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PH.D. THESIS

CONTRIBUTIONS TO THE KNOWLEDGE OF THE ECOLOGICAL BASES OF SIUTGHIOL LACUSTRINE SYSTEM

SUMMARY

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The PhD thesis contains 167 pages and is structured according to the criteria in force, in two parts: documentary part - 42 pages (9 tables and 3 figures) and the experimental part 99 pages (23 tables and 86 figures). Bibliography totals 174 titles and 13 internet sites.

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INTRODUCTION

At the base of the decision to choose the theme of this paper was the love for the coastal area, and especially for water and coastal lakes, as well as the desire to address a topic that will allow me to understand the processes taking place in the ecosystem, in order to choose correct path of action towards the sustainable development of the area.

Human society can not exist, can not grow and develop without the services and resources of natural capital. People have always approached wetlands and settlements were built near water. Therefore, the socio-economic system must take into account the carring capacity of the ecosystems it relies on and to ensure judicious use of natural resources so that they are not exhausted, but rather sustained and regenerated. Relationship between the human and socio-economic lacustrine ecosystems can be summarized as follows:

- Ecosystems provide conditions for the socio-economic system development: ecosystems provide exploitable natural resources, have community importance: enhancing amenity of the area; the shores host human settlements (residential areas - the western shore – and tourism areas - the eastern shore); ecosystems hold tourism importance: providing space for recreation, leisure, education: boating, paddle boat, water scooter, diving, windsurfing, etc.
- Socio-economic system can alter the structural elements and processes of self-organization of lake ecosystems.

Aquatic systems are very sensitive to pollution, being accurate indicators of degradation activities taking place in the catchment area and the human behavior to environmental resources acts as a stressor both locally and regionally. Thus, it requires a continuous and integrated assessment of current ecological status, trends and implementation of sustainable management measures, to make the connection between social and economic development with the protection of Siutghiol ecosystem.

Original contributions that I have tried to bring approaching this subject of the thesi can be summarized to the following aspects:

- "Up to date" knowledge of Siutghiol lacustrine ecosystem, a particular ecosystem due to innercity location, obtained through the use of modern equipment, with in situ precision measuring, regarding the evolution of the physico-chemical quality parameters;
- Development of a monitoring plan of the reference freshwater lake ecosystem, with a network of 11 stations in the central areas, 9 stations at the shore, and 8 stations around Ovidiu island;
- The integrate and dynamic assessment of the physico-chemical water quality parameters, ecotoxicological parameters, and biological elements;
- Devising of a shoreline development index based on 5 components (biotic, aquatic, riparian, shore, aesthetic) for the integrated and rapid evaluation of the ecotone area;
- Retrieval of ponto-caspian relict species after years of absence;
- Use of modern methods for biological, physico-chemical and ecotoxicological data (JMP, ANOVA, correlations/regression).

CHAPTER 1:
SUSTAINABLE DEVELOPMENT – 3rd MILLENIUM IMPERATIVE

Chapter 1 is dedicated to sustainable development, as an imperative of the new millennium and includes the time evolution of this concept, which involves a complex process of integrating environmental considerations, economic, equity and ethics for current and future generations of people, without putting risk of life-support systems on the planet, that ultimately lief relies on (Ekins, 1992). It also deals with aspects of sustainable development as an objective of European Union policy, of our country, ecological, social and economic prospects of sustainomics are presented, as well as issues regarding the sustainable use of aquatic ecosystems, by implementing management programs to determine ecosystem returning to its original state, when human impact was minimal.

Sustainable development has become the global strategy of the 3rd millennium at the signing of the Declaration of Rio de Janeiro and the adoption of Agenda 21 (Strategia de Dezvoltare Durabilă a României, 1999). The objectives of the conference held in Rio de Janeiro, Brazil, were based on the achievements of the Brundtland Report, to meet pressing global environmental problems and to reach agreement on major treaties on biodiversity, climate change and biodiversity (Eurostat, 2003). 21 Agenda is a plan about how to make social, economic and environmental development sustainable in the 21st century. It provides a framework for combating the current social and environmental problems.

1.1 Sustainable development – European Union policy objective

At European level, sustainable development was first introduced as an explicit objective of the European Community in the Single European Act (1987). The requirement to integrate environmental considerations into all Community policies was added in 1992 in the Treaty on European Union (Maastricht Treaty) and strengthened in the Treaty of Amsterdam in 1997.

However the goals for sustainable development could not be achieved just by policy, but by profound changes of mentality (from the daily decisions of citizens to important economic and political decisions), economic and social structures. This involved some evolutionary steps to meet the challenges of the complex relationships between society, economy and environment.

1.2 Sustainable development in Romania

At national level, in 1999, in order to allign to international requirements, the National Strategy for Sustainable Development was issued, which established general principles of sustainable development. It supports the idea that economic development is important for any society, stating that the benefits of economic growth must exceed its costs. These costs must also include the price of environment protection (RNSDS, 1999).

Starting with November 2008, Romania has a new National Strategy for Sustainable Development. Its defining element is our country's full connection to a new philosophy of development, proper to European Union and widely shared worldwide.

1.3 Elements of sustainomics

Munasinghe (2007a), who introduced the term "sustainomics", emphasizes the fact that the focus is explicitly on sustainable development and highlights a neutral approach, free of any disciplinary bias. Sustainomics is a practical transdisciplinary framework that seeks to establish a holistic plan of policy projection and guidance, the foundation being represented by principles, methods and tools developed by many other disciplines.

Sustainomics broadly describes sustainable development as "a process to improve the range of opportunities that will enable individuals and communities to fulfill their aspirations and full potential in a period of time, while maintaining the resilience of the economic, social and environmental systems" (Munasinghe, 2002).

1.3.1 Economic sustainability

For a long time mankind has lived with the belief that the practice of unlimited economic growth is sustainable. However, most argue that unlimited economic growth is unsustainable. Economic efficiency is essential, to ensure an efficient allocation of resources in production and efficient consumption choices, but problems arise in defining the types of capital to be maintained. Most often it is difficult to assign a value to them and to offered services, particularly for environmental and social resources (Munasinghe, 1992, 2007b). Furthermore, ecosystem services, particularly supporting and cultural services, which do not enter the market, are often taken for granted by society and are particularly vulnerable to unintentional degradation, despite their value to society (Costanza et al., 1997).

1.3.2 Ecological sustainability

People depend on natural systems to meet their needs, such as air, water, and resources that are essential to modern societies (Odum, 1993). Modern economies have only recently recognized the need to manage scarce natural resources in a prudent way - for human well-being ultimately depends on ecological services (MEA, 2005). In other words, environmental sustainability expresses the urgent need for fundamental change in the economic, social and political systems, of use and implementation of alternatives to the practices that brought us to an impasse (Gomoiu, 2010).

1.3.3 Social aspects

Social development refers generally to improving individual and overall social welfare, resulting from the social capital increase (Munasinghe, 2007b). Human (eg education, skills, etc.) and cultural (eg social relationships and habits) capital are included in the social capital - although there are fine distinctions. Social capital tends to grow with greater use and erodes through disuse, unlike economic and environmental capital, which are depreciated or depleted by use. Conservation of natural capital and diversity, strengthening social cohesion and reducing destructive conflicts are integral elements of the conceptual framework of sustainomics (Munasinghe, 2004, 2007c).

1.4 Sustainable development and aquatic systems

The ideal scenario for economic development would be one in which humanity interacts with ecosystems based on guiding principle to support their services, rather than to further their degradation. Recognizing the limits of nature to provide these services at the pace required to meet human requirements is critical, although it is often ignored or subordinated in national plans and programs of economic development (WWAP, 2009). Although these services are not typically evaluated in financial terms, thr cumulated economic value estimated at global scale is enormous.

Aquatic systems are very sensitive to human activities conducted in their drainage basins. Lakes for example, receive water with all materials and pollutants in it, thus being sensitive barometers of human activities in the drainage basin (ILECF, 2005).

CHAPTER 2:
SIUTGHIOL LAKE – GENERAL CHARACTERIZATION AND ITS IMPORTANCE IN LOCAL SYSTEMS, NATURAL AND SOCIO-ECONOMICAL

Located in the eastern part of Constanta County, on the Black Sea shore, Siutghiol is a lake defining hydrological and hydrochemical unit for the Romanian seaside. By genesis, Siutghiol Lake is a lagoon and it represents the largest lacustrine unit on the seaside (Gâştescu, 1971). It has a semicircular-elliptical shape, and is characterized by the presence of five bays (Breier, 1976). In the western side of the lake, near the town of Ovid, there is a small island formed by cretaceous deposits - Ovidiu Island (Gâştescu, 1971), with an area of 2 ha and a maximum altitude of 4.9 m (Breier, 1976).

In terms of water balance, Lake Siutghiol has special characteristics. Although the basin is very small compared to the lake surface, the water balance is in surplus under natural conditions (Gâştescu, 1971). Climatic characteristics are a decisive factor for temporal variation in water level for lakes Siutghiol and Tăbăcărie. Atmospheric temperature and potential evapotranspiration regimes play an important role due to climatic conditions specific to the southern area of Dobrogea (Păsculescu, 2011).

Siutghiol Lake is primarily fed by two underground springs located in the deep, hard to reach karst cavities (referate de sinteză ale regiei Apele Române, filiala Constanţa, 1999).

Lake's morphometric characteristics may influence sediment dynamics (sedimentation and resuspension), which in turn may influence the physico-chemical parameters, the amount of sediment in suspension, as well as the primary production (Håkanson, 2005).

Recent data have been published by Telteu and Zaharia (2012), which based on the values of morphometric parameters and calculation formulas provided by literature, rank Siutghiol Lake in the intermediate category, comprising lakes characterized by areas greatly influenced by wind (blowing here from N and NW) and waves, with phenomena of erosion, transport (32.25%) and accumulation (67.75%) of fine particles. It is influenced by the reduction in mean depth (Table 1), by lake surface, but also by features such as wind direction and effective exposure area.

Table 1: Siutghiol Lake morphometry

Date morfometrice	U.M.	Lacul Siutghiol			Lacul Tăbăcărie Gâştescu, 1971
		Gâştescu, 1971	R. Apele Rom., 1999	Telteu, Zaharia, 2012	Gâştescu, 1971
Suprafaţa	ha	1960	1760	1734	99
Volumul	mil. m^3	91	81,84	69,69	2,1
Bazin hidrografic	km^2	92	73,7	-	9,56
Lungime	km	-	-	7,57	-
Lăţime	km	-	-	4,12	-
Lungimea liniei de ţărm	km	30	29,4	27,53	4
Adâncimea					
-maximă	m	17,5	14,9	7,82	6,15
- medie	m	4,75	4,65	4,02	2,15
-faţă de nivelul mării	m	14,95	-	-	4,9

2.2. Disorders of hydric balance

When human intervention was insignificant, the hydrological regime of the lake was characterized by a water balance surplus water and freshwater character. In such circumstances, the lake complex was a net freshwater biotope, inhabited by a species complex of Ponto-Caspian relict origin, including some species of marine origin that resisted sweetening, with overlapping immigrating freshwater elements, with continental origin (Galaţchi, 2005). From this point of view, Siutghiol Lake is the sole biotope in the Black Sea perimeter area hosting populations of marine mysids physiological species (or races), that have managed to develop osmoregulation systems compatible with the freshwater environment (Müller, 1995).

Human activities (construction of industrial facilities, irrigation facilities, tourist facilities, etc.) were amplified around the year 1955 and the population greatly increased in Constanta - Năvodari area and on the seashore from south of Constanta. All this led to a rapid pace of growth in drinking and industrial water needs, which led to increased intakes from Siutghiol Lake. Because of increasingly exploitation of karst aquifer, the lake feeding flor dropped, causing significant level oscillations.

2.3. Physico-chemical peculiarities of water

The physical characteristics of Siutghiol Lake depend on one hand on the climatic conditions of the geographical area where is located, and on the other hand on the morphometric characteristics of basins, salt content in water, aquatic vegetation, etc. (Telteu, 2012).

2.4. Presentation of flora and fauna aspects

Siutghiol Lake was declared a Site of Special Protection (ROSPA 0057), as part of Natura 2000 European ecological network in Romania, based on government decree 1284/2007, published in the Official Gazette (www.mmediu.ro). The main biotopes are marshes (4%) and stagnant water (92%). Among the protected species are mentioned the following: *Branta ruficollis* Pallas (red-breasted goose), *Falco vespertinus* L. (red-footed falcon), *Larus minutus* Pallas (small gull), *Larus genei* Brème (Slender-billed gull). In coastal lakes predominant are the species of flora and fauna that are specific to fresh and brackish waters. These grow and develop based on light, temperature, mineralization, organic substances content. Species of flora and fauna of these lakes constitute mainly planktonic and benthic communities.

2.5. Importance of Siutghiol Lake for local systems

Siutghiol Lake's location snd the wealth of resources, goods and services offered have made the relevant perilacustrine to be modified significantly over time, so that nowadays we need to refer to it as being rather an urban lake. This ecosystem has a major importance for the local systems: natural and anthropogenic (socio-economic):

i. Importance of natural system – Natura 2000 site, offering aquatic and terestrial habitats for resident populations, as well as migration habitats (passage way and/or reproduction), attenuating the estremes of atmospheric temperatures, regulating the hydric regime, flood effects (natural receptor and rainwater storage environment), controlling cycles of nutrients discharged into the lake, supplying food (percent of primary and secondary production for the superior level), assuring genetic resources (for scientific studies, for food).

ii. Importance for the human socio-economic system:

- eastern and western shores of the lake host localities and new residential neighbourhoods on their territories: Ovidiu and Palazu Mare on the western shore, respectively Mamaia summer resort on the eastern shore, with residential spaces built in the past 5-10 years;
- water resources provider (lake water represents a particularly important good for agriculture and industrial activities in the area, food provider;
- the lake offers a series of non-material benefits:
  - amenity, landscape, aesthetic character;
  - improvement of the urban climate;
  - spaces for sports, recreation, tourism activities (kayaking courses, boating, scooter rides, yachting, windsurfing, speed boats racing, fishing, angling, etc.);
  - spaces for educational activities (offering the possibility to observe, study and learn about ecosystems);
  - hosting the historical, traditional, cultural, religious values - "sense of place", appurtenance - local people speak with pride about the legendary Island of Ovid, as the place where there was an old woman's house, the only one in the settlement hosting a foreign traveller; it is said that the settlement was covered by water and the only one that escaped was the old woman's house, thus appearing the lake. Another legend says that the two oak trees rising on the island would have been planted by the great Latin poet, Ovid or that his tomb would be somewhere on the island.

Various activities that take place either on the lake or in adjacent areas may be factors of pollution if not done within legislative, ethical milestones, without exceeding the carrying capacity of the reveiver-ecosystem. The greatest influence on the environmental status of the two lakes was represented and still is the anthropogenic pressure (Păsculescu, 2011). We mention Ovidiu locality, with its new southern neighborhood, which still has not got its own sewage system, the swine farm near the northern shore of the lake, illegal fishing, and tourism activities on the east bank.

The human impact that has had an impact on Siutghiol Lake shorelines as well as on the ecosystem as a whole, leads to degradation of the landscape in time, by increasing construction works, without concern for the rational and aesthetic development, and to degradation of the aquatic environment, biodiversity loss, to the decline in the quality of the natural resources.

One should not leave aside the future projects involving Lake Siutghiol, for example the opening of a channel connecting directly to the sea or the artificial island – lacustrine town. Of course, development is important for an area with such potential. However, it is imperative that decisions concerning new development proposals should be based on "up to date" scientific data - that reflect how appropriate is the development, the potential risks for the environment - and on the public consultation so that the benefits of development to overcome both monetary costs, as well as the non-monetary ones, concerning environment. In this way, both the present generation and future ones will still receive the same quality of services and resources provided by this ecosystem.

CHAPTER 3:
ECOLOGICAL STATUS EVALUATION FOR URBAN LAKE SYSTEMS

Chapter 3 presents the structural and functional elements of lakes, the issues of urban lakes classification; the complementarities of the physicochemical and biological and ecological assessment of an ecosystem are supported, highlighting the role of benthic invertebrates in this respect, in terms of the Water Framework Directive.

In Romania the assessment of ecological status and ecological potential of natural and heavily modified water bodies is done in accordance with the Water Law no. 107/1996, as amended and supplemented, using and testing, in the same time, the methodologies regarding the classification systems and global assessment of the surface water status, developed by the National Research Institute for Environmental Protection in Bucharest, on the basis of biological, chemical and hydro morphological elements, as required by the 2000/60/EC Water Framework Directive (WFD).

CHAPTER 4:
AIMS

Aquatic ecosystems provide a number of benefits to people, but uncontrolled exploitation and intensive antrophic led to alterations in Lake Siutghiol. Its location makes its functions, recreation and leisure, to be heavily exploited, tourism development bringing with it a new land use in the area around the lake. The general tendency consists in its transformation into a metropolitan area, while various problems being claimed, as well as new development projects (lacustrine-town inside the lake, channel connecting with the sea), which requires measures to limit the negative effects to adjust the pressure of human activities, in order to continue to benefit from the resources and ecosystem services, but by maintaining or improving the structural and functional parameters of Siutghiol Lake system.

For these reasons, I wanted this study to materialize into an integrated monitoring plan that will bring current scientific data on ecological bases of Siutghiol Lake ecosystem, to understand how its functions, resources and ecosystem services are affected, what are the stress factors, generators of risk for the various components of the ecosystem. Determination of specific issues is particularly important in order to make decisions about appropriate management of the area (what can be done for resources, what activities can be supported or restricted, as appropriate).

I chose a program to assist in knowledge, learning methods, of the way of working in the field and in the laboratory. The objectives were:

- Analysis of sustainable development concept, as an imperative of the new millenium and especially as application to the management of the natural capital of lake systems;
- Knowedge and assessment of the current general state of Siutghiol Lake, identification of changes and pressures induced by human factor over time;
- Assessment of analysis methods of the health status of aquatic ecosystems, especially from the water Framework Directive point of view;
- Up to date knowledge of the elements contributing to the evaluation of ecosystem structure and functioning and of the means of influencing the resourses that people rely on:
    - Determining the degree of damage to ecological integrity of ecotone area, by application of the shoreline development index;
    - Evaluation of the overal toxicity degree of lake water and sediments;
    - Tracking spatio-temporal dymanics of some water and sediments quality parameters on different depth horizons (temperature, dissolved oxygen, nutrients, turbidity, chlorophyll, conductivity, pH, salinity; metallic elements content in water and sediments);
    - Benthic communities assessment (qualitative structure and population dynamic);
    - Integrate assessment of aqcuired data;
- Identification of the main problems of Siutghiol ecologic system and proposing a set of appropriate measures and reccomendations, in terms of sustainable management of the hydrographic basin.

CHAPTER 5:
MATERIAL AND METHOD

In this chapter have been described the following:

- Sampling points network and sampling frequency (Fig. 1);
- Sampling, conservation, processing methodology for samples;

- Method designed to evaluate the lake shoreline development;
- Methods for evaluation of quality and toxicity dergee of water and sediments, as well as methods for the evaluation of ecological status.

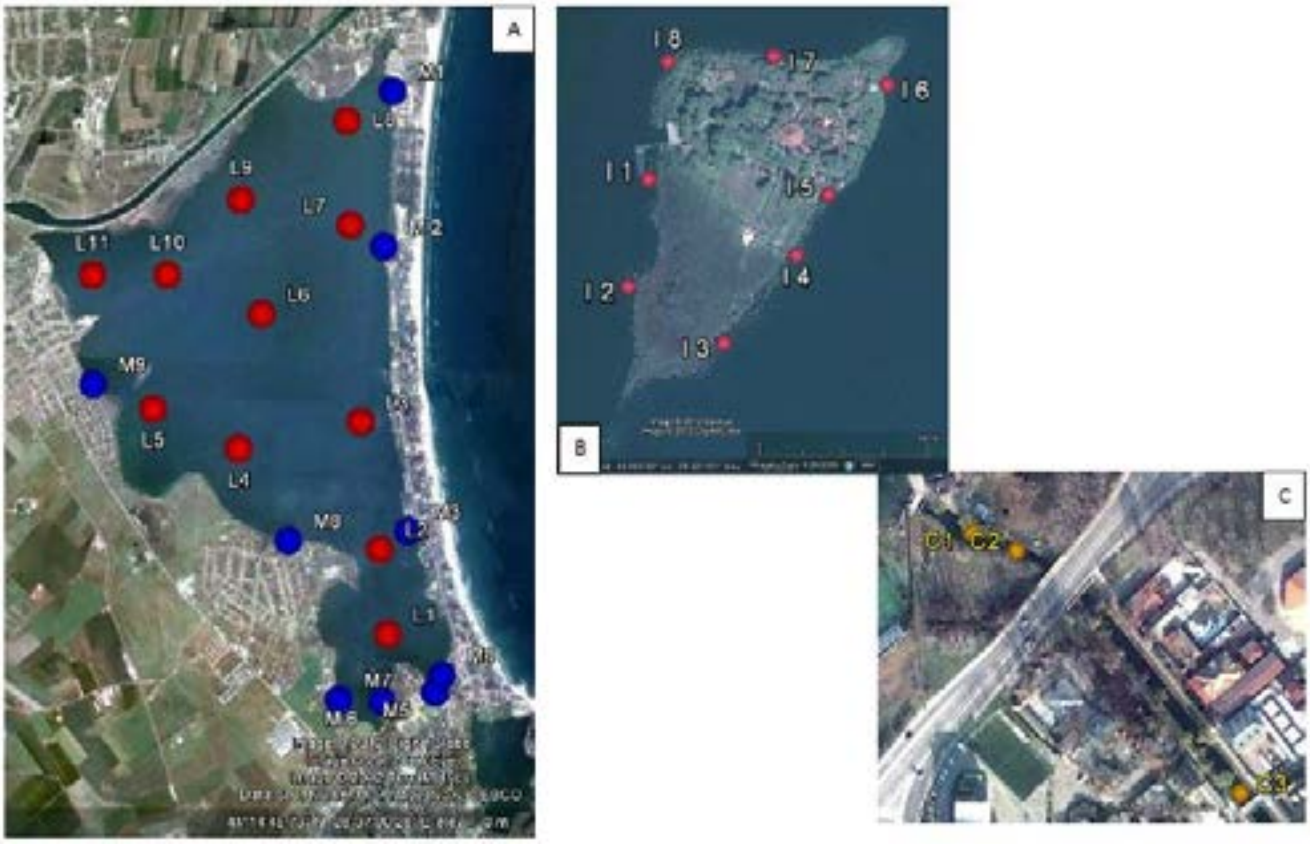


Fig. 1 – Location of sampling stations: A. within the lake (marked in red) and from the shore (marked in blue); B. from Ovidiu Island; C. From Siutghiol-Tăbăcărie channel

Sampling points network has been established in order to obtain a good coverage of the entire lake surface, both within the lake (11 points) and at the shore (8 points) (Fig. 1A), so as to represent the strongly anthropogenic areas, as well as those with less impact. Anthropogenic pressures exerted on the lake extremities are diverse, with one exception, the northern area, affected, at first glance, to a lesser extent by human activities. We have also established eight stations around the Ovidiu Island and three in the channel that connects the lakes Siutghiol and Tăbăcărie (Fig. 1 B and C). Sampling rate and output measurements was seasonal, totalling 8 campaigns.

A number of quality parameters for surface waters were determined *in situ* with YSI multiparameter sonde (equipped with probes that operate on electro-chemical and optical principles) Data were recorded at the surface and then vertically from one meter to another, down to the maximum depth. This resulted in about 3200 *in situ* measurements and laboratory analyzes. There were also collected a total of 636 benthos samples (470 quantitative samples and 166 qualitative samples - Table 2).

By application of the shoreline development index 147 points resulted around the lake, depending on the surface occupied by the functional area and by the possibility to get acces to the shore. For each of these points were filled observation sheets and the informations were processed and analysed in the laboratory.

Table 2: Number and type of samples and measurements

<table>
<tr><td colspan="7">Probe:</td></tr>
<tr><td colspan="2">chimice</td><td colspan="5">biologice</td></tr>
<tr><td colspan="2">Determinări:</td><td>Determinări:</td><td>țărm</td><td>insulă</td><td>larg</td><td>Observații</td></tr>
<tr><td>cantitative</td><td>În laborator
- nutrienți - 104
- spectroscopie de absorbție atomică - 349</td><td>cantitative</td><td>88</td><td>112</td><td>270</td><td>Din care:
235 macrozobentos
235 meiozoobentos</td></tr>
<tr><td rowspan="2">in situ</td><td rowspan="2">2748</td><td>calitative</td><td>56</td><td>16</td><td>66</td><td>69 macrozoobentos
69 meiozoobentos</td></tr>
<tr><td>in situ</td><td>12</td><td>16</td><td>-</td><td>28 probe calitative analizate global</td></tr>
<tr><td>Total</td><td>Aprox. 3200 determinări</td><td colspan="5">Total: 636 probe analizate</td></tr>
</table>

CHAPTER 6:
RESULTS AND DISCUSSIONS

6.1. The current status of the shoreline

Shoreline development index quantifies and helps in understanding the relationship between human activities on land and environmental integrity of the lake. The index has 5 components: aquatic, shore, riparian, biotic and aesthetic. When all these are evaluated together one can get an overview and quantification can be achieved for each station.

- **Aquatic component** achieved a relatively uniform value. In most places we found submersed and floating vegetation, which represents a positive aspect for the aquatic score.
- **Shore component**. Mamaia, Campus, and Scoica Land functional zones received a low score for the shore area. Throughout the eastern shore of the lake the shore is made of concrete, so that the attributed score was 0. Stations for which the shore component received a high score are those from the northern part of the lake, close to Galeşu channel, where the bank is entirely natural, the human intervention being apparently less significant compared to the other functional zones.
- Areas where the **riparian component** received the highest score are Galeşu channel and vis-a-vis Carrefour areas, where the vegetation is abundant. The zone with lower scores for the riparian component was La Scoica Land, where, because of strong anthropic influence, the natural landscape had much to suffer.
- **Biotic component** is related to vegetation presence and a healthy and well cared for natural environment. The channel area, where the vegetation is abundant and there are whole reed sections, the biotic component is present, as well. Therefore, there was a high abundance of birds mainly in several stations of this functional zone.
- **The aesthetic component** received greater scores for the majority of the stations due to pleasant aspect buildings. Built space benefited from a pleasant architecture in most of cases. There were rare cases of stations with unkempt buildings or abandoned or damaged piers that would mean a low score for the aesthetic component.

Most stations (**47**) got a good score, but there were cases in which the score was low due to the large amount of waste, the discharge outlets, or due to degraded built space, which contributed to the decline in the area value (Bucur et al., 2012).

As we move to the north and northwest of the lake, starting with Scoica Land, the number of stations that received average scores decreases and increases the number of stations with good and very score - Mamaia Sat and Ovidiu areas (Fig. 2). In channel Galesu area most stations were rated excellent, human intervention being minimal, with natural banks, and no concrete or built surfaces. The vegetation is abundant, with areas where reed islets were encountered.

Palazu area also recorded low scores, few stations receiving poor rating because of the presence of a large number of waste, and floating debris on the water surface. However, the proportion of stations with low scores of all stations conducted in this functional zone was low.

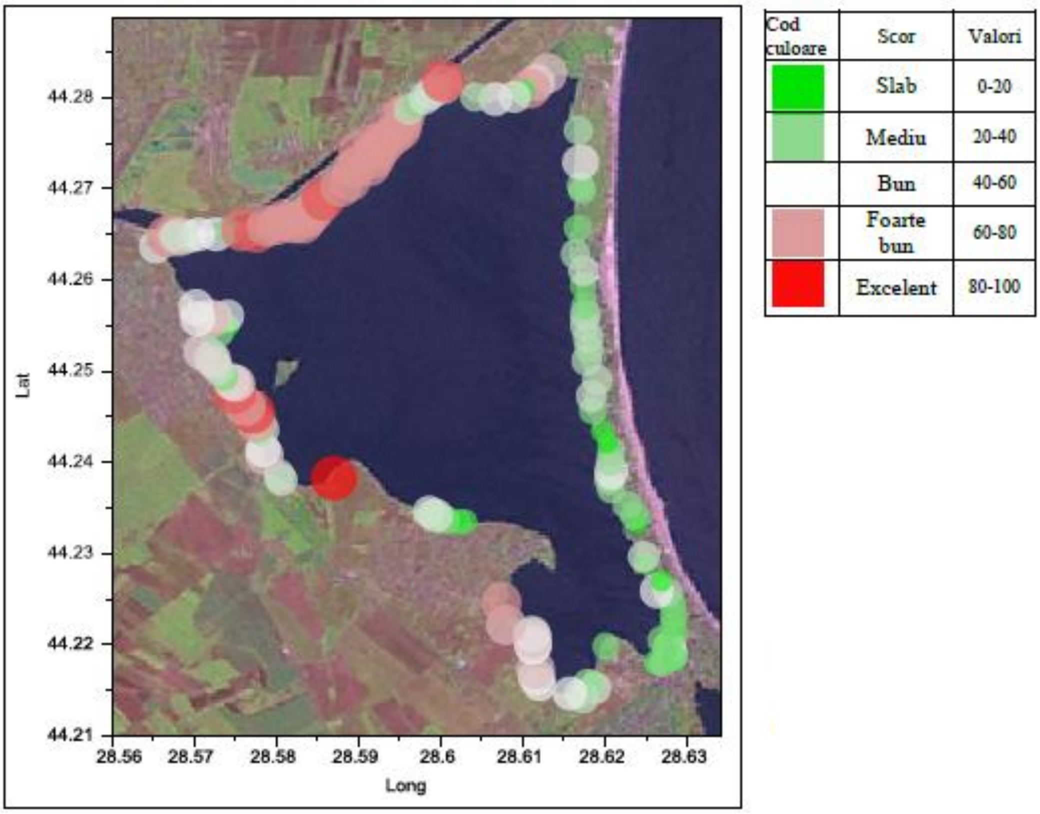


Fig. 2 – Spatial distribution of stations and total scores calculated

6.2. Ecotoxicological evaluation of water and sediments

By using Toxkit microbiotests we are able to capture the synergistic effect of several components (Tofan et al., 2010b). The response is the reaction of living organisms to a multitude of substances that were found at some point in their living environment (water, interstitial water and sediment). After test validation, based on data resulting through measurements of plants roots and stems, we calulated the percent inhibition of growth for the three plant species used, compared to the control groups. The three plant species respond differently to the degree of contamination of sediments (Fig. 3, Fig. 4).

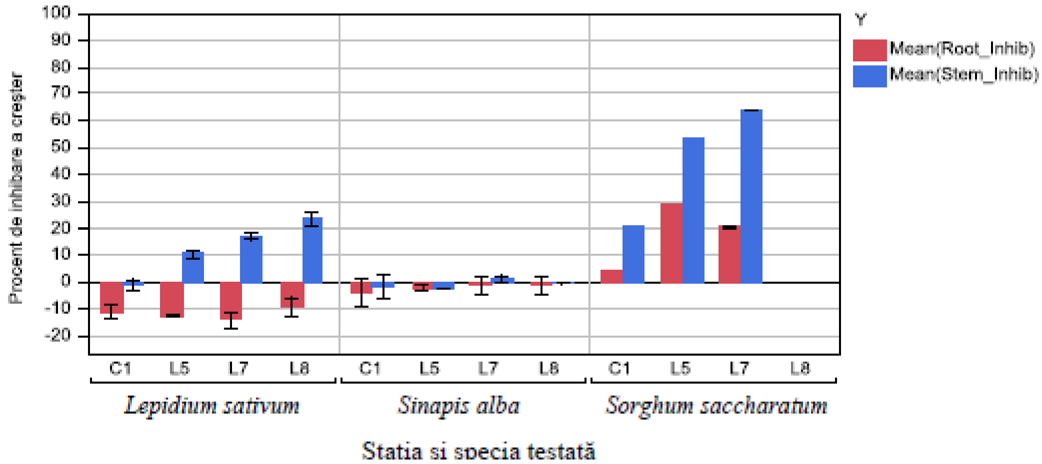


Fig. 3 – Results of sediment phytotoxicity tests for 2009

Growth inhibition percent for *Lepidium sativum* varied by station and recorded negative values, which means that the tested sediment had rather stimulated the growth of roots. The stem exibit the toxic effect of tested sediment for 3 out of 4 stations (Fig. 3). The highest mean inhibition percent was of 23.46, for station L8.

For *Sinapis alba* the tested group had an increased growth compared to the control, thus the calculated percents indicate a stimulation of plant growth, but not as strong as for *Lepidium sativum* (Fig. 3). The only exception is for station L7, where the stem growth inhibition percent was of 1.16%.

Compared to the control, the growth of sorghum was significantly reduced, unlike the other 2 species. Both, the root and stem exhibited inhibition of growth above 50% at stations L5 and L7.

In 2010 we notice that for the majority of the stations negative values of the growth inhibition percents were obtained (Fig. 4). Measurements show a strong stimulation of roots and especially of stem for *Sinapis alba* for all stations compared to previous year. For *Lepidium sativum* growth inhibition percents were calculated for stations L3, L8 and L10. For L5 root growth was stimulated but the stem was inhibited. For *Sorghum saccharatum* station L3 and L5 exhibited stem growth inhibition; for the other samples the effect was of growth stimulation (Fig. 4).

Ostracodtoxkit chronic toxicity test shows the presence of certain elements in water that determined ostracods growth inhibition in three of the four stations. The percentage of growth inhibition was greater than 40%. The highest growth inhibition percent was exhibited at station L5, situated to the south of Ovidiu Island, location that would explain this result, through the discharge of wastewater coming from activities taking place on the island. At station L7, ostracods from test group increased more than the control group, so we obtained a percentage inhibition of -19%, suggesting either the presence in the water of certain substances causing organism growth or the antagonist effect of chemical compounds.

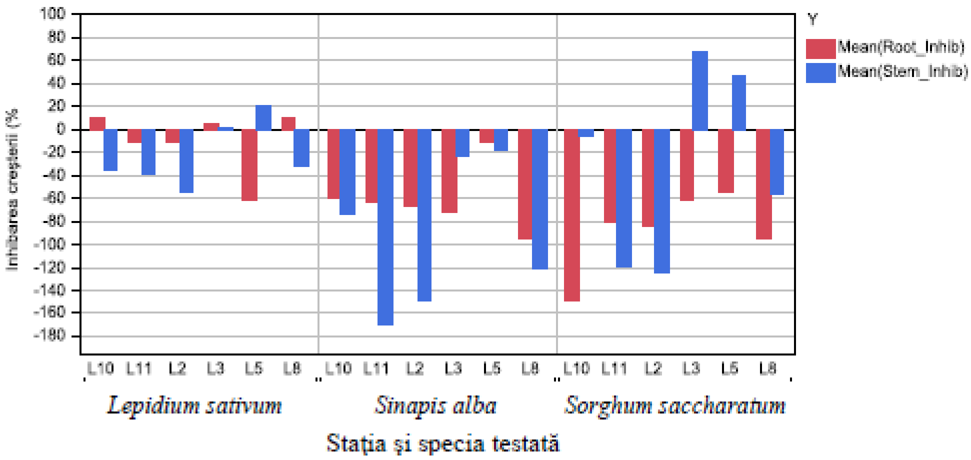


Fig. 4 – Results of sediment phytotoxicity test for year 2010

6.3. Evaluation of Siutghiol Lake water and sediments quality

6.3.1. Analysis based on determinations of physico- chemical quality parameters

● Observations and field measurements show, as we expected, normal seasonal variation of **water temperature**. In November 2009, May and September 2010 we noticed that the temperature for the monitored stations are relatively constant form surface to the bottom.A combined ANOVA for all dates pooled together showed that only date and station have an effect on water temperature. The same effect was noticed for the interactions between date and station, date and depth, station and depth.

● **Water specific conductance** varied very much form one date to another, but the interval determined by the minimum and maximum values for the entire study does not mean a hazard for the resident biota.

● During the study, **water pH** recorded values between 6.81 and 9.22. Compared to data offered by specialty bibliography (Galaţchi, 2005), we noticed an increase of Siutghiol Lake water pH, from a multi-annual average value of 8.19 for 1997-2000, to 8.96 for 2009-2011.

● **Water turbidity** was increased over the entire study period and great, statistically significant variation was observed by date. Differences by depth and by station were not statistically significant.

● **Water oxygen saturation** suffered changes from one determinations phase to another (Fig.5), big variations being observed a decrease trend from surface to the maximum depth, but also from one area of the lake to another. For most of the cases, oxygen saturation has relatively constant values down to 3 meter, then it suddenly decreases, reaching values that do not sustain life.

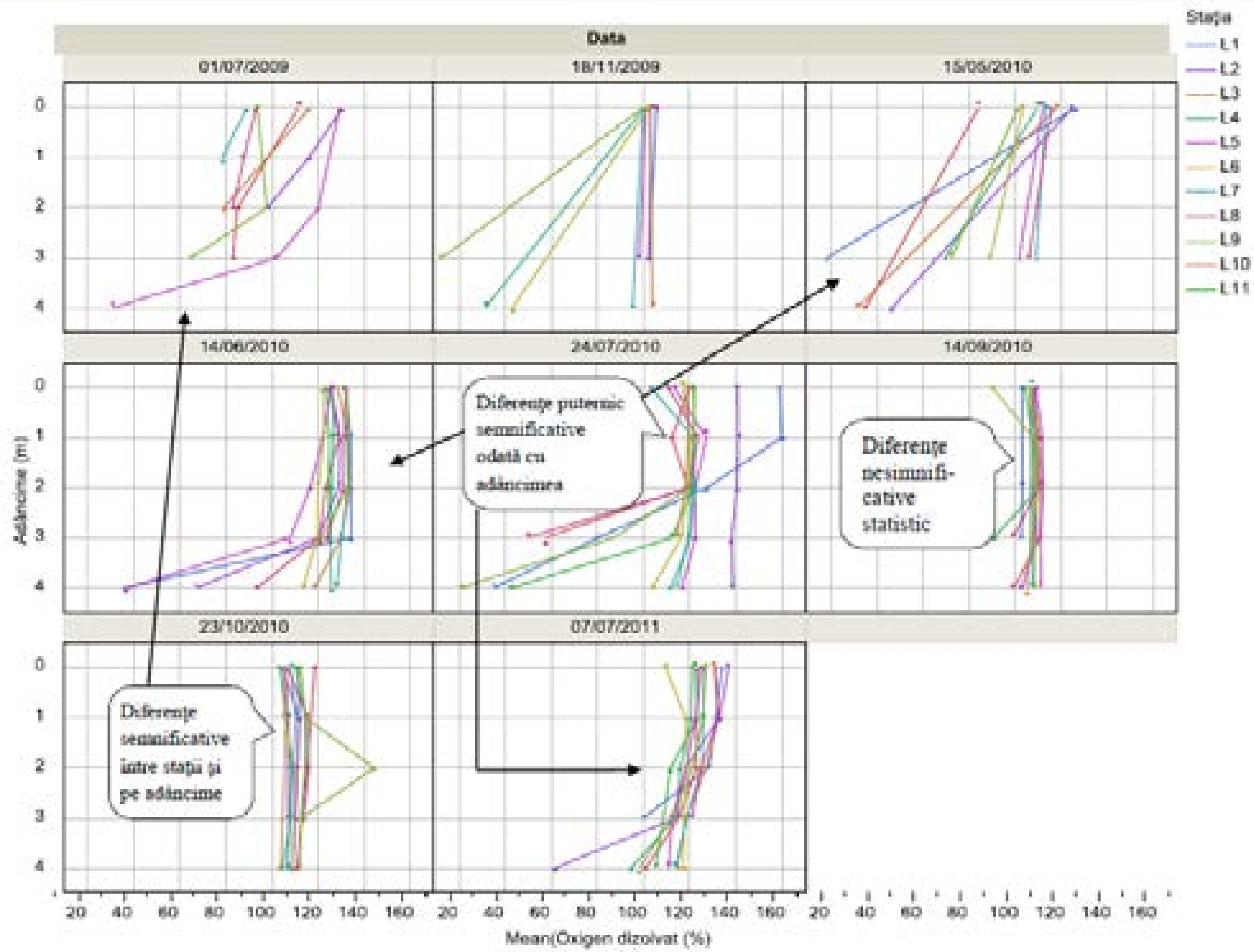


Fig. 5 – Variation pattern of mean values of dissolved oxygen saturation

● **Chlorophyll fluorescence** exhibited large variations over the study period; greater differences between the 11 stations were observed in July 2009, June and July 2010, as well as in July 2011 (Fig. 5-7). However, the statistical analyses show that there were no significant differences by station but rather by depth. The analysis of variance of all the dates pooled together emphasizes the significant effect of date on chlorophyll fluorescence. The effects of the other elements tested, station, depth, interaction between station and depth, were statistically insignificant.

● The **levels of nutrients** were monitored both for the littoral and inside-lake area (Fig. 6). For the water samples taken from inside the lake we noticed that an increase of nitrates concentrations entails an increase of chlorophyll in the water, thus favors the phytoplankton growth. The same trend was also observed for the shore area. This suggests the the green algae in the system are nitrate limited.

As regards phosphates, the relationship was more complex. For the stations inside the lake there was no association between orthophosphates and fluorescence, while for the shore area we noticed a negative relation between phosphate concentration and algae fluorescence.

This suggests that the green algae manage to exploit this phosphorous compound but only up to a point and when the ratio of nutrients in the system changes in favor of excess phosphorus, blue-green algae may outcompete phytoplankton, because these can optionally fix nitrogen in the air, rezulting in vizible algal blooms. In the shore area this process can be accentuated due to greater release of phosphorus from the sediment, which is exploited by cyanobacteria, which outcompete phytoplankton (cyanobacteria react before algae causing blooms or algae adapted to low light conditions).

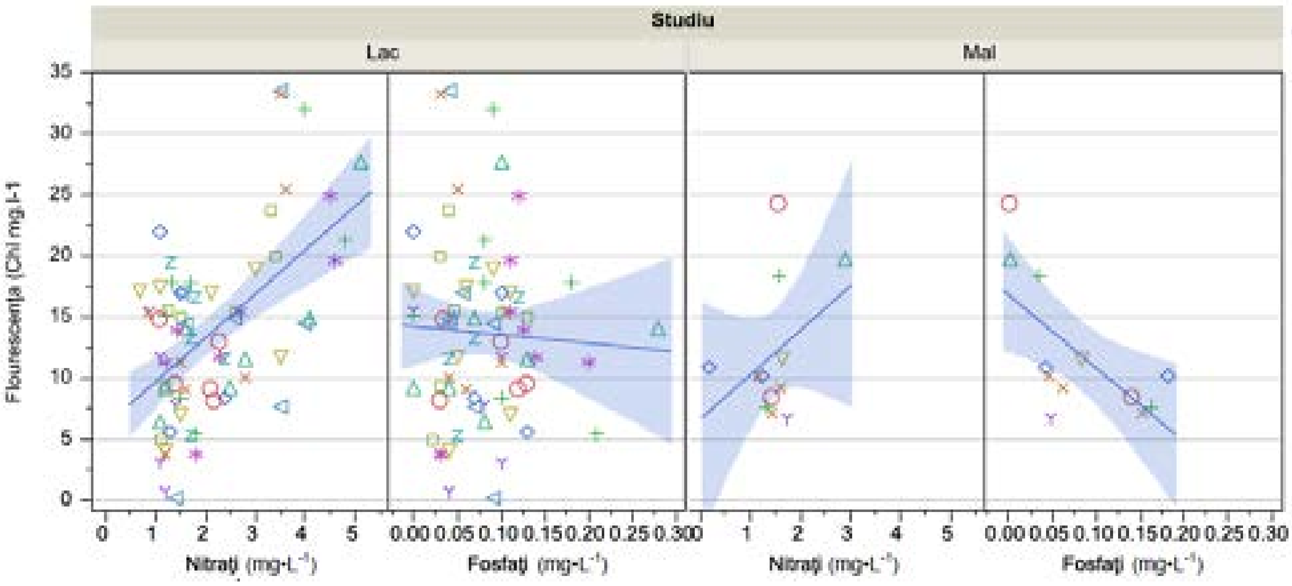


Fig. 6 – Effect of nutrients on chlorophyll concentration for littoral and inside lake stations

An overview of average concentrations of chlorophyll, nitrates and phosphates during the study period indicates a similar pattern for the first two parameters (Fig 7A).

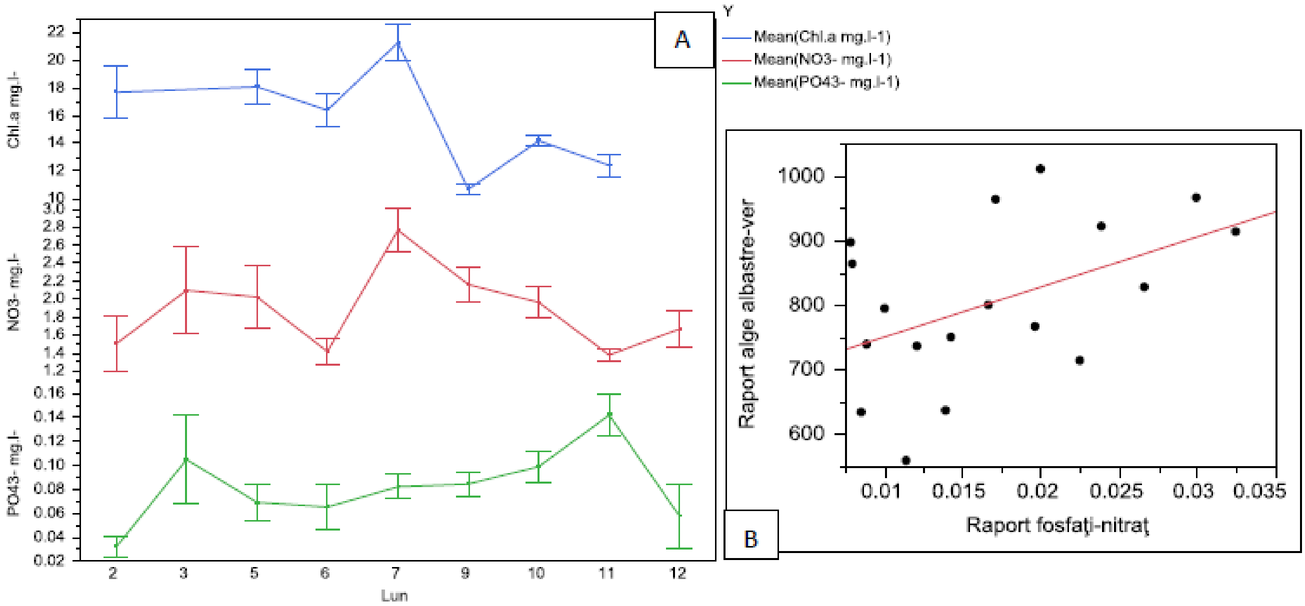


Fig. 7 - Variation in time of chlorophyl and nutrients (A) and the relationship between green algae and chlorophyll vs. nutrinets ratio in the summer of 2009 (B)

Pronounced decrease of chlorophyll in September 2009 (Fig. 7A), while nitrate concentration decrease, can be explained by the accelerated development of cyanobacteria, that under such circumstances have the ability to fix nitrogen from the atmosphere freely. As the relative abundance of phosphate to nitrate increases, so does the relative abundance of blue-green to green algae (Fig. 7B) (Tofan et *al*., 2010a; Tofan et *al*., 2012).

6.3.2. Evaluation of water quality based on heavy metal content determination

In order to evaluate the data obtained regarding the concentrations of heavy metals in waters and sediments of Siutghiol Lake we reported to the maximum permitted values, forseen by the legislation in force: M.O. 161/16.02.2006. Exceeded maximum permissible concentrations were observed for Cd and Hg in surface waters.

6.3.3. Evaluation of lake sediments quality based on heavy metal content determination

In the sediments were determined exceedings of thr limit values for Cd, Pb, Cu, Zn, Hg and Mn. Overall stands stations L4, L5, L7 and L8. The shore area corresponding to stations L4 and L5 is Ovidiu locality, namely the southern extremity, and that for L7 and L8 is northern Mamaia. Both have known an astounding development in the past 5 years.

Accumulation of heavy metals occurs by draining the basin, and not by karst springs feeding the lake. In this regard, reference data (Ovidiu 21 Local Agenda, 2008) on the determination of heavy metals in groundwater adjacent to the lake shows a low level of heavy metals, even lower than in the lake water, therefore, can not be regarded as the source.

6.4. Integrate analysis of ecotoxicological tests results and specific pollution indices

Integrated statistical analysis of ecotoxicology test results and heavy metal content revealed those metallic elements that could cause those effects exhibited in Section 6.2.

For *Lepidium sativum* Pb, Cu, Mn, and Hg led to inhibition of root growth (Fig. 8). Stem growth was inhibited by Pb and Hg, which were present in higher concentrations in 2009, the maximum allowed being exceeded, in particular in stations L5 and L7, with high percents (above 50%) of growth inhibition (Fig. 9).

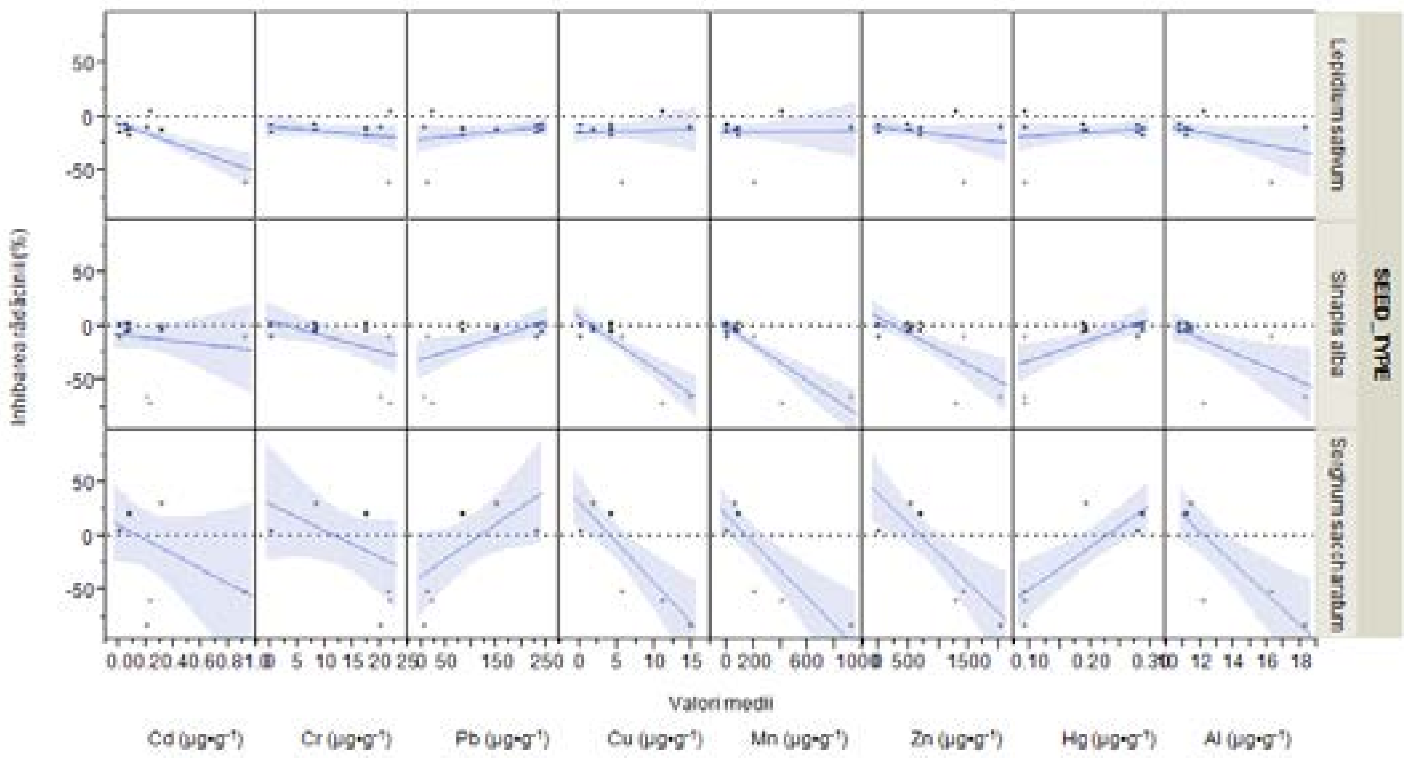


Fig. 8 – Relationship between growth inhibition percent for roots and mean values of metallic elements in sediments

For *Sinapis alba* only Pb and Hg determined an effect of root and stem growth inhibition percents. Concentrations of other tested heavy metals cause rather plant growth stimulation.

Sorgo exibited root and stem growth inhibition trends that are similar to *Sinapis alba* and *Lepidium sativum*, induced by Pb and Hg; in sorgo case inhibition percents were always positive.

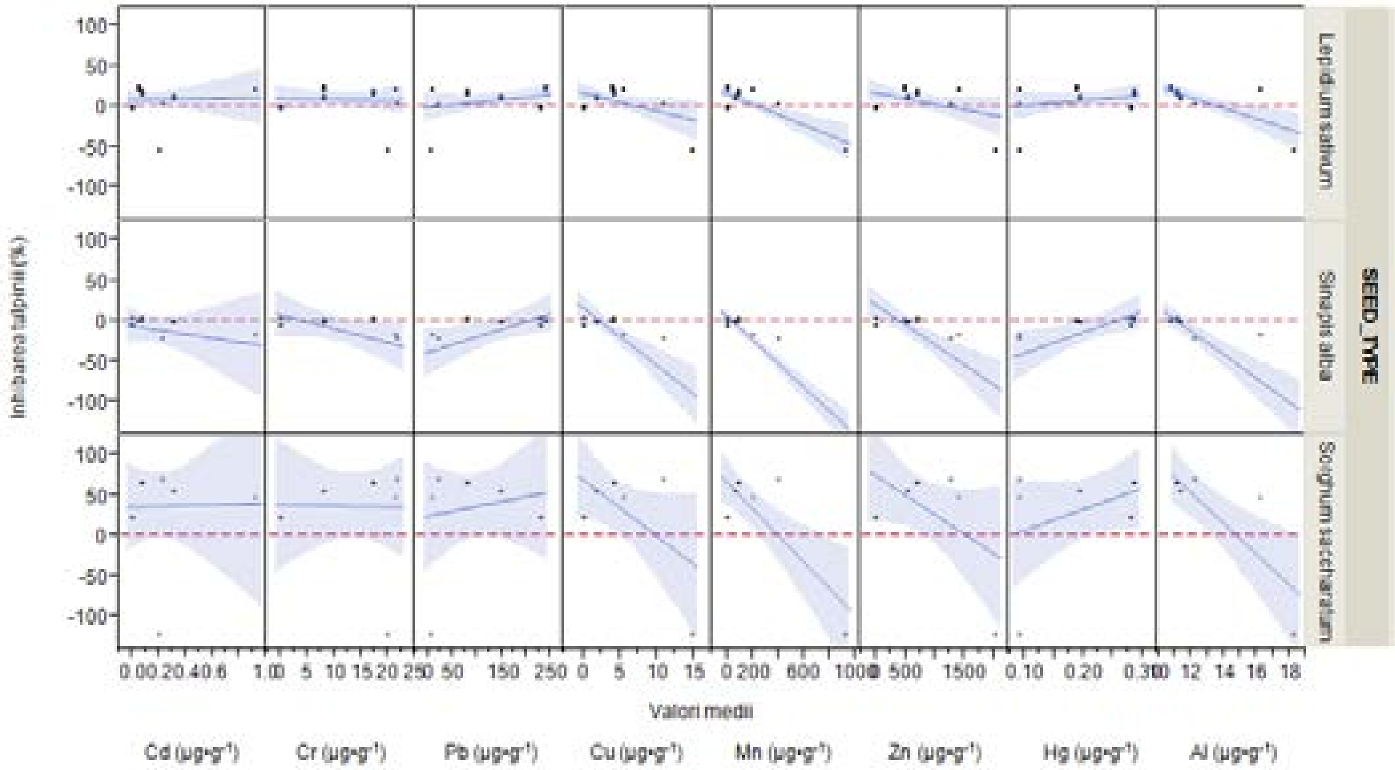


Fig. 9 – Relationship between growth inhibition percent for stems and the average concentrations of metallic elements in sediments

These results suggest the existence of other factors, not measured in this study, which may influence the phytotoxicity of the analysed samples, like the chemical forms of the metallic elements, which determines the bioavailability and their mobilization capacity (Morillo et al., 2002) or sediment nutrient loading (Nakamura et al., 2002).

Presence of large quantities of nutrients in organic matter from sediment may conceal the inhibitory impact of phytotoxic contaminants from sediments, thus changing the evaluation. In adition to this, the interactions between contaminants may have antagonic or synergistic effects, which are hard to predict (Czerniawska-Kusza, 2006). However, the obtained results reflect the effects of stress factors caused by anthropic activities on living organisms.

In the analysis of the relationship between the test results of ecotoxicological test Ostracodtoxkit and water content in metallic elements, Cd, Pb and Al were positively correlated with the percentage of growth inhibition of ostracods.

6.5. The ecological status of Siutghiol Lake – benthic communities assessment

6.5.1 Taxonomic and ecological structure of zoobenthos

Following research in 2009-2011 22 taxa were identified: 10 supraspecific level (nematodes, briozoars, hydracarians, crustacean ostracods and copepods) and 16 species level (Table 3).

The zoobenthic community was numerically dominated by meiobentos, in a proportion of 64% (Fig. 10), with a density of 751,203.5 ind•m^{-2}. Net dominance of meiobenthic forms appear to be associated with the presence of human impact.

According to our study, the macrobenthic community was represented by 19 taxons (Fig. 11).

Noteworthy were Diptera Nematocera insects (larvae, pupa and imago - macrobenthic forms, genus *Chironomus*), represented by three species (Bucur et al., 2012b), with a high density and frequency of occurrence throughout the study, regardless of location or substrate. Chironomids are the main component by determined abundances; these are often used to assess water quality, oxygen condition and trophic status (Brundin, 1949 Sæther, 1979), either separately or together with other groups of benthic invertebrates.

Table 3: List of benthic species retrieved from Siutghiol Lake between 2009-2011

No. crt.	Taxa	Species	Symbol	Macro	Meio
1	Spongia	*Spongilla lacustris* (Linné)	Spong	+	
2	Hydrozoa	*Hydra* sp. (Pallas)	Hydra	+	+
3	Briozoa	*Plumatella* sp. (Linné)	Brioz		+
4	Turbellaria	varia	Turb	+	
5	Polychaeta	*Hypaniola kowalevskii* (Grimm)	PolH	+	+
6		*Manayunkia caspica* (Annenkova)	PolM	+	+
7	Oligochaeta	*Stylaria lacustris* (Linné)	OligSty	+	+
8		Naididae varia	OligNaid	+	+
9		Tubificidae varia	OligTubif	+	+
10	Hyrudinea	*Erpobdella stagnalis* (Linné)	Erpob	+	+
11	Nematoda	varia	Nema	+	+
12	Nematomorpha	*Gordius* sp. (Linné)	Nematmph	+	+
13	Acarina	Limnesiidae varia	AcLimn	+	+
14		Aturidae varia	AcAtu	+	+
15		*Copidognatopsis* sp. (Viets)	AcCopid	+	+
16		varia	Acari	+	+
17	Cladocera	*Daphnia* sp.	Daph	+	+
18	Copepoda	varia	Cope	+	+
19	Ostracoda	varia	Ostra	+	+
20	Amphipoda	*Gmelina aestuarica* (Cărăuşu)	Amphi		+
21	Mysidacea	*Limnomysis benedeni* (Czerniavsky)	Mys	+	
22	Isopoda	*Asellus aquaticus* (Linné)	Isop	+	+
23	Crustacea	varia	Crustv	+	+
24	Odonata	varia	Odo	+	
25	Plecoptera	varia	Plec	+	+
26	Heteroptera	Corixidae-*Micronecta* sp. (Kirkaldy)	Heterop	+	+
27	Coleoptera	varia	Coleo	+	
28	Diptera-Nematocera larve, pupe, imago	*Chironomus plumosus* (Linné)	DiptChp	+	+
29		*Chironomus* sp.	DiptChsp	+	+
30		*Sphaeromias* sp. (Curtis)	DiptSph	+	+
31		varia	Dipt	+	+

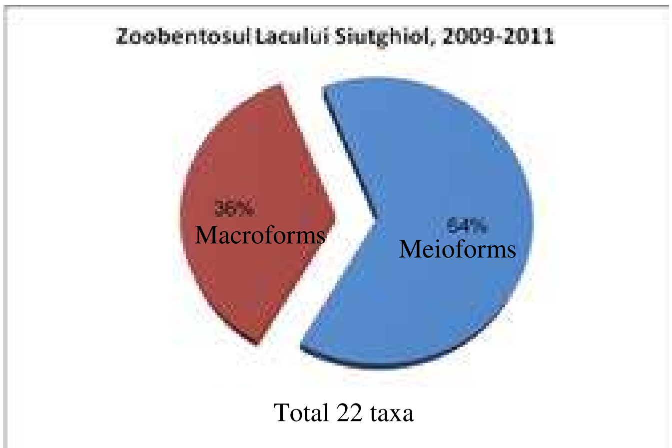


Fig. 10 – Abundance ratio of zoobenthic forms for the entire study period

Copepods are the second most abundant group achieved overall, obtaining 9% of the total, followed by oligochaets, mites, nematodes and isopods. The lowest abundances were recorded by Odonata, Plecoptera and Coleoptera insects (Fig. 11).

Although with an insignifiant share, Ponto-Caspian relics have great scientific importance and significance for the status of Siutghiol Lake ecological system. Their presence, even in small numbers, shows that those areas are true enclaves in this complex system subjected to increasing anthropogenic pressures (Paraschiv et al., in press). Very important to note is the presence of Ponto-Caspian hydrozoar relict species, *Cordylophora caspia* (Pall.), after years since it has not been reported.

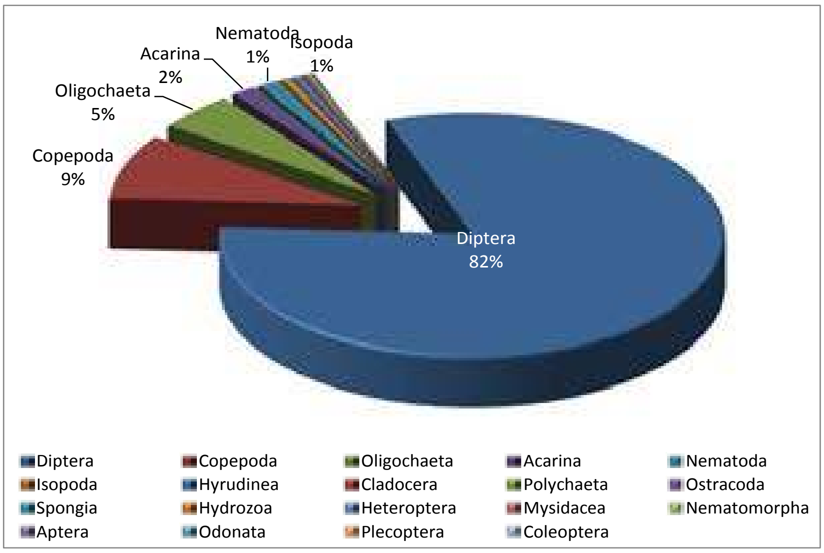


Fig. 11 – Ratio of macrozoobenthic groups of organisms from Siutghiol Lake sediments

Variations were observed in the abundance and biomass recorded at some stations forming the western transect affected to a lesser extent by human activities. The relict species were found in habitats dominated by phytal substrate disposed on the western extremity, in areas with belt vegetation and around the Ovidiu Island. These associations are similar to those existing before the change induced by human intervention. Past reports mention the presence of the Ponto-Caspian relicts, but in greater number than our reports (Paraschiv et al., 2009).

Compared to data from 2000, there were major restructuring. Thus, because of the increased amount of debris in the system, the number of oligochaets decreased. Also, submerged vegetation is poorly represented, so that is why we have not found *Echinogammarus* sp. No molluscs have been represented as in the past, only fragments of different shells being found. In these circumstances, the diversity index is lower (Paraschiv et al., 2009).

In meiozoobentos 15 taxa were identified. The most numerous were the nematodes, which reached an abundance of 410,471.5 ind•m^{-2}, which represents 55% of the total, followed by Nematocera dipterans, with 27% (Fig. 12). The following groups in decreasing order of abundance values were: Oligochaeta, Copepoda, Ostracoda and Acarina. The remaining taxa, which form most zoobenthic meioforms, recorded densities lower than 500 ind•m^{-2}.

Abundance and dominance of certain trophic groups gives us valuable information about how the ecosystem functions, correlated with the available trophic base. For example, dominance of detritivore populations (especially nematodes, oligochaets and some chironomid species) is associated with extremely important ecological role of organic matter cycling through the benthic component of the food chains. Net dominance of meiobenthic forms appear to be associated with the presence of human impact (Paraschiv et al., in press).

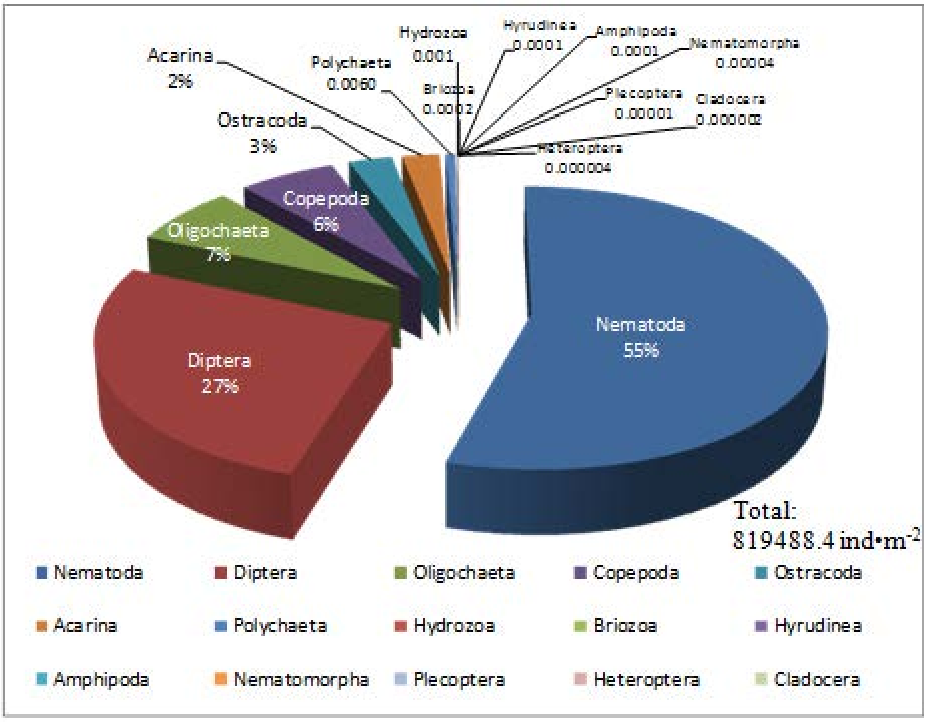


Fig. 12 – Ratio of meiozoobenthic groups from Siutghiol Lake (2009-2011)

6.5.3. Distribution of benthic groups by substrate type

Zoobenthos communities are generally described in close relation to the type of substrate which they inhabit. In Siutghiol Lake three major types of substrate were identified: sedimentary, hard (or rocky) and phytal - represented by submerged plants and their organs, reed stems (Paraschiv et al., 2009). Overall, zoobenthic sedimentofile associations are dominant in Siutghiol Lake, which can be easily explained by their large habitats, associations on rock and phytal substrata.

Sediment substrate within the lake was mostly sandy with silt fraction, predominantly muddy and loamy. Shore substrate was different depending on the area of collection, but all three types mentioned were encountered.

6.5.3.1. Annual analysis of fauna associated to different types of substrate

At first glance, we observe that the benthic fauna on rocky and sedimentary substrate consisted in ten taxa, while the phytal in eight taxa. The following are common: Hydrozoa, Nematoda, Polychaeta, Oligochaeta, Acarina, Copepoda and Diptera. Rocky substrate is distinguished by the presence of sponges, hirudineans, the phytal substrate by bryozoans, and the sedimentary by the presence of mysids and isopods. Ostracods are common for rocky and sedimentary substrates (Fig. 13).

In areas with rock, five of the ten groups obtained abundances that separately represent 16-20% of the total abundance, as opposed to other types of substrates, where there is one dominant group by abundance, of more than 50% of total (Fig. 13).

On the basis of bentofauna associated with different types of identified substrate, it was observed that the highest average density values belonged to taxa on the rocky substrate. The ratio of macroforms to meioforms was 1:1 (Fig. 14). The same ratio resulted for the phytal substrate.

The situation for the sedimentary substrate was different from the other two in that the meiobenthic forms obtained average density values that were higher for both shore and in lake stations (Fig. 14). Macroforms to meioforms ratio was 1:24 for the in lake area, respectively 1:8 for the shore.

In 2010, as we expected, the values obtained regardless of the substrate type, are much smaller. It is a quantitative decrease, of species abundance, as qualitative composition is similar to the previous year. This may be due to temperature differences between summer and the autumn, or to the fact that some species have resistance forms / structures for the winter period. It is noted that the meiobenthic component of zoobenthos was predominant both in the case of sedimentary and phytal substrate (Fig. 15).

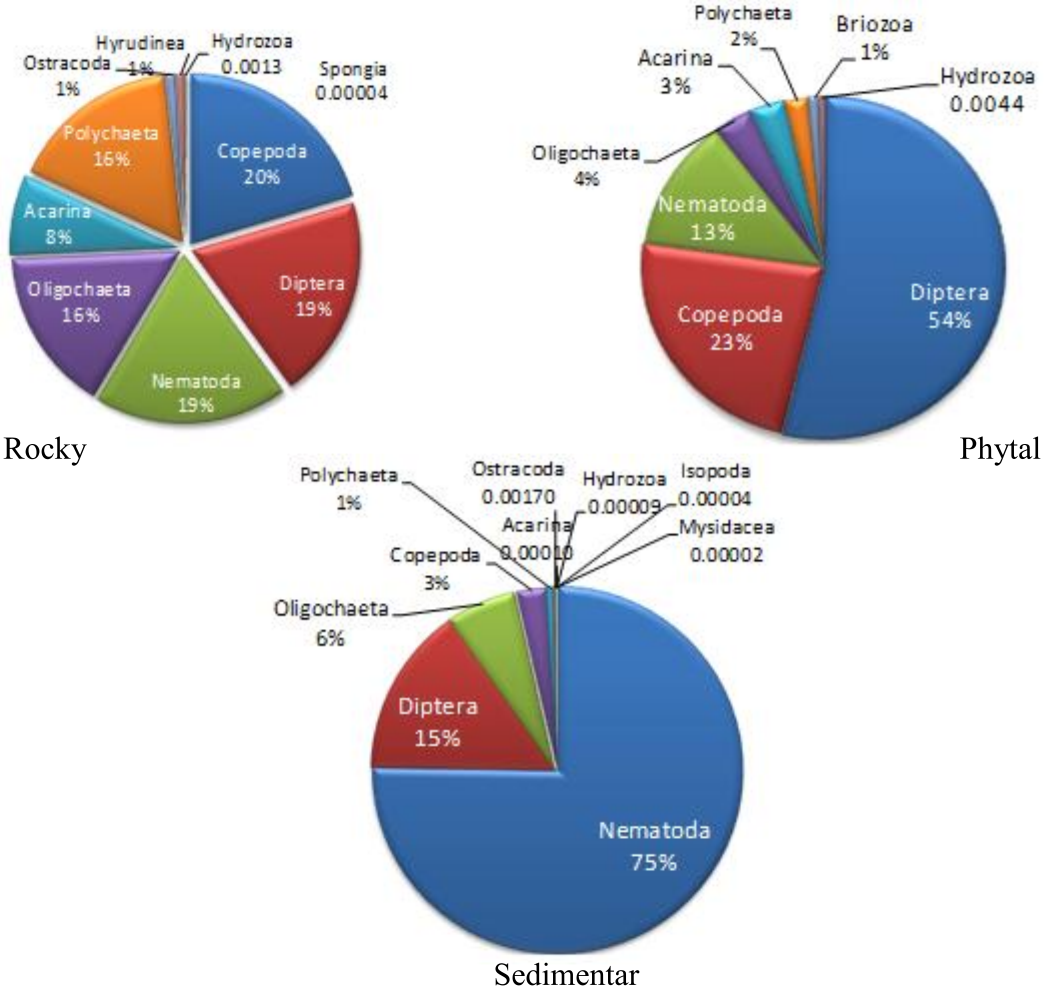
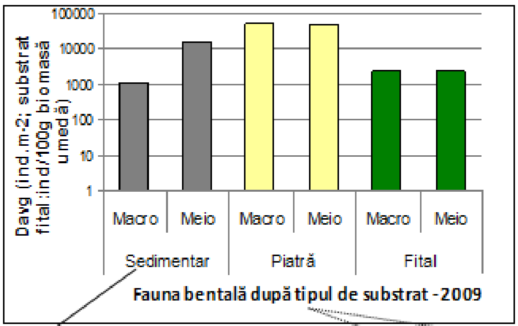
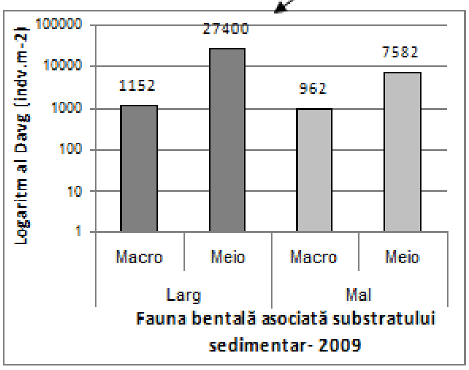


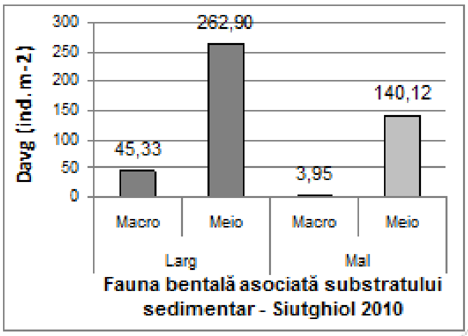
Fig. 13 – Qualitative structure of Siutghiol Lake zoobenthos by substrate type (2009)

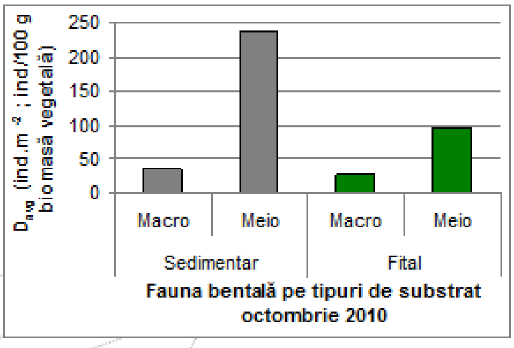




Valori Davg (indv•m^{-2} sau 100g biomasă umedă)			
Macrozoobentos			
Sedim.	Max:	241.242	L9
	Min:	5.866	L2
Piatră	Max:	14335	M2
	Min:	3329	M9
Fital	Max:	1633.6	C2
	Min:	84.5	M5
Meiozoobentos:			
Sedim.	Max:	3490.2	L2
	Min:	26.9	M6
Piatră	Max:	12924.96	M6
	Min:	39.17	M5
Fital	Max:	1105	M4
	Min:	22.5	M2

Fig. 14 – Benthic fauna distribution by substrate type in July 2009





Valori D_{avg} (indv•m^{-2} sau 100g biomasă umedă)		Stație
Macrozoobentos		
Sedimentar	Maxim	L3
	Minim	M3
Fital	Maxim	M5
	Minim	C2
Meiozoobentos		
Sedimentar	Maxim	M4
	Minim	M1
Fital	Maxim	M3
	Minim	M2

Fig. 15 – Distribuţia faunei bentale pe tipuri de substrat în 2010

6.5.4. Assessment of psammophilous benthic communities form the shallow area of Ovidiu Island

Studying sedimentary habitats 14 supraspecific and specific taxa were identified (Table 4), of which over 50% are reported in both seasons. In the summer season were encountered 12 groups, with a density of 166,095 ind•m^{-2}, and in the autumnal season only 8 groups, with a total density of only 46,351 ind•m^{-2} (Fig. 16).

The ration between macro and meioforms remained the same from one season to another, i.e. 32% for macrobenthic populations and 68% for meiozoobenthic ones.

Table 4: Taxonomic list of the zoobenthic community from sedimentary habitats from the shallow area of Ovidiu Island, 2009

No. crt.	Taxa	Species	summer	autumn
1.	**Spongia**	varia		+
2.	**Coelenterata -Hydrozoa**	*Hydra* sp. (Pallas)	+	
3.	**Nematoda**	varia	+	+
4.	**Nematomorpha**	*Gordius* sp.	+	
5.	**Annelida-Oligochaeta**	varia	+	+
6.	**Turbellaria**	varia		+
7.	**Acarina**	varia	+	+
8.	**Copepoda**	varia	+	+
9.	**Ostracoda**	varia	+	
10.	**Amphipoda**	*Gamelina aestuarica* (Cărăuşu)	+	
11.	**Mysidacea**	*Limnomysis benedeni* (Czerniavsky)	+	
12.	**Isopoda**	*Asellus aquaticus* (Linné)	+	+
13.	**Insecta-Plecoptera**	varia	+	
14	**Insecta-Diptera/Nematocera**	varia	+	+

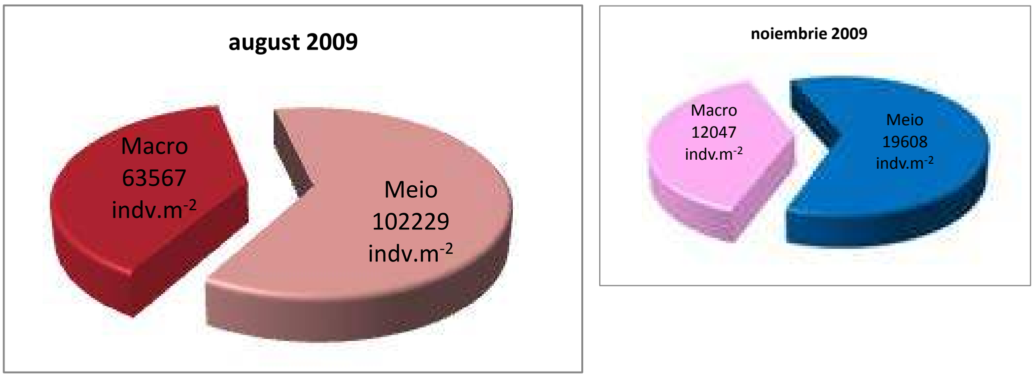


Fig. 16 – Comparative analysis of macro and meiofauna in summer and autumn seasons for the sedimentary habitats of Ovidiu Island

*) Macro – macrozoobenthos; Meio - meiozoobenthos

6.5.5. Analysis of phytophilous benthic communities from Ovidiu Island belt area

Ten supraspecific and specific taxa were identified, of which 50% are reported in both seasons. In the warm period we identified representatives of nine taxonomic groups, and only five in the colder season. The ratio between meiobenthic and macrobenthic forms differed in the two sampling periods, but in both seasons meioforms were predominant (Fig. 17), which experienced an increased percent in the cold season.

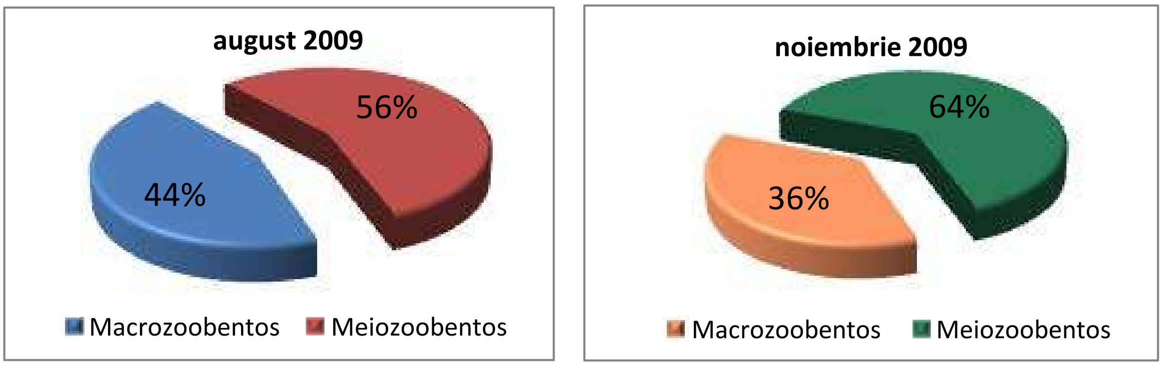


Fig. 17 - Comparative analysis of macro and meiofauna in summer and autumn seasons for the phytal substrate of Ovidiu Island belt area

Representatives of ecological groups Hydrozoa, Turbellaria, Amphipoda and Isopoda were encountered only in samples collected during summer (Tab. 5).

Table 5: Taxonomic list of phytophilous zoobenthic community from Ovidiu Island belt area, 2009

No. crt.	Taxa	Species	summer	autumn
1.	**Coelenterata -Hydrozoa**	*Hydra* sp. (Pallas)	+	
2.		*Cordylophora caspia* (Pallas)	+	
3.	**Nematoda**	varia	+	+
4.	**Annelida-Oligochaeta**	varia	+	+
5.	**Turbellaria**	varia	+	
6.	**Acarina**	varia	+	+
7.	**Copepoda-Harpacticoida**	varia	+	+
8.	**Amphipoda**	*Gmelina aestuarica* (Cărăuşu)	+	
9.	**Isopoda**	*Asellus aquaticus* (Linné)	+	
10.	**Crustacea**	varia	+	
11.	**Insecta-Diptera/Nematocera**	*Chironomus plumosus* *Sphaeromias* sp. varia	+	+

6.6. Integrate assessment of water quality and biological data

Analysis of total densities of organisms based on data organised by month and year revealed a significant reduction in macrobenthic component density with time (Fig. 18).

Meiobenthic component had a low abundance in November 2009, a month with low temperatures, so that the situation can be explained by the development of organisms resistance forms. Along with increasing water temperatures the meiobenthic component recovered and the decline moment of macrobenthos corresponded with increasing abundance of meiofauna, successfully exploiting rich source of detritus in the sediment.

Analysis of biological data and water saturation dissolved oxygen levels show an inverse correlation between total abundance of macrobenthic organisms and dissolved oxygen (Fig. 19). Thus, the water-sediment interface areas with extremely low oxygen saturation were characterized by an impoverished macrobenthic community, with stations where no organisms were found. Most often we encountered chironomids (Diptera, Nematocera) and nematodes, which being well adapted to conditions of hypoxia, are able to resist. Although initially it may seem counterintuitive that high oxygen levels are associated with declining macrobenthic populations, still oxygen supersaturated water is typically associated with hipereutroficaton (Mallin et al., 2006). Thus, even if an acceptable saturation of dissolved oxygen during the day, stress for macrobenthic organisms is higher as during the night the phytoplankton consumed the oxygen from the water, released during the day, in the respiration processes, in particular in sediment, where bacterial respiration processes are very intense (Mallin et al., 2006).

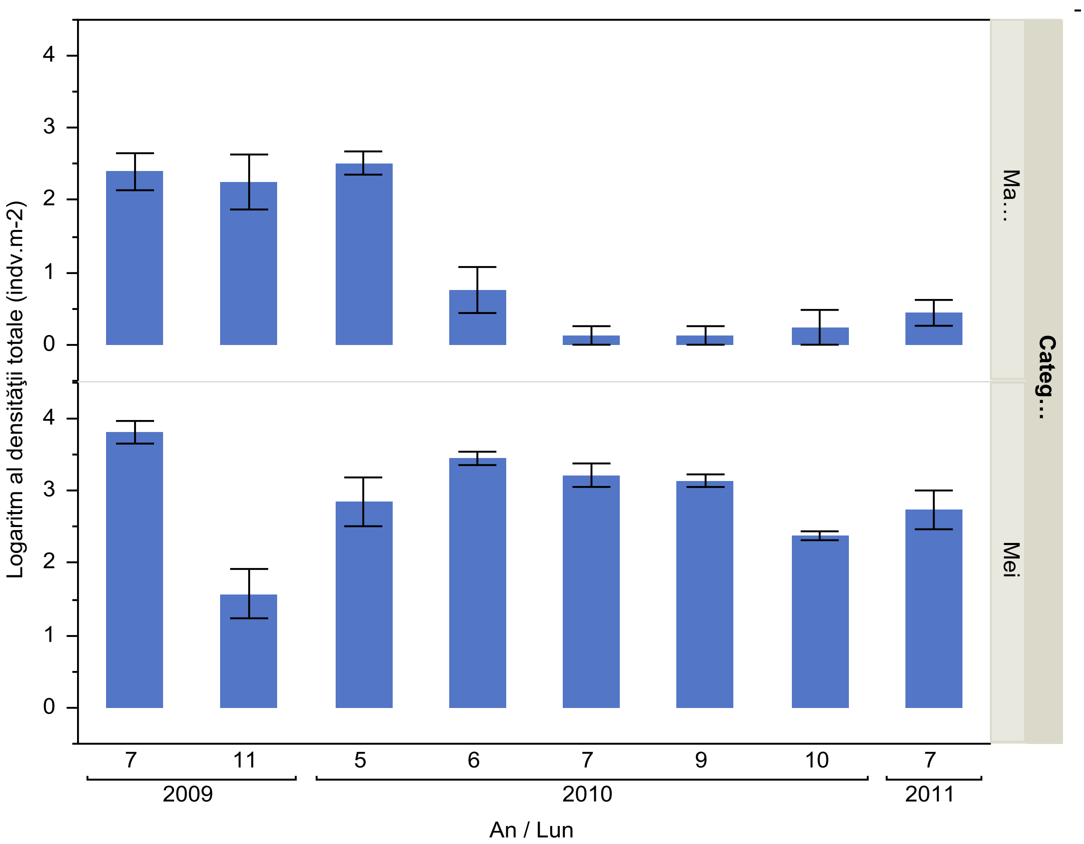


Fig. 18 – Time variation of macro- and meiobenthic communities for the entire study period

A dominance of meiobenthic communities illustrates an increased concentration of particulate organic matter and poor benthic communities status, caused by anthropogenic pressure. The same groups dominates the macrobenthos and meiobenthos by average density, which suggests that benthic systems in Siutghiol Lake undergo increased anthropogenic impact. The presence of species such as *Hydra*, *Hypaniola*, *Manayunkia* and *Limnomysis* proves that habitats they inhabit are affected to a lesser extent by human impact, thanks to less pronounced development of human settlements on the shore line.

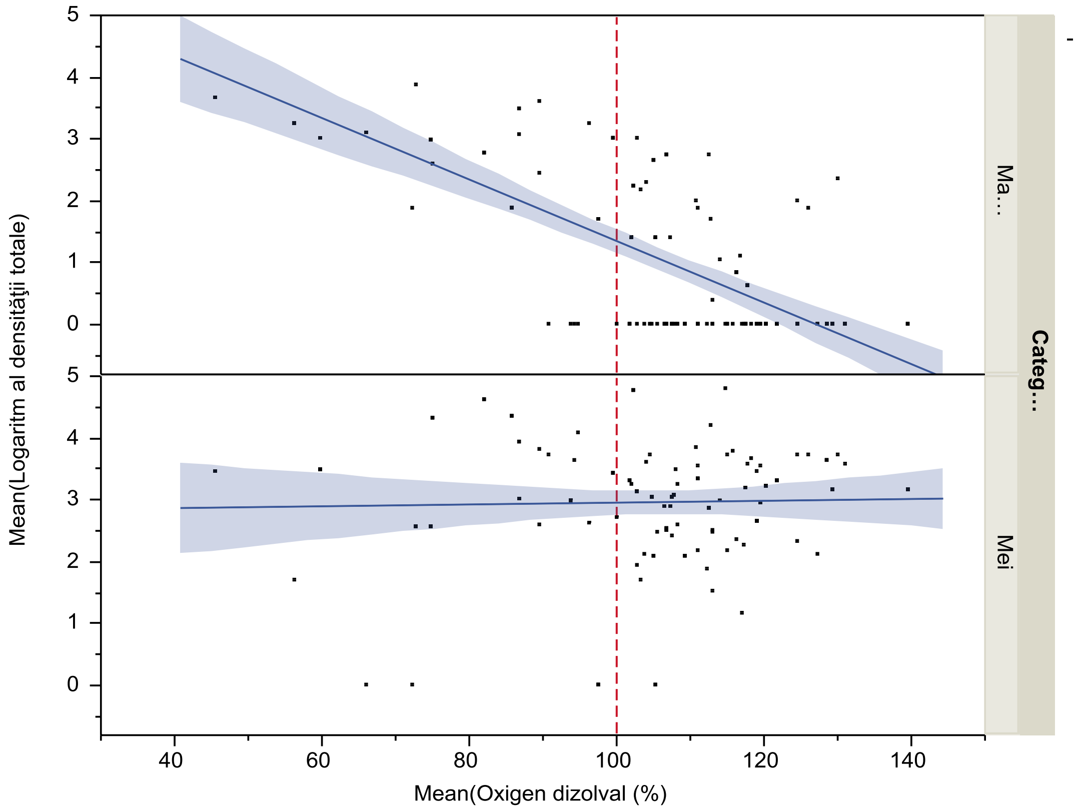


Fig. 19 – Relationship between total macro- and meiobenthic density and dissolved oxygen saturation in water

We did not notice a correlation with dissolved oxygen saturation for the entire study and compared to macrobenthic populations were encountered fewer cases of absence of organisms (Fig. 19). This can be explained on the one hand by the fact that the organisms are tolerant to pollution, respectively low levels of dissolved oxygen in the water, and on the other hand by the reduced need for oxygen per body surface, as compared to macrobenthic organisms. However, when we tested ANOVA separately, only for the summer months data over the study period, for in lake area, we noticed that oxygen saturation influences meiobenthic community at a rate of 26%, the probability value being 0.001 (Table 6).

Table 6: Statistical parameters for the analysis of oxygen saturation influence on meiobenthic communities during warm periods over the entire study

Model	R	R^2	Adjusted R^2	Estimation standard error
Meiobenthic component	0.510	**0.260**	0.241	13.6308107
Macrobenthic component	0.487	**0.237**	0.231	13.7707667

CONCLUSIONS AND RECOMMENDATIONS

Siutghiol Lake is one of the largest lacustrine formations of the Romanian seaside, which is currently subject to extensive anthropogenic pressures, conducted in its drainage basin. Exploitation and intensive human intervention represent the general trend of the last decade. Except the northern shore of the lake, bordered by Galeşu channel, all other sides were quickly modified towards the development of residential areas in an irrational manner (buildings located at less than five meters from the shore, absence of sewerage systems, and improper arrangement of building sites close to the shore). All this led to the degradation of this urban ecosystem while each year, observing phenomena deepening of algal bloom, with dramatic effects on ecosystem structure and functioning.

In order to get to know the current ecological status of the Siutghiol urban system, we looked at the evolution of physico-chemical parameters of water and sediment quality, toxicity level and how these influence the composition and abundance of benthic fauna. We also looked at a number of issues relating to ecotone space to capture the relationship with the perilacustrine area.

Research results show the following:

1. Morphometric characteristics of the lake have changed. Thus, the maximum depth decreased from 17.5 m in 1971 to 14.9 in 1999 m, so that in 2012 to get to only 7.82 m. Thereupon, , lake volume decreased from 91 to approximately 70 million m^3. These changes influence the sediment dynamics, which further determines the physico-chemical changes, sediment volume, ecosystem functioning.
2. Shoreline development index is a quick method of assessing the positive or negative development of the shoreline. It revealed functional areas with a total score corresponding to very good and excellent ratings - Galeșu channel area - respectively Mamaia and Scoica Land, with scores corresponding to poor and average ratings. 30% of all stations have achieved poor and average scores, reflecting a deterioration of the shoreline landscape and a lack of concern in this respect, as well as a loss of habitat through improper use and development.
3. Phytotoxicity tests showed low sediment toxicity, due to factors such as chemical forms of metallic elements or nutrient loading of sediments. Presence of large amounts of nutrients from the organic matter in the sediment may mask the impact of inhibitor phytotoxic contaminants in the sediment. Likewise, the interactions between contaminants may have antagonistic or synergistic effects that are difficult to predict. However, the results reflect the effects of stress factors caused by human activities on living organisms.
4. The analysis of sediment phytotoxicity test results and heavy metal concentrations in sediments shows that some of these have toxic effects. Thus, only the effect of Pb and Hg is significantly correlated with the percentage of root growth inhibition.
5. Ostracodtoxkit chronic toxicity test shows the presence in water of elements that determined ostracods growth inhibition for most samples. Positive correlations between the percentage of growth inhibition and metallic elements content were observed for Cd, Pb and Al.
6. Physico-chemical parameters - Water temperature recorded normal seasonal variations. Differences were observed from one area of the lake to another, as well as by depth. Significant differences in temperature were observed at depths of approximately 3 m, with 2°C amplitude. The highest temperatures were measured in July 2010.
7. The general trend for the water pH is the maintenance of the alkaline register. Comparing the annual average in the literature for the period 1997-2000 with that for 2009-2011 of 8.19 (8.96), we observed an increase in the pH values of 0.77 points. High pH values were determined in the summer of 2011 (9.3).
8. Water specific conductance varied widely, highlighting its natural variability. Differences by date and by depth were not as high as to involve a risk to biota. Generally, slightly higher values, of 2450 $\mu S \cdot cm^{-3}$, were measured at stations on the eastern edge, due to sea salt intrusion through sandy isthmus.
9. Water turbidity varied greatly both by station and by depth. High values of turbidity at the surface were due to high concentrations of algae bloom that characterize the blooms phenomenon. At greater depths high turbidity is explained by resuspension processes, favoured by the movement of water and the decrease of lake's mean depth.
10. Dissolved oxygen varied greatly over the entire study period. Hypoxia was determined at higher depth, being characteristic to warm periods of the year.
11. Fluorescence measurements surprised the accentuated algal bloom phenomenon. This poses a threat to water quality resulting from uncontrolled discharges of wastewater and storm water in the catchment.
12. Lake nutrient levels influence the algal blooms. Nitrates are those that limit the growth of phytoplankton in the offshore, as well as onshore. Phosphates in the offshore area are taken by

green algae only to a point, and when the ratio of nutrients in the system changes by increasing the concentration of phosphates, blue-green algae (cyanobacteria) are the ones that outcompete phytoplankton because they can fix atmospheric nitrogen. In the shore area this process can be enhanced by more pronounced release of phosphorus from sediments, which is exploited by cyanobacteria, capable to act before algae causing blooms or before those adapted to low light conditions. As the relative abundance of phosphates to nitrates increases, so does the relative abundance of blue-green algae to phytoplankton.

13. Heavy metal levels in water were normal. Normal variations were observed by date. Exceedings of the maximum allowed values were recorded for Cd in the southern area (stations L2 and L3), and for Hg in western and north-western areas (stations L5 and L10).
14. Heavy metal build-up was visible for sediment. Exceedings of the maximum allowed concentrations stipulated by law were observed for cadmium, lead, copper, zinc, mercury and manganese. Chromium and aluminium were within normal limits. Overall, stations L4, L5, L7 and L8 stand out. Area from the shore corresponding to stations L4 and L5 is Ovidiu locality, namely its southern extremity, which has known an astounding development. Here, in the past five years a new neighbourhood was built, but it did not beneficiate from adequate amenities: incomplete sewage system, some houses have septic tanks. During significant rainfall episodes (e.g. the latest - July 2010, May 2012) Caragea Dermen and Canara valleys are simply washed away by rain, then the storm water goes into the lake. As regards stations L7 and L8, the original destination of the north-eastern shore of the lake was changed, green space being replaced within 4-5 years by relatively large buildings (residential or tourism).
15. Overall, the benthic community was represented by 22 taxa: 10 were identified at supraspecific level (nematodes, bryozoans, mites, ostracods and copepod crustaceans) and 16 at species level.
16. Zoobenthic community was numerically dominated by meiobentos, in a proportion of 64%, with a density of 751,203.5 ind•m^{-2}. Net domination of meiobenthic forms in some areas of the lake seems to be associated with the presence of human impact.
17. Zoobenthos communities were presented according to the substrate in which they were found. Several types of habitats have been identified: sedimentary (sandy, muddy, mixture of sand and mud, clayey), hard/rocky and phytall. Most of the basin is covered by sedimentary substrate dominated by muddy fraction. Sandy sediments, arranged by the eastern shore, cover a narrower area. Phytall and rocky subtrates are limited to the belt area, with a discontinuous disposition, but al so around Ovidiu Island.
18. Extensive sedimentary biotopes are populated by fauna with affinity for this type of substrate: sandy habitat was dominated by nematodes, chironomids, oligochaets and copepods, but freshwater polychaet species were also encountered; muddy substrate was dominated by nematodes, ostracods and Diptera Nematocera larvae, but recorded densities were much lower than those in sandy habitats; habitat consisting of a mixture of sand and silt was clearly dominated by nematodes, followed by Diptera larvae, copepods and oligochaets, with much lower densities .
19. Benthic fauna in the belt area was clearly dominated by larval and pupa stages of Nematosera dipterans.
20. Analysis of the qualitative structure of zoobenthos communities shows that an important factor for their structuring is the food resource abundance and in a lesser extent the substrate. This explains the fact that the larvae of chironomids appear constantly in all types of habitat. In sedimentary habitats oligochaetes and nematodes occur quite frequently, and copepods in the sandy ones also copepods.
21. From a quantitative perspective, lake bentofauna was dominated by the same groups of organisms that constantly appear in identified habitats.
22. Water-sediment interface areas with extremely low oxygen saturation were characterized by macrobenthic impoverished community, with stations where no representative of this group was found. Meiobenthic component recorded fewer cases of total absence of organisms, because they have the ability to successfully exploit rich detritus resource and cope with hypoxia.
23. Meiobenthic component was dominant in the shallow habitats of Ovidiu Island.

24. Fourteen taxonomic groups were identified in the sedimentary habitats. Dominant were the larval and pupal stages of Diptera Nematocera, nematodes and oligochaetes, followed by mites and harpacticoids, which were determined consistently in all samples of the 8 sampling sites. There were also representatives of taxonomic groups that were only met in one or two samples/sites: hydrozoar species (Ponto-Caspian relict) *Cordilophora caspia* (I2), mysid species (I4), amphipods (I5, I6), isopods (I2, I6) and turbellariates (I2, I3). The diversity character of the benthic fauna is confirmed, because we encountered the majority of types of organisms described in a lake coast.
25. Ten taxonomic groups were identified in the phytall substrate. Nematocera dipterans, nematodes, mites and oligochaetes were dominant. Benthic invertebrate community associated to phytall substrate was characterized by a much lower biodiversity compared to similar habitats in less affected lakes, and with more numerous populations.

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* *

Recommendations

The mismanagement of the ecosystem itself, as well as for all the activities undertaken inside the lake's drainage basin reduces the natural capacity of recovery, the loss of essential functions, damage and even loss of resources and services. Under these circumstances, it is required a basin-wide approach for Siutghiol ecological system, to make the connection between social and economic development with protection of natural ecosystems.

The main issues identified for Siutghiol ecological system refers to the phenomena of eutrophication, sedimentation and contamination, problems that do not exclude each other. In this regard, we propose the following:

- Recovery of belt vegetation – because stations with excellent scores for the shoreline development index were characterised by the presence of shoreline vegetation, dominated by reed, we propose belt vegetation recovery. It has a role of natural filter, reducing the erosion processes that lead to sedimentation amplification, but the eutrophication as well, by taking significant amounts of nutrients and pollutants. Belt vegetation is also an essential habitat for fauna;
- Precise identification and monitoring of point sources (illegal discharge pipes) and diffuse pollution sources;
- Hypoxia accompanies water blooms, so that water oxygenation is necessary;
- Control of blooms, reducing periods of cyanobacteria bloom, accomplishing conditions for microalgae development (important trophic resource for limnetic systems);
- Removal of putrescible sediment from the lake;
- Construction of sewer systems where these lack, in order to stop organic pollution (e.g. new neighbourhood of Ovidiu locality);
- Use of water, sediment and biota quality parameters monitoring in order to improve and conserve resources;
- Protection of underground resources feeding the lake, by controlling underground intake;
- Achieving a good waste management to stop it getting into lake.

Other measures aiming necessary aspects for a sustainable management of Siutghiol Lake system:

- Achievement of the land use map for Siutghiol Lake catchment area, establishing of area that are suitable for development, those to be preserved and those to be restored;
- Forbidding or authorizing those economic activities that may have a significant impact on the area and imposing public consultation process (by applying questionnaires) through impact assessment procedure;
- design and implementation of questionnaires outlining people (in the neighbouring areas or tourists) perception and values;
- Riparian (and not only) public awareness programs on the effects of activities undertaken by them which could be detrimental to the lake, where they procures resources and which increases the value of occupied perilacustrine space;

- Monitoring the evolution of the lake after recovery measures, verification of steps taken by establishing and using performance indicators, and appropriate readaptation of measures based on the lessons learned;
- Implementation of the "user pays" and "polluter pays" principles and of effective economic instruments (e.g. taxes on excessive application of fertilizers substances) in the management of ecosystem services. Internalizations of costs for services related to water resource assessment and financial and economic resources evaluation;
- Respecting the balance between competitive requests of resources: domestic, municipal, agriculture, industrial and environmental;
- Effective use of water volumes taken from the lake or from adjacent underground aquifer, in order to reduce consume;
- Respecting people's right of water access – areas with limited access to lake were encountered around the lake, mostly due to construction sites – e.g. Palazu and Ovidiu areas;
- Rehabilitation of the shore, where the concrete surface is not well maintained. Organizing shaded places, where people could come to admire the like, for bird watching, fishing, etc.

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