THE IMPACT OF HYDROGEOMORPHOLOGICAL CHANGES ON PLANKTON EVOLUTION IN MUSURA LAGOON (THE DANUBE DELTA)

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Abstract. Musura Lagoon belongs to the avandelta, part of the Danube Delta, Biosphere Reserve. The aim of this study was to compare the historical data recorded in Musura with those more recent (2005-2007), in order to reveal the impact of hydrogeomorphological changes on structural and functional diversity of the plankton communities. In the last 30 years, the ecological researches in lagoon highlighted the relative fast dynamics at spatial - temporal scale. The resultant of the ecosystem evolution consists in a gradual transition from marine gulf stage to a half-closed lagoon, with many freshwater traits. The impact of factors as: the variation of water level (the decreasing of depth), the progressive decreasing of initial value of salinity (1942-12‰; 2005-0.18‰) and the geomorphological changes, were favourable to the proliferation of typical freshwater vegetation. The structural diversity of phytoplankton assemblages recorded increased values in the period 1987-1989, but a low taxonomic constancy. It was reported the presence of 7 halophilic species. During 2005-2007, the species richness reached a total number of 200 species, belonging to 7 taxonomical groups, mainly ubiquitous and typical for freshwater ecosystems. The average of zooplankton species richness during 1954-1974 was 32 species and, currently, has increased up to 76 species in the last decades, according with the changes of the water chemistry. Only one marine zooplanktonic species, the meroplanktonic larvae of *Balanus improvisus* Darwin 1854 (Cirripedia), was revealed between 2005 and 2007. The functional diversity of bacterioplankton was defined by the dominance of the members of the organic matter with sulphur decomposers group. This fact is a peculiarity of the marine environment. Nowadays, the physiological groups of bacterioplankton became characteristic to the freshwater ecosystem. From 2000 until present, Musura Lagoon has underwent an increased trend of isolation from the marine water of the Black Sea.

Keywords: hydrogeomorphological changes, Musura lagoon, plankton diversity, the Danube Delta.

Rezumat. Impactul modificărilor hidrogeomorfologice asupra evoluţiei planctonului din Golful Musura (Delta Dunării). Laguna Musura este localizată în avandeltă, parte a Deltei Dunării, Rezervaţie a Biosferei. Scopul acestui studiu a fost realizarea unei comparaţii a unor date istorice cu altele mai recente (2005-2007), în vederea evaluării impactului schimbărilor hidrogeomorfologice asupra diversităţii structurale şi funcţionale a comunităţilor planctonice. În ultimii 30 ani, cercetările efectuate în lagună, au evidenţiat o dinamică relativ rapidă la scara spaţio-temporală. Rezultanta evoluţiei ecosistemului a constat într-o tranziţie graduală de la stadiul de golf maritim la o lagună semi – închisă, cu multiple trăsături de apă dulce. Impactul unor factori ca: variaţia nivelului apei (descreşterea adâncimii), descreşterea progresivă a valorii salinităţii (1942-12‰; 2005-0,18‰), şi modificările geomorfologice au fost favorabile proliferării unei vegetaţii tipice de apă dulce. Diversitatea structurală a fitoplanctonului a înregistrat valori crescute în perioada 1987-1989, dar o constantă scăzută. A fost raportată prezenţa a 7 specii halofile. Între anii 2005-2007, bogaţia specifică a atins un număr de 200 specii, aparţinând la 7 grupe taxonomice, majoritatea ubicviste şi tipice pentru un lac deltaic. Media bogăţiei specifice a zooplanctonului în perioada 1954-1974 a fost de 32 specii şi a crescut la 76 specii în perioada actuală, în strânsă legătură cu schimbarea în chimismul apei. Doar o singură specie marină a fost întâlnită în perioada 2005-2007, şi anume larva meroplanctonică *Balanus improvisus* Darwin 1854 (Cirripedia). Diversitatea funcţională a bacterioplanctonului a fost dominată de grupul descompunătorilor materiei organice cu sulf. Acest aspect este o particularitate a mediului marin. În perioada actuală, bacterioplanctonul este reprezentat de grupe fiziologice caracteristice apelor dulci. Din 2000 până în prezent, Laguna Musura a avut o tendinţă de izolare de apele Mării Negre.

Cuvinte cheie: schimbări hidrogeomorfologice, laguna Musura, diversitate planctonică, Delta Dunării.

INTRODUCTION

Worldwide, the transitional waters are an important topic in ecology studies because of their status as interface between two different environments that gives them distinct features (GONENC & WOLFLIN, 2005). Musura Lagoon represents the interface of transitional waters between the Danube Delta and the northwestern part of the Black Sea. This area belongs to coastal lagoons, covering 13% of the world's coastal zone (GÜREL et al., 2005). The water of Musura channel and bay comes from two sources – the Chilia branch and the lagoon located between the Chilia and Sulina branches and the Black Sea; consequently, the geomorphological evolution of the Romanian – Ukrainian border and of the territorial waters in the immediate proximity of the Danube mouth is highly influenced by this contact (GÂŞTESCU & ŞTIUCĂ, 2006).

From the geomorphologic point of view, the channel and Musura bay are very recent: they formed through alluvial processes occurring near Cardon, between the delta of the Chilia branch (original much smaller and located north of the present location) and Sulina; this process started in the nineteenth century and the Musura bay appeared in the first half of the twentieth century, being then part of Romania, in the nineteenth century (DRIGA, 2004; FLORESCU & MOLDOVEANU, 2008). The same phenomenon that formed the Musura Bay presently transforms it in a swamp with reeds; east of it, there emerges a new bay, located between the mouth of the Old Stambul and the end of dam located along the Sulina branch. A sandy coastal belt formed and there appeared an island, still unnamed (Fig. 1).

During the last 30 years, the ecological researches in this lagoon revealed the relative fast dynamics at spatial - temporal scale. The outcome of the ecosystem evolution consists in a gradual transition from marine gulf stage to a half-enclosed lagoon, with many freshwater traits. The decrease of the water level, the progressive reduction of salinity (1942-12‰; 2005-0.18‰) and the geomorphological changes allowed the proliferation of the typical freshwater vegetation. As a result, both structural and functional diversity of the plankton community (phyto, zoo and bacterioplankton) changed (ZINEVICI et al., 2005; ZINEVICI & PARPALĂ, 2007; IONICĂ et al., 2008).

The aim of this study was to determine, by comparison between historical data and our data, the impact of the hydrogeomorphological changes on the structural and functional diversity evolution of the plankton community from Musura Lagoon.

MATERIAL AND METHODS

Study site and sampling:

Musura Lagoon, (45°10'48.12"N latitude, 29°39'21.34"E longitude), belongs to the avandelta, part of the Danube Delta, Biosphere Reserve (Fig. 1).

The samples were collected between 2005 and 2007, seasonally (May, July and October) from five stations, using a Patalas-Schindler (5 litres) device on water column.

Methods

The phytoplankton conservation was made in 500 ml plastic containers, with 4% formaldehyde solution. In the laboratory, phytoplankton samples were concentrated by sedimentation and filtration, using an Ø 65 mm network (VOLLENWEIDER, 1969; BRITTON & GREESSON, 1987). The identification of the phytoplankton species and abundance (10^3 ind L^{-1}) assessment were made using a Zeiss inverted microscope according to UTERMÖHL (1958). Phytoplankton biomass (mg wet weight L^{-1}) was established by volumetric and gravimetric measurements (OLRIX et al., 1998).

The zooplankton samples were collected by filtering 50 litres of water using a Patalas-Schindler device (5 l) on water column through a 65 µm Ø mesh network, and preserved in 4% formaldehyde solution.

The zooplankton species were identified by following keys: for Ciliata (FOISSNER et al., 1991-1995), Testacea (BARTOŠ, 1954; GROSPIETSCH, 1972), Lamellibranchia (MARSDEN, 1992), Rotifera (VOIGHT, 1956; RUDESCU, 1960), Cladocera (NEGREA, 1983; BROOKS 1959), Copepoda (DAMIAN-GEORGESCU, 1963; 1966; 1970).

The abundance (ind L^{-1}) was assessed by microscopic methods, using a Zeiss inverted microscope type, by direct counting into a Kolkwitz chamber (UTERMÖHL, 1958).

For zooplankton biomass calculations, it was used the wet weight of the organism (µg wet weight L^{-1}) according to: WINBERG (1971) for Ciliata and Testacea, STANCZYKOWSKA (1976) for Lamellibranchia, DUMONT et al. (1975) for Rotifera and ODERMATT (1970) and SEBESTYEN (1958a, b) for biomass estimation of the crustaceans. The biomass was evaluated by volumetric and gravimetric measurements, taking account the organism volume of each identified species.

To identify the structure of the bacterioplankton community and to assess the abundance of the different physiological groups, cultivation on selective media was performed.

Data analysis

Statistical analyses were performed using SPSS 15.0 Windows Evaluation Version, available for download at http://www.spss.com.

For comparison, a data base (old records from 1954, 1961, 1970, 1987-1989) was used. The long-term results belong to the database of the Institute of Biology Bucharest.

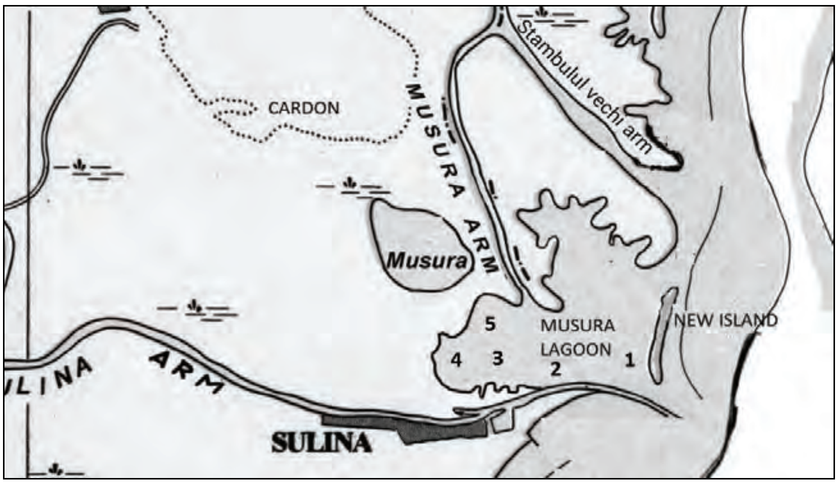

Figure 1. The map of Musura Lagoon (the Danube Delta) with sampling points (adapted after wikimedia.org).

RESULTS AND DISCUSSION

The assessment of physical and chemical parameters confirmed that Musura had specific characteristics of a freshwater ecosystem. It is possible that, certain features of brackish water appeared when the NE winds blew, but the influence of the Black Sea between 2005 and 2007 was insignificant (POSTOLACHE, 2006; COMAN & SANDU, 2009). In the 6th decade, the Musura Bay was strongly influenced by the Black Sea waters (BURGHELE, 1946). Due to process of silt deposition at the mouths of these two branches and sea currents, its connection with the sea got narrower (STANCU-STOIANOVICI, 1992; ZINEVICI et al., 2005).

In the year 1955, research conducted in Musura, described the existence of two distinct biotypes, freshwater and marine with brackish areas (ENĂCEANU, 1955). There was certain salinity, but it decreased halfway between the sea and Cardon, in this area approaching 0. In the marine area, 7 species of zooplankton were reported (BREZEANU & ZINEVICI, 1971). Phytoplankton was very monotonous and poor and the marine species were present (*Ceratium tripos* O. F. Müller 1777; Nitzsch. 1817, *Chaetoceras* sp.). In 1967, the study area was classified as brackish waters (salinity ranged from 0.11 to 7.12 ‰), having an unstable character, due to the fluctuations of marine waters depending on the hydrology and local climate (freshwater input, wind direction, direction of sea currents) (BREZEANU & ZINEVICI, 1971).

Between 1987 and 1989 a high structural diversity was recorded at phytoplankton level. 7 species were halophilic and the others ubiquitous, with a wide range of salinity tolerance (Fig. 2).

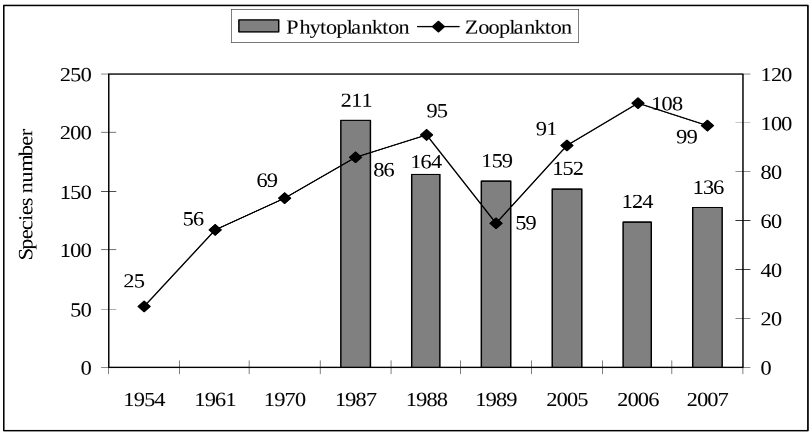

Figure 2. The evolution of species richness of phytoplankton and zooplankton.

In 1988, 8.42% of total number of zooplankton species were halophilic (*Oikopleura dioica* Fol 1872), (*Podon polyphemoides* Leuckart 1859), (*Balanus improvisus* Darwin 1854) and in 1989, the percentage of marine species was 11.32%, including species as (*Tintinnopsis meunieri* Kofoid & Campbell 1929), (*Noctiluca miliaris* Suriray 1816), Polichaeta larvae, (*Synchaeta litoralis* Rousselet 1902).

By comparison, in 2005-2007, the marine species were completely absent, only freshwater or brackish species were identified (*B. improvisus*) larvae (Cirripedia). Regarding the species richness, in Musura Bay, a total of 200 species of phytoplankton was recorded (Fig. 2). In 1988, Musura Bay showed a specific diversity of 134 species (STANCU-STOIANOVICI, 1992).

It can be appreciated that there was a high biodiversity of phytoplankton, sensitive close or even higher than in the Danube Delta lacustrine ecosystem. In 2001, Lake Roşu diversity registered 144 species, and in Puiu, in 1987, 82 species were reported (TUDORANCEA & TUDORANCEA, 2006).

In 2005-2007, in terms of species frequency, 33.5 % of phytoplankton species were constant, 25% accessory and 41% accidental (Fig. 3a).

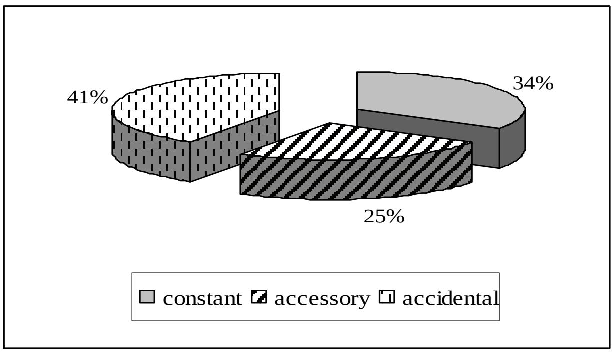

Figure 3a. The frequency of phytoplankton species in 2005-2007.

The frequency analysis of groups revealed the persistency of diatoms (38.04%), followed closely by euglenoids and chlorophytes (35%, respectively 33.33%). The Cyanobacteria had only 19.35 % contribution to the phytoplankton assemblage. The significantly higher number of constant species and high specific diversity indicated a considerable stability degree of the ecosystem found in a state of transition from brackish to lacustrine deltaic ecosystem, with 0 salinity. The typical freshwater macrophytes appeared and the general aspects of the ecosystem tend to be a deltaic lake (RADU et al., 2008). Also, the phytoplankton communities included ubiquitous species, characterized by a wide range of tolerance to salinity. In the period 1954-2005, 220 zooplankton species were recorded (Fig. 2).

Zooplankton species richness showed an ascending trend, due, probably, to the reverse relationship between the number of species and the decrease of salinity.

The evolution of specific diversity was estimated using diversity indices. Notice the minimum phytoplankton diversity in 2006, which showed the decline of species; the Shannon index decreased, indicating that it takes into account the numerical abundance (Figs. 2; 3b). The minimum zooplankton diversity was achieved in 1989, which is emphasized by the two evaluated indices (number of species and Shannon index).

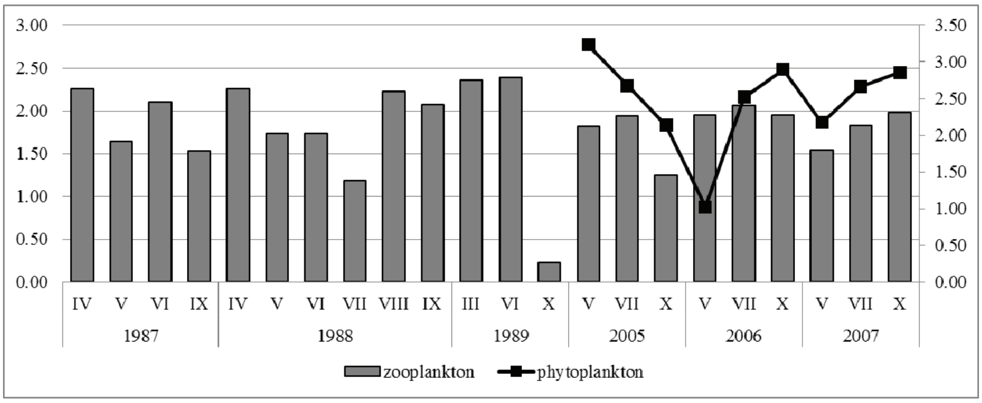

Figure 3b. The variation of Shannon-Wiener Diversity Index of phyto- and zooplankton species.

The gravimetric abundance of phytoplankton has been changed during 2005-2007 compared to the 1987-1989 period, especially regarding the number and percentage of the taxonomical groups. Thus, Bacillariophyceae decreased from 58% to 40%, Chlorophyceae from 34% to 16%, and a new group (Xanthophyceae) was observed in the last period (Fig. 4).

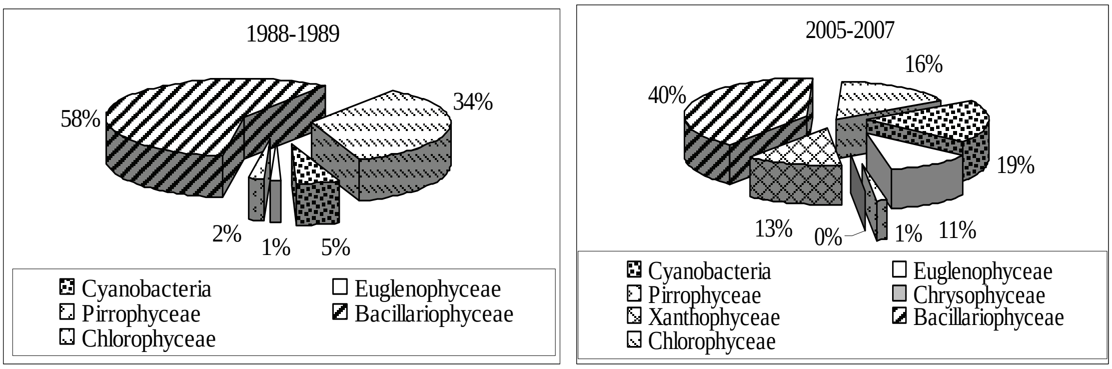

Figure 4. The gravimetric abundance of phytoplankton between 1987 and 1989 and between 2005 and 2007.

Zooplankton community showed a shift in number and dominance; the dominance of Cladocera was replaced by Rotatoria in 2005-2007 (Fig. 5).

Taxonomically, there is a structural simplification due to the gradual disappearance of marine species. These observations are proved by the values of Shannon-Wiener index (Table 1).

Table 1. Diversity indices of planktonic taxonomical and physiological groups.

Diversity indices	**Phytoplankton**		**Zooplankton**		**Bacterioplankton**	
	1988-1989	2005-2007	1987-1989	2005-2007	1987-1988	2006-2007
Shannon-Wiener Diversity	0.960	1.529	1.203	0.927	1.687	1.614
Evenness	0.597	0.853	0.868	0.844	0.941	0.901

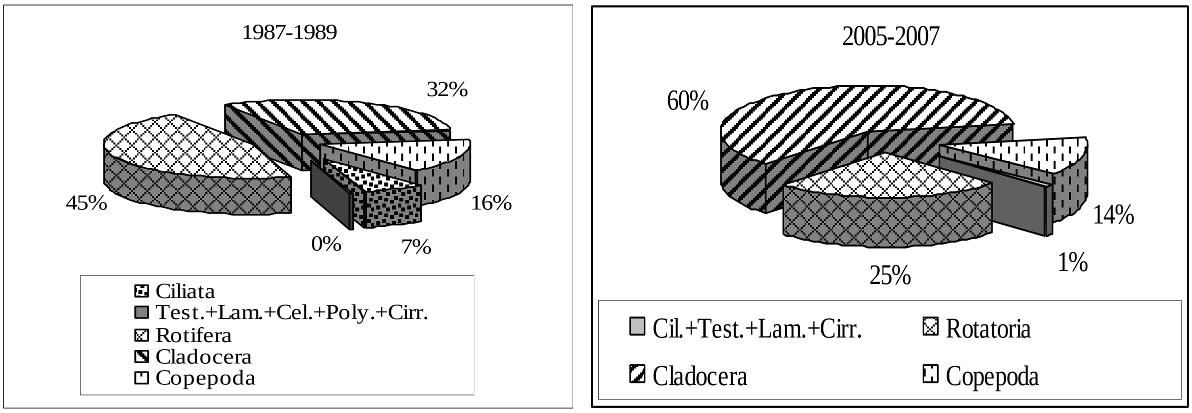

Figure 5. The gravimetric abundance of zooplankton between 1987 and 1989 and between 2005 and 2007 (Cil. = Ciliata; Test. = Testacea; Lam. = Lamellibranchia; Cel. = Coelenterata; Poly. = Polychaeta; Cirr. = Cirripedia).

The functional diversity of bacterioplankton is less or more sensitive to hydrogeomorphological changes (Fig. 6, Table 1). It is notable the presence of the sulphur decomposers of organic matter, which is a peculiarity of the marine environment.

During 1974-1975, the bacterioplankton community had not a characteristic seasonal dynamics, because the environmental factors from the impact area between the Danube water and marine water were instable (NICOLESCU & IONICĂ, 1995).

The response of plankton communities is reflected at structural and functional diversity level (the species richness of phytoplankton and zooplankton and diversity of physiological groups of bacterioplankton).

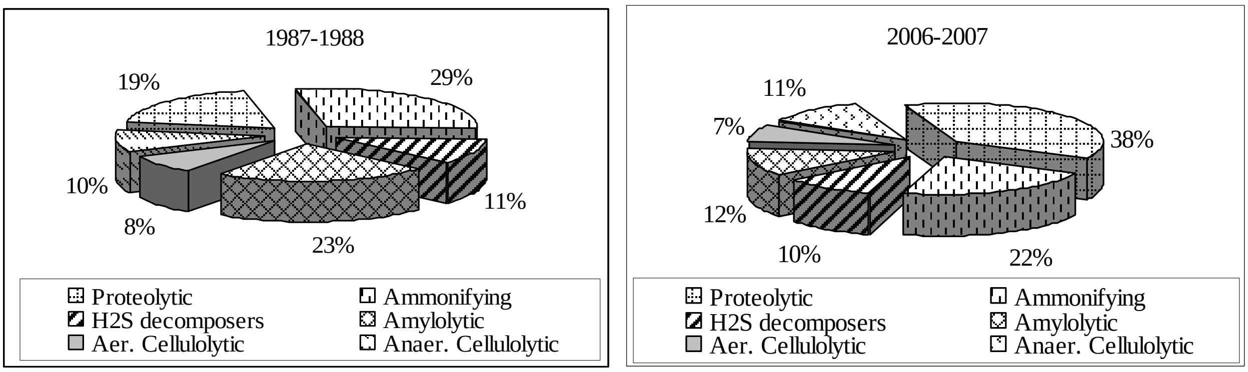

Figure 6. The numerical abundance of bacterioplankton between 1987 and 1989 and between 2005 and 2007.

The seasonal, annual and spatial distribution of biotic parameters among the sampling station was assessed by analysis of variance (ANOVA). The influence of spatial distribution of the sampling sites was assessed using the same statistical test, but no significant relationship was found with the parameters of interest (F<Fcrit., p>0.05). This result supports our hypothesis that Musura Bay has changed to a semi-enclosed freshwater lagoon, with homogenous structural and functional characteristics.

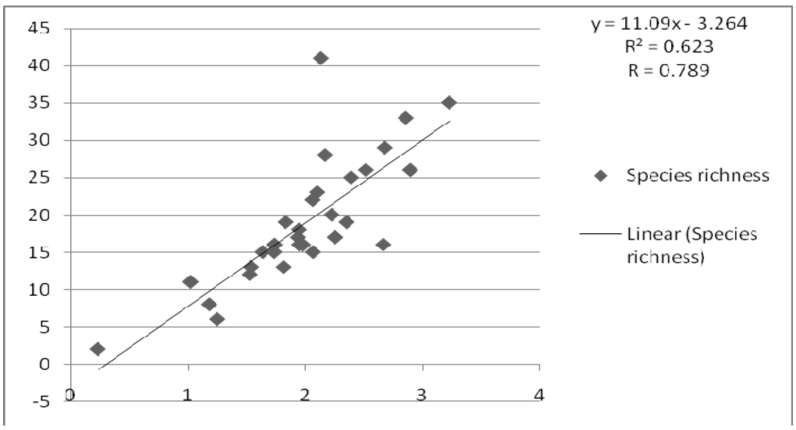

Figure 7. Pearson correlation between Shannon diversity and species richness of plankton communities.

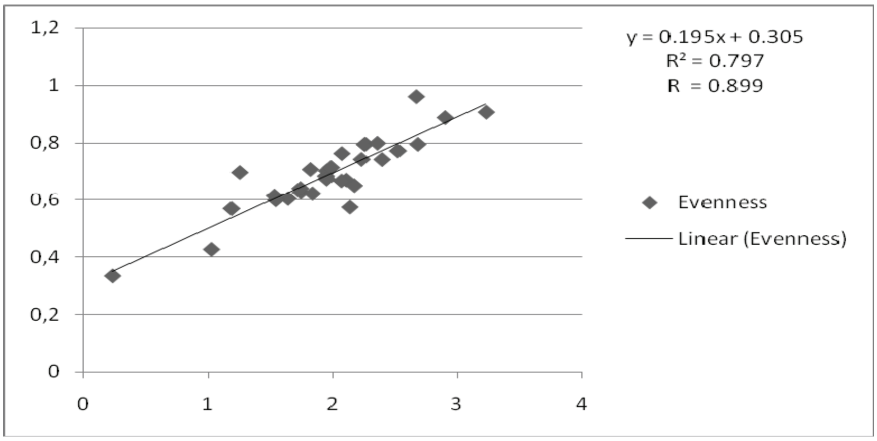

Figure 8. Pearson correlation between Shannon diversity and evenness of plankton communities.

In order to establish the relationships between diversity and other indices that characterize the populations of plankton (phytoplankton and zooplankton) simple correlations were used. By analysing Pearson correlation coefficient and the coefficient of determination R^2, it was concluded that diversity is determined mainly by evenness (81%) (R = 0.8996, R^2 = 0.8094), the number of species (R = 0.7896, R^2 = 0.6235) having a lower influence (62%) (Figs. 7, 8).

The control factors that modulate the evolution of this ecosystem were essentially the natural, climatic, hydrological, geomorphological ones, which led to the relatively rapid transition from a marine bay to a semi-enclosed lagoon with freshwater features, comparable to those of a typical deltaic lacustrine system.

CONCLUSIONS

From 2000 until present, Musura Lagoon has underwent an accelerated trend of isolation from the marine water of the Black Sea, due to an active process of remodelling of its borders between the real Delta, marine waters and the allochthonous flow of the Danube River.

Species richness and specific diversity, taxonomical composition, gravimetric abundance of taxonomical groups, marine/freshwater species ratio are the most sensitive diversity parameters of the plankton communities which responded to the hydrogeomorphological changes.

These changes have led to the formation of an ecosystem similar to that of a freshwater lake from the maritime delta. Currently, the interaction between the Danube, the Danube Delta and the Black Sea waters enhanced the alluvial and clogging processes that led to to the formation of a new island, still nameless.

Our study has a practical meaning and should be a valuable tool for the management and conservation politics of the transitional waters.

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