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EVOLUTION OF TROPHIC PARAMETERS FROM AMARA LAKE

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Abstract

The transformation of lentic ecosystems in other types of ecosystems (plain, forest) is a part of normal process of ecological succession that occurs slowly, at geological scale. The filling of cuvette with eroded material transported by precipitations, air masses or detritus produced *in situ*, start from the moment when the body of water lakes is formed and has different rates depending on many factors: geographical location, geological substrate type, types of existing uses in the basin. Nutrient pollution, especially those originating from human activity, leads to water eutrophication, which accelerates the aging process of lakes. This is the case of Lake Amara, whose body of water has decreased considerably in recent years, large areas being now covered reed. Amara Lake, located in south-eastern Romania, is one of the five lakes in the country where they form mud exploited for therapeutic purposes. The importance of the lake derives both from the position of spa tourism, and the status of special protection avifaunistic area. These functions depend on maintaining constant parameters lacustrine ecosystem, the preservation of the current status and finding ways of halting and reversing the processes of nutrient pollution, so the process of eutrophication. From this reason, Amara Lake is constantly monitored in terms of trophic parameters, for that the measures to stop the eutrophication to be applied at time. In this paper, are presented the actual trophic status of Amara Lake and his evolution in the last decennium. This study can gives useful information for the management decisions that to allowing the sustainable development of this area.

Key words: aqvifaunistic area, ecological succession, eutrophication, trophic parameters

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1. Introduction

Ecological succession is a process that takes place with different rates depending on a variety of factors of which some can be listed: geographic position, geological substrate type etc. In lentic ecosystems, this process consists in filling the basin, covering the following phases: shallow lake, marsh reed long, plain. Field can be covered by shrubs and trees, turning into forest ecosystem. This transformation does not necessarily have a negative impact, excepting the point of view of human use, and can seriously affect types of resources of natural capital to which the population has access, with economic and social repercussions. The unbalance of these factors influences the rate of ecological succession and leads to its acceleration (Andersen et al., 2006).

Increasing the amount of nutrients in lake water causes an explosive growth of aquatic plants in the first phase, then unbalancing the entire trophic network of ecosystem, with more or less severe

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effects, depending on the type of nutrients found in excess, on the opportunistic algal associations or time for self adjustment (Thomas, 1969).

Eutrophication means the enrichment of water in nutrients, especially by nitrogen and phosphorus compounds, which cause an accelerated growth of algae and superior forms of vegetable life, producing an undesirable disturbance of the balance of organisms present in water and of waters quality (Parvu, 1999). In other words, eutrophication is a process of ecosystem degradation caused by the existence of large amounts of nutrients, and this process can be: natural - when done in a long time, or anthropogenic, due to human activities - when its evolution is rapid (Vadineanu et al., 1999). Phenomena and processes described for a lentic ecosystem do not overlap exactly one another because of differences in morphological, climatic and anthropogenic use. The status of a eutrophic lake can be established only when compared to its previous state or a reference lake (similar as geographic location etc.) (Rougé et al., 2013). Eutrophication of freshwater bodies (but not only, since it has been observed blooms in Black Sea, marine bays and estuaries) is currently the main problem of interest for researchers and political and economical decisions makers (Carpenter et al., 1999; Yang et al., 2008).

In Romania, the requirement of monitoring trophic status of water bodies lies with the National Administration Romanian Waters, in the view of complying with regulations and European standards for collection, analysis and interpretation of physical-chemical and biological samples. Evolution of trophic lakes is studied based on investigative methods developed by ICIM - Environmental Engineering Research Institute in 1984 (ICIM, 1995).

The importance of the Amara Lake derives both from its position for tourism and from its special status as protected aqvifaustic area for 54 bird species. Amara Lake is a shallow lake, very sensitive to nutrient pollution because it is surrounded by farmland steppe and the climate is favourable for wind transport phenomena and the leaching of nutrients from the sides toward the water. Also, being a lake used for tourism and treatment, it supports a high pressure of human factors, especially in the summer. The influence of these factors have determined the gradual reduction of water surface, since large areas, especially those of shallow bay types are already covered with reeds (Fig. 1).

In consequence, a constant monitoring of Amara Lake in terms of trophic parameters is required, in order to implement timely measures to stop eutrophication.

In this study we presented both the actual trophic status of Amara Lake and its evolution in the last decade. The study offers useful information for the management decisions for allowing the sustainable development of this area.

2. Experimental

The evaluation of water quality and its compliance with quality classes was done by collecting and analyzing water samples from 13 sampling points (Table 1), determined after plotting transects on the lake map (Fig. 2), during of 2002 – 2013 period.

In all these points an ecological monitoring program was conducted, six of them being additionally supervised for vulnerability to nutrients (points 4, 5, 8, 9, 10 and 13), while 5 points (5, 8, 9, 10, 13) being monitored for fish life. Since 2007, four annual monitoring campaigns have been achieved, and the number of monitoring points was reduced to one (2007, 2008, 2009, 2010- Middle lake - position 7 in Table 1), maximum two (2008, 2011, 2012, 2013- Middle lake and Perla Complex - out lake – positions 7 and 12 in Table 1).

In 2008, the Middle lake point and the profile „photic zone limit" were monitored. The 13 sampling points were monitored discontinuously, most recordings being focused on the Middle lake point (code 1120340), and while the fewest records were those for Tail Lake (code 1120310) and Wharf points (code 1120320).

In Table 2 it is summarized the frequency of water quality monitoring, at collection points set out in sections of Amara Lake. None of the sections did benefit from constant monitoring over the 10 years referred in to the study. The monitoring program was established by SGA Buzau-Ialomiţa, which, for administrative reasons, political, financial or climate (flooding) reasons have ranged and the number of sampling campaigns per calendar year.

(a) (b)

Fig. 1. Satellite image of Amara Lake in 2009 (a) and 2013 (b) (Google Earth)

The year with the most campaigns was 2006 – with 9 campaigns in 6 points from the 13 sampling points established. During the period 2002-2005 4 annual campaigns were conducted (one in each spring and autumn and 2 in each summer) in 12 points by 13 points. Between 2008-2010 there were four campaigns covering only two sampling points from 13, while four campaigns were scheduled in 2007, but in one monitoring point - Middle lake (code 1120340) (Table 2). The main eutrophication parameters monitored in sampling points established on Amara Lake are: transparency, suspended solids, total phosphorus, total nitrogen and total phytoplankton biomass.

Fig. 2. Amara Lake – sampling points location

Table 1. The coordinates of sampling points from Amara Lake, used for monitoring in 2002-2013 period

No.	***Section name/ Sampling point***	***Code***	***Eastern longitude***	***Northern latitudine***	***Layering***	***Monitoring Program[1]***
1	Lake tail (Center) / 0 m	112031010	27°21′27″	44°36′10″	unlayered	ES[1]
2	Lake tail (Center) /2.5 m	112031020	27°21′27″	44°36′10″	unlayered	ES
3	Lake tail (Mirceşti)/ surface	112032010	27°21′27″	44°36′10″	unlayered	ES
4	Lake tail (Mirceşti) / photic zone	112032020	27°21′27″	44°36′10″	unlayered	ES,VN[2]
5	Dock /0m	112033010	27°21′10″	44°36′25″	unlayered	ES,VN, FL[3]
6	Dock / 2.5m	112033020	27°21′10″	44°36′25″	unlayered	ES
7	Middle lake/surface	112034010	27°20′42″	44°36′33″	layered epilimnion	ES
8	Middle lake/photic zone	112034020	27°20′42″	44°36′33″	layered epilimnion	ES,VN, FL
9	Middle lake photic zone limit	112034030	27°20′42″	44°36′33″	layered hipolimnion	ES,VN, FL
10	U.G.S.R.[4]/0m	112035010	27°20′12″	44°36′39″	unlayered	ES,VN, FL
11	U.G.S.R./2.5m	112035020	27°20′12″	44°36′39″	unlayered	ES
12	Perla Complex (lake outlet)/surface	112036010	27°19′09″	44°36′23″	layered epilimnion	ES
13	Perla Complex (lake outlet) /photic zone	112036020	27°19′09″	44°36′23″	unlayered	ES,VN, FL

[1]ES = ecological surveillance; [2]VN= vulnerability to nutrient; [3]FL = fish life; [4]U.G.S.R= former name meaning „General Union of Trade Unions of Romania"

Table 2. The sampling frequency for Lake Amara monitoring, in period 2002-2013

Section name/ Sampling point/ year/ number of campaigns		***2002***	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***
1	Lake tail (Center) / 0 m	4	4	4	4	-	-	-	-	-	-	-	-
2	Lake tail (Center) /2.5 m	4	4	4	4	-	-	-	-	-	-	-	-
3	Lake tail (Mirceşti)/ surface	4	4	4	4	9	-	-	-	-	-	-	-
4	Lake tail (Mirceşti) / photic zone	4	4	4	4	9	-	-	-	-	-	-	-
5	Dock /0m	4	4	4	4	-	-	-	-	-	-	-	-
6	Dock / 2.5m	4	4	4	4	-	-	-	-	-	-	-	-
7	Middle lake/ surface	4	4	4	4	9	4	4	-	-	-	-	-
8	Middle lake/ photic zone	4	4	4	4	9	-	4	-	-	-	-	-
9	Middle lake photic zone limit	-	-	-	-	9	-	-	-	-	-	-	-
10	U.G.S.R.[4]/0m	4	4	4	4	-	-	-	-	-	-	-	-
11	U.G.S.R./2.5m	4	4	4	4	-	-	-	-	-	-	-	-
12	Perla Complex (lake outlet) /surface	4	4	4	4	9	-	-	-	-	4	4	4
13	Perla Complex (lake outlet) /photic zone	4	4	4	4	-	-	-	4	4	-	-	-

Each of this parameter has been analyzed according with the standard procedures (Fresenius et al., 1988; ICIM, 1995), and on the basis on their determined values, the evolution of throphic state of Amara Lake has been discussed.

3. Results and discussion

3.1. Monitoring of suspended matter and water transparency

Light affects photosynthesis through radiation with a wavelength between 390-710 nm, which represents 46-48% of the incident solar radiation (Buruian, 2002). Regarding Amara Lake whose water surface is not shaded by tall slopes, lake photo-autotrophies are influenced by the number of days of sunshine and water transparency. The amount of the incident light has also seasonal variations (with a minimum in winter and maximum in summer) and diurnal variations. Water transparency depends on a number of factors related to climatic peculiarities of the area, morpho-geology of basin, hydrological regime and the type and intensity of biological processes.

Depending on transparency and hence the percentage of light incident radiation which is reflected in the water body, two layers are defines: *photic or trophogenic zone* (intake of > 1% of the amount of light) and the *aphotic or tropholitic zone* (input <1% of the light) between which a compensation area exists (Brezeanu and Simion-Gruiţă, 2002). Transparency index, as the ratio between transparency and depth (T/A) is associated with the development of macrophytes. At a ratio lower than 0.20, there are not conditions for photosynthesis of organic substances in lake water (Yang et al., 2014), and this significantly influence the eutrophication of water.

Shallow lakes usually have a low transparency because moving air masses causes the waves and currents, which leads to the entrainment of deposits from the bottom of the basin, leading to an increase in the amount of suspended solids in the water.

In Table 3 there are presented the limits of photic zone for sampling point "Middle lake" (code 112034030) correlated with the amount of suspended matter and water transparency index, for one year taken as example – 2009.

Increasing the amount of suspended matter, in samples obtained during harvesting campaigns, reduces the limit of photic zone, but transparency index values do not falls below 0.20, which is proved by the presence of some macrophytes such as: *Phragmites australis, Potamogeton pectinatus, Chara vulgaris, Cladophora glomerata, Spyrogira sp., Filamentous algae*) in water samples.

Fig. 3 illustrates the variation of the amount of suspended matter (mg/L) in water samples from different sampling points, during of 2004 – 2013 period. It can be observed that in the studied period, the value of this parameter increases very little with the depth, due to sedimentation processes. Also, the experimental measurements highlight that, in the last three years a stabilization of the amount of suspended matter occurs, which increases the photic zone depth (Table 4). The values summarized in Table 4 show that the lake water transparency is lower in the summer period, when the algae growth is favored and when the amount of exogene dust transported by wind is higher, in comparison with autumn period, when these factor and less important.

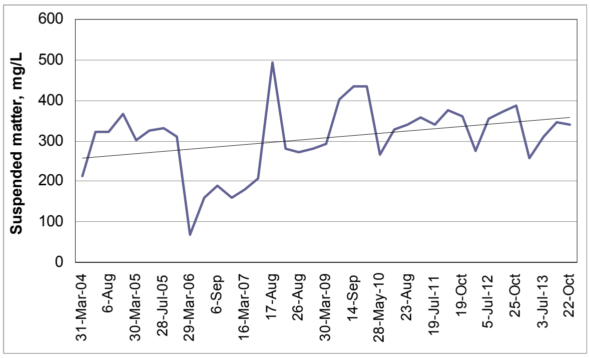

Fig. 3. Variation of amount of suspended matter in Amara Lake, in 2004 – 2013 period

Table 3. Transparency index of water from Amara lake – "Midle lake" sampling point, 2009

Date	03/30	06/20	09/14	12/02
Limit of photic zone (m)	2.80	2.90	2.30	1.50
Suspended matter (mg/L)	304.0	423.0	506.5	474.5
Index of transparency (A = 4.1 m)	0.68	0.70	0.56	0.36

Table 4. Transparency of Amara Lake in 2010 – 2013 period

Year	***Date***	***Middle lake***	***Lake tail***	***Year***	***Date***	***Middle lake***	***Lake tail***
2010	05/28	250	220	2011	05/03	100	110
	06/23	150	70		06/19	280	260
	08/23	150	110		08/29	200	250
	09/27	150	110		10/19	70	70
2012	05/08	280	210	2013	04/26	220	230
	06/05	110	110		06/03	350	325
	09/17	80	85		08/16	300	180
	10/25	200	200		10/22	130	250

3.2. Monitoring of phosphorus content

The dissolved organic phosphorus is mineralized by specific bacteria and transformed in inorganic phosphorus that can be metabolized by algae, and this process is significantly influenced by temperature (Ludwig et al., 2003; Macoveanu et al., 2005). The phosphorus concentration in water depends on the concentration of organic substances, temperature and intensity of bacterial activity. The wastewater with high content of organic matter increases the phosphorus level, increasing the risk of eutrophication. There are two major anthropogenic sources of phosphorus: domestic wastewater loaded with detergents and organic substances (watery faeces) and animal manure from livestock farms (Arnaldos and Pagilla, 2010; Qin et al., 2015).

In case of Amara Lake, the annual average of total phosphorus content, plotted in Fig. 4, shows that for the last four years a stabilization of values without sudden positive or negative changes occurred, which suggests is a tendency toward balancing processes in the lake.

3.3. Monitoring of nitrogen content

Nitrogen is an essential element for life in the biosphere because it is included in the structure of all proteins, nucleic acids, chlorophyll, vitamins and hormones. Atmospheric diatomic nitrogen (N≡N) is an inaccessible gas for most of biologic systems, and therefore is converted at fix forms (NH_4^+, NO_3^-, NO_2) (He et al., 2015; Mihaescu et al., 2007). Molecular nitrogen penetrates quite easily from atmosphere into water, diffuses to the depths. In this form, the nitrogen can be used only by fixing bacteria and by some blue algae (Bouwman et al., 2009). After the mineralization which ensure the conversion in utilizable inorganic forms, the nitrogen becomes available and for other plants and microorganisms, and this process is essential for the cycle of this element in nature (Berca, 2000).

The annual average of total nitrogen content is illustrated in Fig. 5. The average obtained values shows that in case of Amara Lake significant fluctuations appear, during of studied period. These fluctuations are influenced by the hydrological regime of the area, the ascending curves being corresponding to the rainy years.

3.4. Monitoring of phytoplankton biomass

The dominant species of phytoplankton biomass in Amara Lake, during of 2002 – 2013 period were: Cyanophyta-*Aphanizomenon flos-aquae, Microcystis aeruginosa, Merismopedia elegans, Synechocystis sp, Gloeocapsa minima, Bacillariophyta- Cocconeis pediculus, Cyclotella meneghiniana, Fragillaria crotonensis, Stauroneis anceps, Anomoconeis sphaerophora, Nitzschia closteriu, N. Sigmoidea, Criptophyta- Chroomonas caudata, Chroomonas acuta,* Chlorophyta-*Cosmarium leave, Scenedesmus quadricauda, Chlamydomonas sp, Ankistrodesmus minutissima, Oocystis submarina, Ankira sp,* Euglenophyta-*Monomorphina pyrum, Phacus longicauda* and *Euglena viridis.* All these species have been periodically measured and expressed as total phytoplankton biomass. The evolution of the total phytoplankton biomass for Amara Lake, in the last decade is presented in Fig. 6.

It can be observed that the total phytoplankton biomass altered between periods with high microalgae production (for years 2005 and 2012) and clear water phase of Amara Lake (where the average value of total phytoplankton biomass is not higher than 3.0 mg/L).

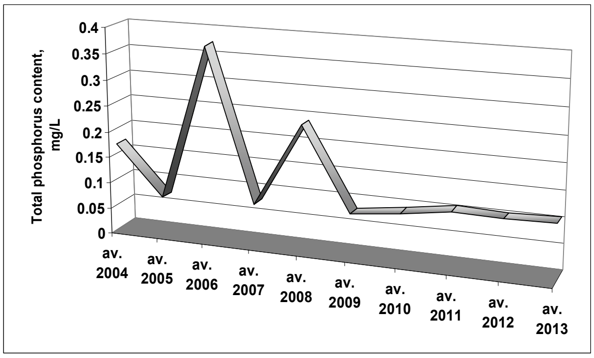

Fig. 4. Annual average of total phosphorus content in water of Amara Lake, in 2004 – 2013 period

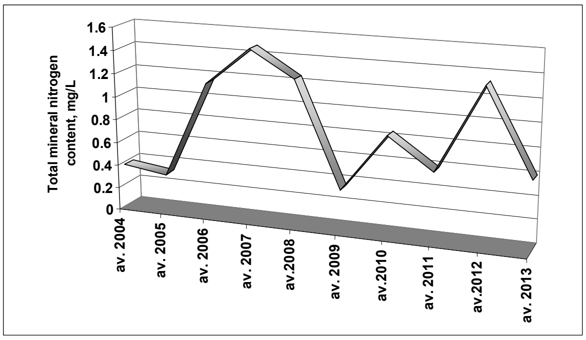

Fig. 5. Annual average of total mineral nitrogen content in water of Amara Lake, in 2004 – 2013 period

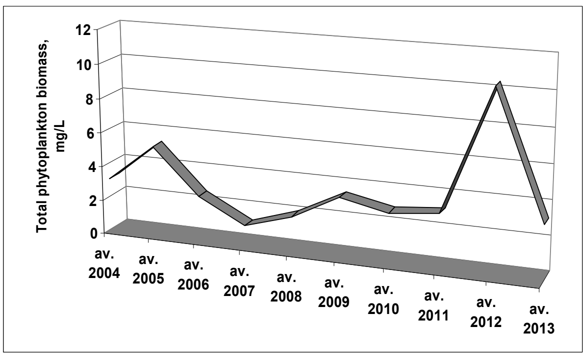

Fig. 6. Annual average of total phytoplankton biomass in water of Amara Lake, in 2004 – 2013 period

Table 5. Framing in quality class of Amara Lake, for 2002 – 2013 period

Indicator \ Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	Quality class											
Total phosphorus	E	H	H	E	H	E	E	E	H	E	E	E
Total mineral nitrogen	U	U	O	O	E	E	E	O	O	O	E	E
Total phytoplankton biomass	E	M	M	E	O	O	O	M	E	O	M	E
Global quality class	E	E	E	E	H	E	M	E	H	E	E	E
Conventional number	4	4	4	4	5	4	3	4	5	4	4	4

Notations: "U" – ultraologotroph (cn = 1); "O" – oligotroph (cn = 2); "M" – mesotroph (cn = 3); "E" – eutroph (cn = 4); "H" – hypertroph (cn = 5); cn – conventional number

These fluctuations are mainly determined by the climatic regime of the year, in special during of summer. Thus, in warmest years (such as 2005 and 2012), the high nutrient concentrations and warm temperatures stimulated the phytoplankton growth. In the years where the summer temperatures were not so high (such as 2007), the microalgae biomass is strongly reduced, and in consequence the phytoplankton growth is lower. It should be also noted that the fluctuations of total phytoplankton biomass are offset because of the time necessary for carrying out biological processes.

3.5. Quality class of Amara Lake

Considering the global quality classification as a function of main indicators of eutrophication (www.daib.rowater.ro), the Amara Lake can be still included in E category, which demonstrates an equilibrium state of these indicators (Table 5).

For a complete picture of the state of the lake in terms of eutrophication, we compared the evolution of the main indicators (total phosphorus, total mineral nitrogen, total phytoplankton biomass) in Amara Lake, for 2004 – 2013 period, which is presented in Fig. 7.

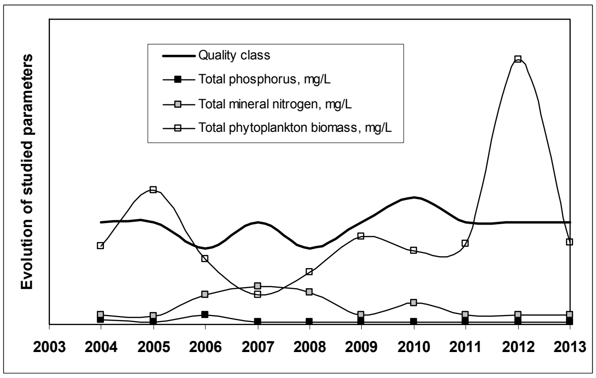

Fig. 7. Parameters of eutrophication degree and quality class of Amara Lake, in 2004 – 2013 period

It can be observed that, with exception of total phytoplankton biomass, whose variations could be correlated with other physical and chemical factors (temperature, pH, diversity index etc.), all the other indicators have insignificant variations during the last three years. This indicates that the Amara Lake is in a self-regulation stage of biological and physicochemical processes.

4. Conclusions

The functions of Amara Lake depend on the the possibilities of maintaining constant various parameters of lacustrine ecosystem, the preservation of the current status and finding ways of halting and reversing the processes of nutrient pollution, such as the process of eutrophication.

In this paper, it is presented the evolution of some parameters responsible for the eutrophication process of Amara Lake. The obtained average values of studied parameters (suspended matter, water transparency, total phosphorus, total mineral nitrogen, total phytoplankton biomass) have shown insignificant variations for the last three years, which suggest that the Amara Lake is in a self-regulation stage of biological and physicochemical processes.

The current trophic status of the lake and its evolution in the last decade can give useful information and support for management decisions that to allowing the sustainable development of this area.

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