native individuals	5.71	21.97	1.59
% biomass of non-natives	3.57	5.20	5.54
% of tolerants	96.70	80.65	94.04
% biomass of tolerants	73.39	23.24	88.04
Total number of intolerants	0	0	
Proportion of individuals as Omnivores	73.86	55.25	35.1
% biomass of Omnivores	72.57	21.27	86.21
Proportion of individuals as Invertivores	4.69	4.23	4.5
% biomass of Invertivores	<0.001	<0.001	0.28
Proportion of individuals as Piscivores	4.44	19.35	1.86
% biomass of piscivores	26.70	78.55	12.17
Proportion of individuals as Herbivores	0	0	
% biomass of herbivores	0	0	
Proportion of individuals as Planktivores	16.88	21.17	58.01
% biomass of planktivores	0.58	0.15	1.34
Number of individuals	788	496	755
BPUE (kg/h)	47.3	149.9	55.6

Considering the occurrence of omnivores, the second reservoir is in the intermediate position with the abundance of 55.25% (abundance is 73.85% in the first reservoir and 35.1% in Lake Balaton). However, considering biomass, it is the lowest in the second reservoir (21.27%) and quite similar in the other two water bodies (72.57% and 86.21%, respectively).

With regard to trophic guilds, piscivores or top carnivores are indicative for assessing the loss of trophic diversity and keystone species [18]. Both their abundance and biomass are the highest in the second reservoir: 19.35% and 78.55%, respectively. In fact, this high biomass value is rather extreme, caused by the high population size of *Silurus glanis*.

According to Launois *et al*. [13], the decrease in piscivores and an increase in planktivores might reflect eutrophication. Seemingly, this is the most considerable difference between the first reservoir and Lake Balaton: biomass of planktivores is low in all water bodies but their abundance is surprisingly high in Lake Balaton, with 58.01%. In fact, considering other metrics, such as non-natives or tolerants, the first reservoir and Lake Balaton seem to be rather similar.

One main question is whether biomass-based values provide more information than abundance-based metrics. Seemingly, in case of some metrics (such as presence of tolerants, omnivores and piscivores), biomass-based data give a completely different picture than abundance-based ones, showing no correlation (Spearman correlation KBWPS first reservoir: $r=0.6$, $df=4$, $P=0.208$; KBWPS second reservoir: $r=0.429$, $df=4$, $P=0.391$; Lake Balaton: $r=0.371$, $df=4$, $P=0.468$). In general, biomass-based data might provide a more sensitive description of the functioning of the ecosystem. However, as the stress during sampling is higher (fish specimens have to be removed and individually measured), this metric is best used if the ecosystem status is to be assessed involving other elements such as phytoplankton, zooplankton, etc.

The other main point is whether the selected attributes and metrics can provide a proper tool for assessing the status of such a complex lake-reservoir system. The answer is yes and no. Yes, as the fish-based assessment could successfully differentiate between the second reservoir and the two other water bodies, showing its ‘best’ ecological quality (it was the only water body with intolerant species). However, seemingly the first reservoir and Lake Balaton have a rather similar ecological status while the anthropogenic pressure on the two water bodies is different. The first reservoir is of artificial origin, but its colonization by fish occurred in a natural way and no man-made control exists on its fish stock. On the contrary, Lake Balaton is a natural water body, but its fish stock is heavily controlled, via stocking. Such anthropogenic pressure is not reflected, however.

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