Contribution to the assessment of ecological status in some of the lakes of the Danube Delta according to the European Water Framework Directive

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ABSTRACT. The present work includes a model for assessing the ecological status of shallow lakes, based on the principle of the integrative method used previously in Finland, Sweden, Estonia, Denmark, Germany, Poland, Great Britain and Holland. The authors included into the respective method those elements that are local-specific to the Danube Delta, taking also into account the current Romanian national legislative framework and the recommendations of the Water Framework Directive.

Key words: ecological status, shallow lakes, Danube Delta, Romania

INTRODUCTION

Historically water quality was usually assessed on the basis of physico-chemical parameters but since 1990 much greater emphasis has been placed on biological criteria of quality. The EU Water Framework Directive requires principally an ecological assessment of water quality [17]. According to EU Water Framework Directive ecological status is an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters. Furthermore, the WFD provides a selection of the most relevant quality elements for the classification of ecological status [18]. Notwithstanding, the zooplankton are not included in the WFD as a biological quality elements the authors believes that a good picture of the current conditions of ecological status of the Danube Delta lakes can be also derived by looking at zooplankton indicators such as their biomass, abundance and species diversity. One the other hand, has been proved that in the Danube Delta Biosphere Reserve there is a high diversity of the zooplankton species [15], and the abundance of zooplankton has been responsible to the bottom up and top down control of phytoplankton in Danube Delta lakes [10].

In Romania water quality standards is represented by 5-class system of physico-chemical standards for surface waters used on water quality assessment for human consumption, 5-class system of biological standard as Saprobe index based on the presence or absence of indicator species (plankton, phytobentos and macrobentos) for rivers quality assessment and a trophic state system for quality assessment of the lakes [19].

In these circumstances the process of ecological status evaluation of the Danube Delta lakes, expressed as WFD requirements is quite impossible to be achieved due to the lack of biological parameters as aquatic vegetation and fish and also due to the different class value for certain parameter (total phosphorus) used for different class systems [19].

A direct method of assessing ecological quality of water surfaces is initiated in this paper based on WFD requirements [18] and Romanian low on surface water [19] leading to a system of water quality very similar with ECOFRAME scheme [8].

MATERIALS AND METHODS

Three lakes (Cuibul cu Lebede, Isac and Uzlina) were chosen for the determination of ecological status in Gorgova-Isac aquatic complex during 2007.

Ecological assessment of water quality was based on physicochemical and biological assessment. The following physicochemical parameters were used for ecological status evaluation: Secchi depth (T), temperature (°), pH, oxygen (O2), total phosphorus (P). The biological variables used for evaluation are in case of phytoplankton: algal diversity (Da), chlorophyll “a” (chl ‘a”), number of blooms/year and type of blooming [13]. It must be pointed out that the evaluation of the phytoplankton blooms was expressed in terms of abundance (no. cells / l). As well, composition (number of species - Ns), the abundance (A) measured as average percentage volume infested (PVI) and water surfance cover (WSc) were estimated in case of aquatic flora. The estimation of the amount of plant mass is illustrated on the basis of a five...
The ratio of numbers of large species of Cladocera (Cₗ) to total numbers of Cladocera (Cₜ), the biomass ratio of zooplankton (zpk) to chlorophyll "a" [4, 5], macroinvertebrates diversity (Dm), the ratio of Oligochaeta (O) to Chironomids (CH) [8], the biomass ratio of predator to prey (% of predators-%P), percentages of biomass of exotic species of fish (%E), the presence of sensitive species (+S), were used also for ecological evaluation. Therewith, was estimated the ratio of diversity index obtained during investigation and the index from the reference condition.

The assessment of the ecological integrated status has been made according to Moss [8], and includes the following steps:

1. Establish the frequency of variables with high status.
2. Sum the number of biological variables classified as high ecological status and if this constitutes more than 80% then the lake is accorded high ecological status.
3. If the frequency of variables with high status constitutes less than 80% sum the number of biological variables with either high and good status, and if this constitutes more then 80 % then the lake is accorded good ecological status.
4. If the frequency of sum of the variables (high, good) were less than 80% repeat steps adding the variables classified as moderate status and classify the lake on the basis of percentage as previous have been described.
5. The classifications go on until the lake is classified based on biological variables
6. Repeat steps 1-5 for all of the variables (biological and chemical) and classify the lake on the basis of all variables.

RESULTS AND DISCUSSIONS

Only recently have attempts been made to evaluate the typology of the Danube Delta lakes based on historical data and a multivariate analysis of biotic factors (abundance and composition of plankton, aquatic vegetation and fish) and abiotic factors (soil substrate, morphometrics, hydrology and water quality) [10]. In the last five years some studies have focused on developing an abiotic typology of surface waters of Danube Delta according to the Annex II Art.1, Section 1.2 of the Water Framework Directive [18] (the results being available at the Romanian authority level but no in scientific publication), the reference conditions and few steps have been made for ecological status classification.

Annex V, section 1.4.1 of Water Framework Directive [18] require that the ecological status shall be expressed as ecological quality ratios. These ratios shall represent the relationship between the values of the biological parameters observed for a given body of surface water and the values for these parameters in the reference conditions (high ecological status, with no, or with very minor evidence of disturbance) applicable to that body. The ratio shall be expressed as a numerical value between zero and one, with high ecological status represented by values close to one and bad ecological status by values close to zero [18].

On the other some of the variables selected for ecological status description were chosen to created a scheme whose categories were subdivided into a range limits for each ecological classes (Table 1). In this scheme, the range of limits from the parameters used for description of the ecological status based on zooplankton is according to ECOFRAME tested system [8].

According to studies carried out during 2007 the recorded value of transparency were high, the temperature of the water and oxygen concentration were undisturbed and the average values of total phosphorus reach the upper limit of eutrofic status (Table 2).

The phytoplankton community is widely considered the first biological community to respond to eutrophication pressures and is the most direct indicator of all the Biological Quality Elements of nutrient concentrations in the water column [1]. The WFD definition of ecological status indicates that declining ecological quality is considered when taxonomic composition, average abundance, frequency and intensity of phytoplankton blooms is significantly dissimilar to undisturbed conditions [18]. Only recently have
attempts been made to evaluate de ecological status by using phytoplankton matrix based on number of blooms / year and diversity [13].

The investigations carried out during 2007 have been shown no blooming of phytoplankton, recorded as abundance of species [14]. The abundance of phytoplankton range between $4 \times 10^5$ – $13 \times 10^5$ no. of ind/l in case of Cuibul cu Lebede lake; $0.5 \times 10^5$ – $10 \times 10^5$ no. of ind/l in case of Isac lake and $0.3 \times 10^5$ – $12 \times 10^5$ no. of ind/l in case of Uzlina lake. Nevertheless, the cyanobacteria was 22.14% form the total phytoplankton abundance in lake Cuibul cu Lebede in July and more then 41.82% in August. The dominant cyanobacteria species was Microcystis aeruginosa and M. viridis in July and Microcystis aeruginosa, Lingbya limentica, Oscillatoria limosa in August. The cyanobacteria recorded high abundance in spring and early summer in case of Isac Lake. The dominant cyanobacteria species was Aphanothece minutissima in April and Chroococcus limneticus and Aphanothece minutissima in May. High abundance of colonial and filamentous cyanobacteria have been induces the high amount of recorded chlorophyll “a”.

According to reference conditions the blooms of phytoplankton could have been occurs only when the abundance of cyanobacteria is less then 10% of the total amount of phytoplankton, the chlorophyll “a” is equal or less then 10 µg/l

Taking into account the reference conditions and the situation recorded during 2007 (Table 3) the ecological status of investigated lakes (Table 7) is bad in terms of value of chlorophyll “a” and very good related to number of blooms / year.

In terms of diversity the ecological status is very good in case of Cuibul cu Lebede Lake and good in case of Uzlina and Isac Lakes.

The macrophyte community is generally regarded as a key indicator of the ecological status of lakes as macrophytes provide habitat for many other aquatic biota to feed, seek, refuge or breed [1], [3]. According to WFD ecological quality is considered as declining when the composition of macrophytic taxa and the average of macrophytes abundance are significantly dissimilar to undisturbed conditions [18].

In many lakes of the Danube Delta the dominance of submerged vegetation varies along a gradient of connectivity: the vegetation composition occurring in lakes with a close connection to the main river branches differs from those isolated within the extensive reedbeds in the Delta [2]. The large lakes in the Gorgova-Uzlina are typically turbid lakes with sparse submerged vegetation [6].

Based on field investigation results (Table 4) the ecological status in case of vegetation is good and moderate (Table 7). The presence of association Ceratophylletum demersi, the value of abundance equal with 1, the surface cover equal of 70 and PVI equal with 62% indicate a moderate ecological status in Cuibul cu Lebede Lake. Due to the presence of Potametum association the ecological status of Lake Uzlina is moderate, but the value of abundance equal with 2, the surface cover equal with 95 and 75% of PVI includes the Uzlina Lake in a good ecological status. A similar situation was found in case of Lake Isac: association with Potametum, value of surface cover equal with 90 and 63% PVI.

On the other hand, the aquatic vegetation seems to be predominantly determined by a soil gradient. Lakes situated within plaur areas, having soft organic sediment and often supplied with a large proportion of reed water are contrasted to the lakes on mineral sediment. Within these gradients, hydrology has a strong qualitative impact [10]. A high abundance of sensitive species to eutrophication have been recorded when the water level was low in case of Uzlina and Isac lakes.
Average value of aquatic vegetation parameters (2007) and the ratio between reference conditions (RC) and the average values (Gogova-Isac lake-complex).

<table>
<thead>
<tr>
<th>Lakes</th>
<th>Association</th>
<th>Ns</th>
<th>Ns/RC</th>
<th>A</th>
<th>WSc</th>
<th>PV%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuibul cu Lebede</td>
<td>Ceratophylletum demersi</td>
<td>5</td>
<td>0.5</td>
<td>1</td>
<td>70</td>
<td>62</td>
</tr>
<tr>
<td>Uzlina</td>
<td>Potametum without P. pectinatus</td>
<td>7</td>
<td>0.7</td>
<td>2</td>
<td>95</td>
<td>75</td>
</tr>
<tr>
<td>Isac</td>
<td>Potametum without P. pectinatus</td>
<td>7</td>
<td>0.7</td>
<td>2</td>
<td>90</td>
<td>90</td>
</tr>
</tbody>
</table>

Where: 1 = scarce abundance; 2 = moderate

On the other hand, the aquatic vegetation seems to be predominantly determined by a soil gradient. Lakes situated within plaur areas, having soft organic sediment and often supplied with a large proportion of reed water are contrasted to the lakes on mineral sediment. Within these gradients, hydrology has a strong qualitative impact [10]. A high abundance of sensitive species to eutrophication have been recorded when the water level was low in case of Uzlina and Isac lakes.

The transfer of energy and carbon, fixed by phytoplankton, to higher trophic levels largely depends on the edibility of phytoplankton for zooplankton or invertebrate filter feeders [11], [12].

The evaluation on ecological status included zooplankton for additional information about the biological situation of the lakes.

The ratio of numbers of large species of Cladocera to total numbers of Cladocera (Table 5) have been shown that the ecological status of investigated lakes is very good in Cuibul cu Lebede lake and moderate in Uzlina and Isac lakes (Table 7). A high ecological status have been also recorded when the aquatic vegetation ensure a hiding place for zooplankton species [16]. The evaluation of ecological status based on biomass ratio of zooplankton to chlorophyll a is an independent measure of the zooplankton influence on phytoplankton. In this case the ecological status of Cuibul cu Lebede and Uzlina lakes are bad and moderate for Isac Lake.

Average value of zooplankton parameters (2007) used for ecological status evaluation (Gorgova-Isac complex)

<table>
<thead>
<tr>
<th>Lakes</th>
<th>No. Cc / No. Ct</th>
<th>Zpk/ chl''a'' (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuibul cu Lebede</td>
<td>0.63</td>
<td>14.34</td>
</tr>
<tr>
<td>Uzlina</td>
<td>0.37</td>
<td>10.95</td>
</tr>
<tr>
<td>Isac</td>
<td>0.29</td>
<td>34.12</td>
</tr>
</tbody>
</table>

Benthic invertebrates play an essential role in key processes of lakes – in food chains, productivity, nutrient cycling and decomposition [1]. In the WFD, a declining ecological quality is associated with poor diversity and dominance of a few invertebrate taxa [18].

In the assessment of ecological status of the investigated lakes the authors consider that the most relevant benthic invertebrate quality component is represented by the ratio of Oligochaeta and Chironomids. The larvae of genus Chironomus and freshwater worms, oligochaets are common in the Danube Delta lakes. They have a low variability during one year and according to historically studies made in Europe they are useful tools for detecting long term environmental perturbation, due to theirs highly specific environmental tolerances based on trophic status and dissolved oxygen concentration [1]. The ecological status based on ratio of oligochaets and chironomids (O/CH) (Table 6) shows that the Cuibul cu Lebede and Isac lakes can be included in moderated status and Uzlina lake in poor status.

Average value of benthos parameters (2007) and the ratio with reference conditions (RC) used for ecological status evaluation (Gorgova-Isac lake-complex)

<table>
<thead>
<tr>
<th>Lakes</th>
<th>Dm</th>
<th>Dm / RC</th>
<th>O/CH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuibul cu Lebede</td>
<td>0.289</td>
<td>0.08</td>
<td>0.75</td>
</tr>
<tr>
<td>Uzlina</td>
<td>1.082</td>
<td>0.32</td>
<td>1.20</td>
</tr>
<tr>
<td>Isac</td>
<td>0.984</td>
<td>0.29</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Measures of diversity using Shannon diversity index [7] showed a low diversity associated with eutrophic ecosystems (Table 7) leading to the poor ecological status.

Due to their complex ecological requirements, fish are sensitive indicators for habitat quality at various spatial scales. As consumers and / or top predators, they integrate information on trophic conditions across the food chain and provide detailed information on the trophic level [1]. The WFD ecological status classification, indicate that: changes in species composition and abundance; decreases in type sensitive
species and changes in age structure as a disturbance in reproduction or development of a particular species will fall down the water quality classification [18].

Identification of the reference conditions for fish in the Danube Delta was made by using historical data and spatial method.

The previous studies on ichthyofauna carried out in Gorgova-Uzlina complex lake have showed that the complex shelter a richness fish of 27 species, with 4 exotic and 23 native species. Depending on sampling methods (electric or gillnet fishing) the diversity index range between 1.66 -2.03 in Cuibul cu lebede lake, 1.49-1.75 in Isac lake and 1.38-1.52 in lake Uzlina. The most abundant fish species were bitterling (Rhodeus amarus) and rudd (Scardinius erythrophthalmus) in case of Cuibul cu lebede lake; tube-nosed goby (Proterorhinus marmoratus) and bleak (Alburnus alburnus) in case of Isac lake; belica (Leucaspius delineatus) and bitterling (Rhodeus amarus) in case of Uzlina lake [9].

Taking into account the assumption that a diversity index between 1-1.5 indicate poor ecological status and a diversity index between 1.5-2.3 indicate moderate ecological status, the ecological status of the investigated lake should be moderate for Cuibul cu Lebede and Isac lakes and between poor and moderate for Uzlina lake.

Furthermore, the evaluation carried out during 2007 (Table 6) have been showed that the ratio between predacious and prey fish (Bp/Bp); percent of predacious fish (%Bp) from the total catchments; percent of exotic fish (%Bp) and presence of sensitive species (+S) indicate a moderate (M) ecological status for the investigated lakes (Table 7).

<table>
<thead>
<tr>
<th>Lakes</th>
<th>Bp/Bp</th>
<th>%Bp</th>
<th>(%Bp)/RC</th>
<th>%BpE</th>
<th>+S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuib cu Lebede</td>
<td>0.19</td>
<td>17</td>
<td>0.42</td>
<td>34</td>
<td>5</td>
</tr>
<tr>
<td>Isac</td>
<td>0.36</td>
<td>27</td>
<td>0.67</td>
<td>36</td>
<td>5</td>
</tr>
<tr>
<td>Uzlina</td>
<td>0.2</td>
<td>17</td>
<td>0.42</td>
<td>44</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 7. Ecological status of Isac, Uzlina and Cuibul cu Lebede lakes evaluated using integrative method.

CONCLUSIONS.

The method presented in the present paper should improve the knowledge on the ecological status evaluation in the Danube Delta. Consequently, this method provided an integrated assessment of the

Taking into account the principle of the method more accurately results of ecological status might be expected than an evaluation based on chemical or biological estimation.

According to this type of evaluation the ecological status in case of investigated lakes from the Danube Delta Biosphere Reserve have in 2007 the following ecological status: Cuibl cu Lebede and Isac lakes have a moderate ecological status; Uzlina lake has a poor ecological status.

REFERENCES

