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TROPHIC STATE AND MACROPHYTE BASED ASSESSMENT OF THE ECOLOGICAL STATUS OF SELECTED RESERVOIRS IN BULGARIA

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Abstract

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The objectives of the study were to assess the trophic state and to compare it to the ecological potential of the water bodies according to the macrophyte assemblages within selected reservoirs. The studied reservoirs varied greatly in their trophic status, as well as in species composition and abundance. Sampling was conducted between 2009 and 2014. The concentrations of nutrients and the Carlson's trophic state indices were used to assess the trophic state of the reservoirs. The trophic state varied between oligo-mesotrophic to hyper-eutrophic, with the majority being eutrophic. A discrepancy between the expected trophic state and the measured one was observed for each water body type. No correlation was observed between the trophic state and the ecological status of the water bodies. Trophic state assessment, traditionally, is focused on the "open water" conditions and not so on the littoral aquatic plant communities. The latter, on the other hand, can modify the trophic state by reducing the nutrient inputs to the water bodies. The two assessment schemes have different ecological meanings as the former assesses the algal biomass and the latter – the deviation from reference conditions. Our results show the need to further investigate the relationship between the different biological quality elements, and their response to the changes in the supporting physicochemical parameters.

Key words: WFD, BQE's, macrophytes, reservoirs, bioindication, monitoring, eutrophication

Introduction

For the purposes of implementing the WFD, macrophyte data was collected from a series of reservoirs throughout Bulgaria. The aim was to examine the relationships among different classification systems for estimation of the quality of the water bodies. The Bulgarian Reference Index of Macrophytes (RI_{BG}) (Gecheva et al., 2010) was used to define the ecological status, and the trophic state was assessed according to the Carlson's Trophic State Indices (Carlson, 1977). The sampled reservoirs span along the trophic gradient from oligotrophic to hypereutrophic and those for which RI_{BG} could be calculated ranged from mesotrophic to hypereutrophic.

The trophic state is among the main environmental factors affecting the development of aquatic macrophytes in lakes (Spence, 1967; Hutchinson, 1975; Best et al., 1984). Other factors are general water chemistry (Kadono, 1982; Hoyer et al., 1996), substrate characteristics (Pearshall, 1920; Barko et al., 1986), light availability (Canfield et al., 1985), prevailing winds (Duarte and Kalff, 1986) and lake morphology (Pearshall, 1917; Duarte and Kalff, 1986). The effects of these factors can be modified by the water level fluctuation in reservoirs, thus affecting the development of macrophytes. As fluctuations increase in magnitude the macrophyte populations get sparse. This results from the littoral zone of such water bodies being irregularly flooded and dried up, with corresponding changes in basin slope and depth.

When conditions are stable and the above mentioned factors are favorable for aquatic macrophyte growth, significant

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relations exist between aquatic macrophyte abundance and lake water chemistry (Canfield et al., 1983), phytoplankton abundance (Landers, 1982) and many other limnological processes (Hutchinson, 1975). Aquatic macrophytes and their communities have been shown to indicate changes occurring in lakes due to eutrophication (Roelofs, 1983; Lehmann and Lachavanne, 1999). The importance of aquatic macrophytes to the overall functioning of the lakes and reservoirs decreases as they get larger and deeper (Rounsefell, 1946; Tilzer and Serruya, 1990). Although, the aquatic macrophytes reflect, more or less, the changes in their environment, Alaoui et al. (2013) highlighted the limitations of using macrophytes to assess reservoir status according to the Water Framework Directive. The highly variable environment in reservoirs affects the biological diversity, biomass, and community structure of the macrophytes, without corresponding changes in the trophic state of the water bodies.

The main studies on the composition of aquatic macrophytes in Bulgaria are the ground works of Yordanoff (1931), Kochev and Jordanoff (1981) and Kochev (1983) among others. The assessment of water quality by macrophytes and their relation to the main physicochemical parameters and trophic state in Bulgarian water bodies is given in Gecheva et al. (2010), Tosheva and Traykov (2010), Gecheva et al. (2011), Tosheva and Traykov (2012), Tosheva and Traykov (2013), Savchovska et al. (2013), Gecheva et al. (2013), Teneva et al. (2014).

Materials and Methods

Eighty one reservoirs, situated from 28 to 2375 ma.s.l., from the two (12-Pontic province and 7-Eastern Balkans) ecoregions in Bulgaria were investigated between June 2009 and July 2014. An assessment of macrophyte composition and abundance and of water quality was carried out in the reservoirs. From the whole data set we selected twenty nine reservoirs with various morphometric conditions and a wide spectrum of water quality and anthropogenic pressures and macrophyte abundance, for assessment of the relationship between the trophic state and the macrophyte based assessment of the ecological status. These reservoirs are presented in Figure 1.

The sampling was done on one site in the deepest part of the reservoirs for trophic status determination. At each sampling station, field measurements were made of physical variables including temperature, dissolved oxygen, pH, spe-

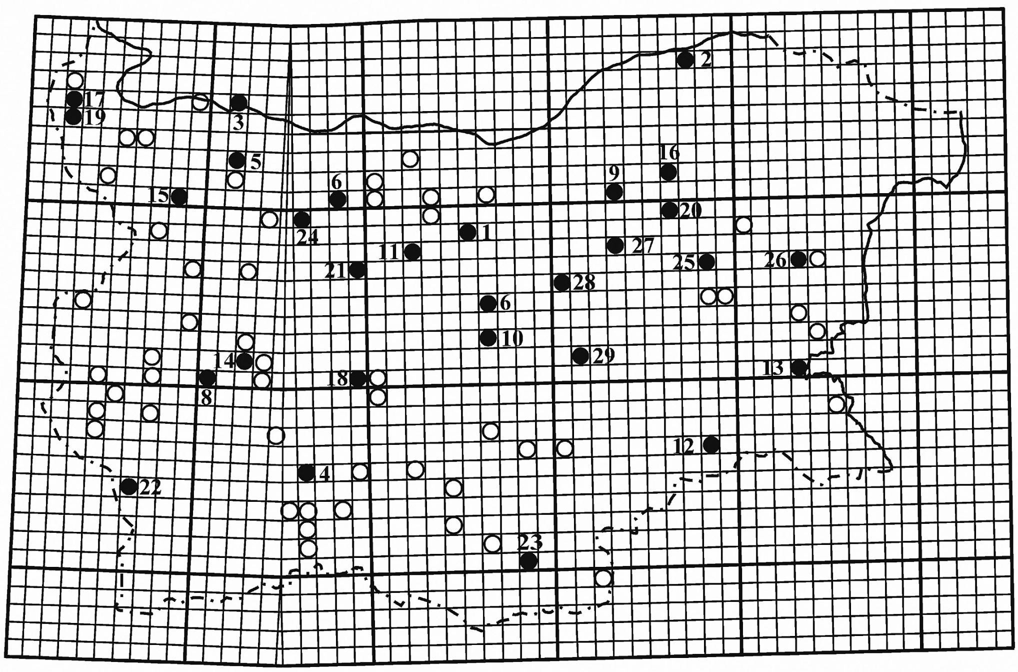

Fig. 1. An UTM grid map of Bulgaria showing the location of surveyed water bodies mentioned in the text (Scale 1:1500000): 1 – Al. Stamboliyski, 2 – Antimovo, 3 – Asparuhov val, 4 – Batak, 5 – Barzina, 6 – Christo Smirnenski, 7 – Gorni Dabnik, 8 – Iskar, 9 – Kavatsite, 10 – Koprinka, 11 – Krapets, 12 – Malko Sharkovo, 13 – Mandra, 14 – Ognyanovo, 15 – Ogosta, 16 – Pchelina-2, 17 – Poletkovtsi, 18 – Pyasachnik, 19 – Rabisha, 20 – Saedinenie, 21 – Sopot, 22 – Stoykovtsi, 23 – Studen Kladenets, 24 – Telish, 25 – Ticha, 26 – Tsonevo, 27 – Yastrebino, 28 – Yovcovtsi, 29 – Zhrebchevo

cific conductance and Secchi disk visibility. Integrated water samples were taken from the epilimnion, according to Wetzel and Likens (2000) for laboratory determination of chemical variables including total alkalinity (ISO 9963-1) and nutrient concentrations: total and phosphate phosphorus, ammonium nitrogen, nitrate and total nitrogen. All determinations were done with MERCK test kits on WTW spectroFlex 6100 spectrophotometer. Biological variables included chlorophyll-*a* (ISO 10260) and macrophyte reference index (RI_{BG}), according to Gecheva et al. (2010).

Field surveys, applying belt transect method, were carried out according to the RI_{BG} field protocol (Gecheva et al., 2010), which is closely related to the RI protocol (Schaumburg et al., 2007). Sampling was carried out during the main growth season of macrophytes (from July to September) on three to seven sampling sites, according to the area and the altitude of the water bodies. All submerged, floating-leafed and helophyte species were recorded, while bryophytes and filamentous green algae were not recorded. The abundance of each species was estimated according to a five-degree scale (Kohler, 1978). The abundance was used to estimate the plant quantity according to the function $y=x^3$, where y is the quantity and x is the abundance according to the five degree scale (Melzer, 1988; Kohler and Janauer, 1995).

Carlson's trophic state indices were used to assess the trophic state of the water bodies (Carlson, 1977; Carlson and Simpson, 1996*)*.

Descriptive statistics were used to describe the studied environmental variables. The relationships between the variables were assessed by means of Spearman rank correlation and regression analysis (PAST software).

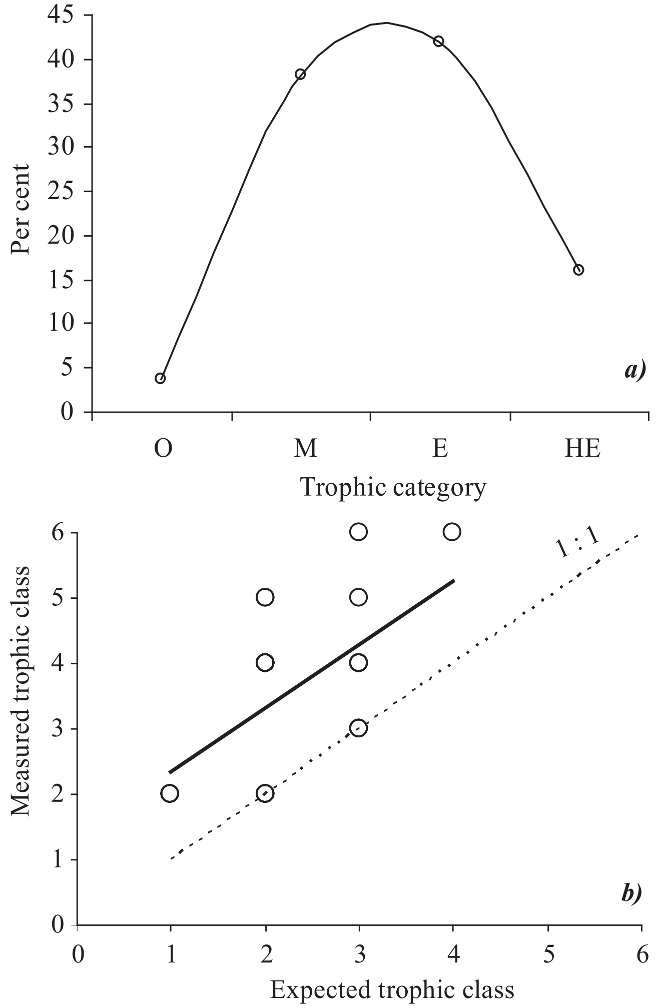

Fig. 2. *a*) – per cent distribution of the reservoirs between the trophic categories. *b*) – discrepancy between the expected and measured trophic state. Given classes are: 1 – oligotrophic; 2 – oligo-mesotrophic; 3 – mesotrophic; 4 – meso-eutrophic; 5 – eutrophic; 6 – hyper-eutrophic

Results and Discussion

Trophic state

Only high altitude reservoirs, Belmeken and Karagyol, showed oligotrophic conditions with average TSI of 30.6 and 36.7, respectively, due to their small catchment areas and low nutrient load. The only exception was Drenov Dol – a mid altitude, off channel storage reservoir with long residence time, fed up by derivation canals from small semi-mountain rivers. This allowed for substantial reduction of TSI, throughout the period of low inflow to a summer average of 39.9, which is just below the mesotrophic threshold.

The distribution of the studied water bodies to the corresponding trophic category is shown in Figure 2a. The distribution was close to the bell shape, with four per cent oligotrophic, 38% mesotrophic, 42% eutrophic and 16% hyper-eutrophic reservoirs.

Most of the mesotrophic and eutrophic reservoirs showed the expected quality according to their position in the watershed (Vannote et al., 1980) and intensity of the anthropogenic influences. The hypereutrophic reservoirs were relatively small and highly nutrient-enriched due to their use for intensive fisheries, and/or as receivers of untreated wastewaters, such as the reservoirs Chirpan and Sinyata Reka. The latter reservoirs had average TSI of 80.3 and 88, respectively.

Part of the reservoirs had no macrophytes in them, another part had only helophytes and just in 29 of the studied water bodies we had sufficient abundances for the calculation of the Bulgarian Macrophyte Reference Index (RI_{BG}) for lakes. The trophic status of these reservoirs ranged from mesotrophic (Stoykovtsi reservoir – TSI_{AVRG} = 42.1) to hyper-eutrophic (Mandra reservoir – TSI_{AVRG} = 78.4), with majority of them (55%) being eutrophic. The reservoirs belonged to 10 lake types, grouped in four biological types for macrophyte based assessment, according to the accepted in Bulgaria typology of the surface water bodies (Belkinova and Gecheva, 2013). According to their passports, each lake type has a corresponding trophic level. The expected trophic levels for these lake types ranged from oligotrophic to meso-eutroophic conditions, respectively for the high altitude types and for the Black See coastal lakes. Obviously, the measured trophic state did not correspond to the expected one (Figure 2b). According to the trend line depicting the relationship between expected and measured trophic state, the latter was, at least, one trophic category higher.

The only consistent biological type, according to the expected trophic state was the group of the high altitude lakes (L1, L2 and L3), but instead of oligotrophic, the measured trophic state in all of the studied reservoirs in this group was mesotrophic. The next biological type, incorporating lake types L4, L5 and L7 (low to mid altitude lakes), is not consistent and includes water bodies with expected trophic state in both mesotrophic and eutrophic categories. The other two biological types – the big reservoirs (L11, L14 and L15) and small to medium size reservoirs (L12, L13, L16 and L17) – include water bodies with expected oligotrophic and mesotrophic trophic state. Thus, the biological types incorporate water bodies belonging to, in most cases, more than one trophic category. This implies that reservoirs with very different physicochemical variables will have to be assessed by one and the same EQR scale. If we take, for instance, the Secchi disk visibility, the TSI oligotrophic threshold value is set at 4 m and that of mesotrophic – at 2 m, thus for the biological types incorporating both oligo– and mesotrophic water bodies, a reference macrophyte community is expected to emerge at very different light regimes. It is well known that the average water transparency determines the maximum depth of colonization for the aquatic macrophytes in the littoral zone (Caffrey et al., 2007). In dam reservoirs, however, several other factors, such as high water level fluctuations, steep slopes or presence of herbivorous fishes, affect the establishment and growth of macrophytes. According to Dutartre and Bertrin (2012) macrophyte communities in fluctuating bodies of water are exposed to physical conditions, preventing the growth of communities with enough diversity and stability to achieve ecological status as determined by the European Water Framework Directive.

We tried to relate the trophic state to the RI_{BG} values for each biological type. The two parameters were not correlated, due to the huge discrepancies that were sometimes observed with broad range of trophic states corresponding to a single ecological status class. Thus, good ecological potential in the big reservoirs can correspond to mesotrophic or eutrophic conditions, while in the small to medium size reservoirs – it relates to mesotrophic up to hyper-eutrophic conditions. In the same biological types, bad ecological potential can be observed also at mesotrophic or eutrophic conditions. The relationship between the trophic state and ecological status was dependant also on the lake type within each biological type. Thus, the oligo-mesotrophic big reservoirs (type L11) corresponded to good and moderate ecological conditions; the mesotrophic big lowland reservoirs (type L14) corresponded to moderate, while their equivalent (type L15) reservoirs in ecoregions 7 corresponded to bad ecological conditions.

The two assessment schemes have different ecological meanings as trophic state indices are indicative of the algal biomass and the RI_{BG} – the deviation of the observed macrophyte community from a type specific one. Although, they are not directly comparable, both planktonic and littoral plant communities are affected by increased loading of nutrients. And, further, both communities are designated as biological quality elements in the WFD, and should be considered, together with the other quality elements, in the assessment of the ecological status of the water bodies.

Our study found no correspondence between the projected type specific trophic state and the estimated one, with an average increase of one trophic state category from the type specific value. Our findings also illustrate the huge discrepancies between the trophic state and ecological status within a single lake type. Thus, good ecological potential can correspond to mesotrophic up to hyper-eutrophic conditions. Our study showed the importance of reconsidering the lake typology, so more consistent response could be obtained between the targeted "good" ecological state and the trophic state, i.e. anthropogenic pollution.

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