THE ACTUAL STATE OF THE BENTHIC FAUNA IN THE INNER DANUBE DELTA, ROMANIA

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Abstract. The benthic invertebrates are one of the most important components of the aquatic ecosystems and are considered in the research and monitoring programs dealing with dynamics of the ecological state of the Lower Danube Wetland System. During 2009-2010 period, field observations were made on the benthic fauna of the shallow lakes and channels in the Inner Danube Delta, located in Romania, between r.km 170 (Brăila) and r.km 365 (Călăraşi) on the Danube River. The sampling program, with seasonal periodicity, included 23 stations along a longitudinal gradient according to the water loading in the complex of ecosystems. The present work discusses the composition and structure of the benthic fauna and compares the results with those obtained in the previous period (1993-2009) in the same area and in the costal Danube Delta (1975-2000) with the aim of identifying the main trends of its dynamics. Aquatic worms and insects, represented by Oligochaeta and Chironomidae respectively, continued to represent the constant and dominant components of the bottom fauna in terms of both number and biomass abundances.

Keywords: Inner Danube Delta, natural aquatic systems, benthic fauna, structure, dynamics.

Rezumat. Starea actuală a faunei bentonice din delta interioară a Dunării, România. Fauna nevertebratelor bentonice este una dintre cele mai importante componente ale ecosistemelor acvatice, fapt pentru care este luată în considerare în programele de cercetare şi de monitorizare privind dinamica ecosistemelor identificabile la scara Sistemul Dunării Inferioare. În perioada 2009-2010, s-au făcut cercetări asupra faunei bentonice din lacurile şi canalele puţin adânci, situate în zonele inundabile (insulare şi riverane) ale deltei interioare a Dunării, distribuită în lungul sectorului fluvial cuprins între kilometrul 170 (Brăila) şi 365 (Călăraşi). Frecvenţa programului de prelevare a probelor bentonice a fost sezonieră şi a inclus 23 de staţii distribuite de-a lungul unui gradient hidrologic longitudinal, în funcţie de încărcarea apei din Dunăre în complexul de ecosisteme. Lucrarea de faţă discută compoziţia şi structura faunei bentonice şi compară rezultatele actuale cu cele obţinute în perioada anterioară din aceeaşi zonă (1993-2009) şi cu seturile de date din Delta Dunării (1975-2000), cu scopul de a identifica principalele tendinţe în dinamica acesteia. Viermii şi insectele acvatice, reprezentate de Oligochaeta şi respectiv Chironomidae, continuă să reprezinte componente constante şi dominante în structura faunei bentonice atât din punct de vedere al abundenţelor numerice cât şi în biomasă.

Cuvinte cheie: delta interioară a Dunării, ecosisteme acvatice naturale, fauna bentonică, structura, dinamica.

INTRODUCTION

The benthic invertebrate fauna of inland waters are one of the most abundant, diverse, and a key component found on/in submerged substrates. Their well-adapted biological and behaviour mechanisms to the contrasting challenges of living, makes them excellent competitors for their integral role in the ecological processes, nutrient cycling and energy flow. The structural and functional peculiarities of the benthic species make them excellent indicators considered in research and monitoring programs dealing with biomonitoring, dynamics of the ecological state, restoration ecology and so on (COVICH *et al*.,1999; CHALONER *et al*., 2009; STRAYER, 2009).

Knowledge of the benthic fauna inhabiting various aquatic ecosystems of the Lower Danube Wetland System (LDWS) is further compounded by a lack of information. This fact has been proven by different authors that especially studied the aquatic systems of the costal Danube Delta and the river stretch (BOTNARIUC *et al*., 1985, 1987; POPESCU-MARINESCU, 1992; IGNAT *et al*., 1997; RÎŞNOVEANU *et al*., 1997; RÎŞNOVEANU & VĂDINEANU, 2003; RÎŞNOVEANU, 2006; VĂDINEANU *et. al*., 2000, 2001, 2003).

In comparison with the extensive and intensive research programs performed in the costal Danube Delta, in the eight decade of the former century, as well as with results of the studies implemented in the former floodplain lakes, in the 1960's, the current state of the benthic fauna of the lakes remained under natural flooding regime in the inland delta is relatively less known. In addition, as RUSSEV (1998) and TUDORANCEA (2006) emphasized "except for general faunistic and taxonomic studies, the attention has been focused on three major groups: Gastropoda, Oligochaeta, Chironomidae" the others receiving far less concern.

The benthic fauna of the shallow lakes from the insular and riparian zones of the Inner Danube Delta (IDD - one of the six components of LDWS) (VĂDINEANU, 2009) become of particular interest especially after 1990's, since the Small Island of Brăila (SIB - a remnant wetland in the former inner delta), became a pilot region for sustainable development and an International Long Term Ecological Research (ILTER) site. The respective data has been published in few papers and mainly in the project reports (i.e. "Functional Role of Biodiversity in the Lower Danube System" - RFB, 1999, "Ecological Network of the Lower Danube System" - REDI, 2001).

Taking into consideration the state of knowledge and the role of the benthic fauna for the bioeconomy of the aquatic systems from IDD, the research brings contributions to the knowledge of composition and structure of the benthic communities inhabiting the aquatic ecosystems remained in this area.

MATERIAL AND METHODS

The present study is a subprogram of a complex, multi - and trans - disciplinary research program developed by the Research Center of System Ecology, Eco-Diversity and Sustainability (RCSEES/CCESES) of the University of Bucharest. The subprogram was designed at a temporal and spatial scale of the aquatic complex of ecosystems in the IDD.

Study area. In the LWDS (Fig. 1. A), the IDD (Fig. 1. B) extends over 2,413 (km^2) between Southern Romanian Plain and Dobrogea Plateau along the river Danube stretch of 215 kilometers long, from Brăila (r.km 170) to Călăraşi (r.km 365) (CRISTOFOR *et al*., 2003; VĂDINEANU *et al*., 2003). The region constitutes an environmental mosaic that is characterized by a network of heterogeneous and dynamic complexes of aquatic ecosystems, in different stages of succession, according to the degree of connectivity and location (***REDI, 2001). From the entire surface of IDD, only the SIB (Fig. 1. C) remained under natural flooding regime and is now a Long Term Ecological Research platform, a natural reserve and also a Ramsar Site (Figs. 1 A-E).

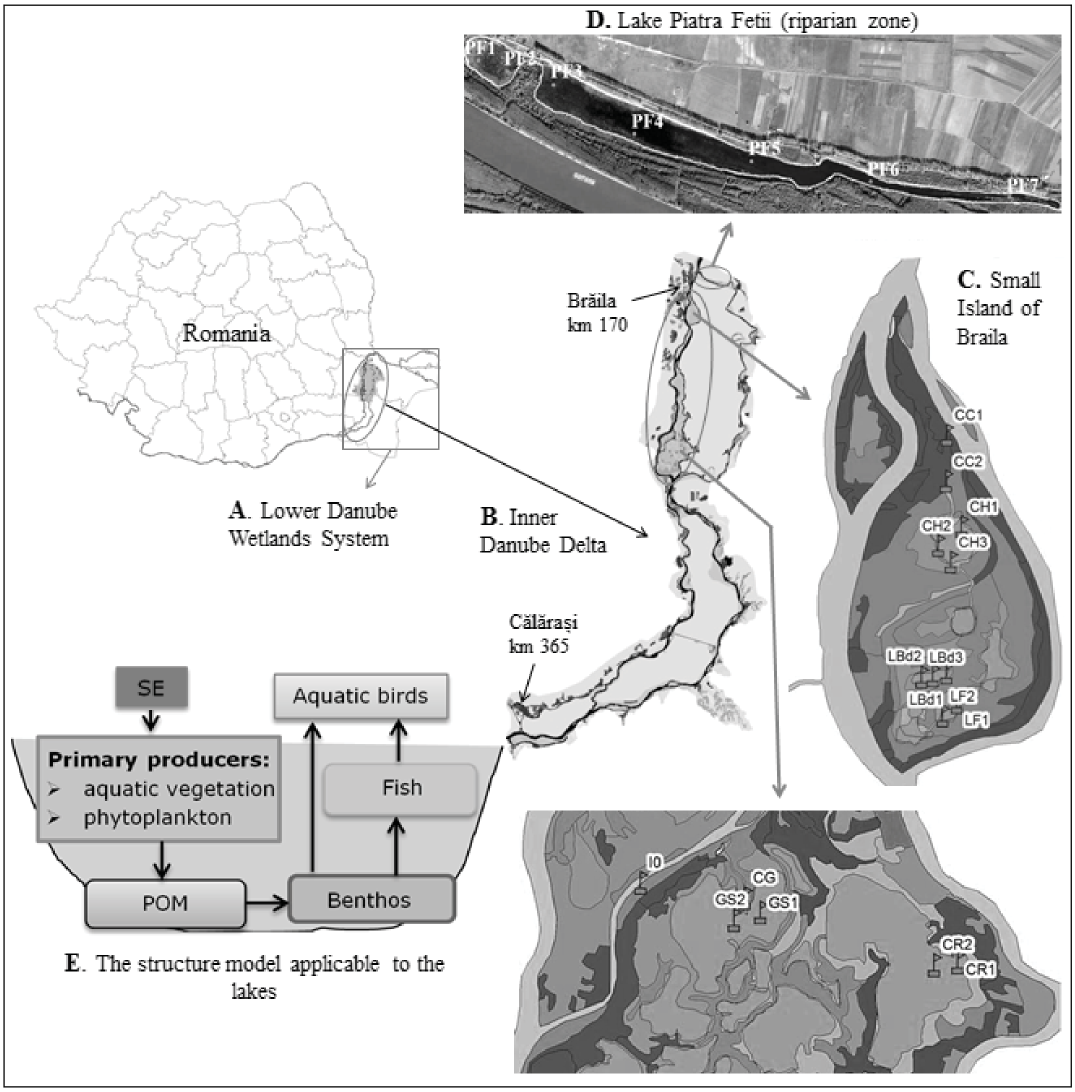

Figure 1. A – E. Location of the sampling sites in the IDD, Romania (I0 – the Danube riverbank; CC1, CC2 – Chiriloaia Channel; CG – Gâsca Channel; CH1, CH2, CH3 – Lake Chiriloaia; LBd1, LBd2, LBd3 – Lake Bordeiele, LF1, LF2 – Lake Fundu Mare; GS1, GS2 – Lake Gâsca; CR1, CR2 – Lake Curcubeu; PF1 – PF7 – Lake Piatra Fetii). E: The structural model showing the pathway crossed by the zoobenthos in the SIB. The arrows show the unidirectional matter and energy flows into the system. SE – solar energy, POM – particulate organic matter (redrawn from ADAMESCU, 2004; VĂDINEANU, 2009). / Figura 1. A – D: Localizarea siturilor de cercetare la nivelul deltei interioare a Dunării, România (I0 – mal Dunăre; CC1, CC2 – canal Chiriloaia; CG – canal Gâsca; CH1, CH2, CH3 – lac Chiriloaia; LBd1, LBd2, LBd3 – lac Bordeiele, LF1, LF2 – lac Fundu Mare; GS1, GS2 – lac Gâsca; CR1, CR2 – lac Curcubeu; PF1 – PF7 – lac Piatra Fetii). E: Model structural care arată locul faunei bentonice la nivelul insulei mici a Brăilei. Săgeţile indică fluxul de masă şi energie în sistem (adaptată după ADAMESCU, 2004; VĂDINEANU, 2009).

Figure (1. E) shows a general pattern of mass and energy flows applicable to the shallow lakes (less than 3 meter deep) characteristic and representative for the SIB. The primary producers are represented mainly by aquatic vegetation. The plants represent an important habitat for epiphytic invertebrates and also a significant source of detritus (POM) for zoobenthos. Nevertheless, heavily vegetated areas, as is the case of the shallow lakes in SIB, can get oxygen limited and become a stressor for benthic fauna, limiting invertebrate diversity and the provision of ecosystem services they are supporting (***RFB, 1999; ***REDI, 2001; VĂDINEANU *et al*., 1992, 2000; WHILES & GRUBAUGH, 2009).

Sampling methods. The benthic invertebrate communities were sampled, and the main physical and chemical parameters of the water bodies were measured in six representative shallow lakes, two channels and the Danube riverbank in the IDD (Figs. 1. C, D) Totally, 23 stations were established along a longitudinal gradient according with the water loading into aquatic complex from the river. During 2009-2010, ten samples were sampled from spring to autumn, each of them consisting in 6 to 21 sampling unites per system, in accordance to the expected heterogeneity of the natural capital. Benthic samples have been taken randomly including 3 replicates per sampling point (station), using a core with a surface area of 24.6 cm^2. The bottom samples were washed through a 230 µm mesh sieve and preserved in formalin 4%, in plastic bags. In the laboratory, the taxonomical identification has been performed to the main taxa groups using a stereomicroscope Olympus SZX7 and the appropriate identification guidebooks (PENNAK, 1953; GODEANU, 2002).

In order to analyse and integrate the data of the benthic fauna, a number of structural parameters have been investigated. The invertebrate abundance (ind./m^2 and g. dry mass /m^2), numerical (A1%) and biomass (A2%) relative abundance and the frequencies of occurrence (F%) were calculated. The dominant taxa were established following the usual conventional criteria (A1 ≥ 15% and A2 ≥ 10%), (VĂDINEANU, 1998).

Taxa richness, Shannon-Wiener and equitability were examined for their potential value in describing the state of the benthic communities.

RESULTS AND DISCUSSIONS

During 2009 – 2010, a total of 15 invertebrate taxa were identified in the structure of benthic fauna of the studied systems (Fig. 2). In each aquatic system at each sampling moment, the number of invertebrate groups varied between 2 and 7. The maxim number was recorded in spring (April and May 2010, L. Piatra Fetii located in the riparian zone) and autumn (November 2010, C. Chiriloaia). High taxa richness (5-6 taxa per sample moment and aquatic ecosystem) was recorded in June 2009 (Danube riverbank, channel and lake Chiriloaia and L. Curcubeu), June 2010 (C. Chiriloaia and L. Bordeiele) and November 2010 (lakes Chiriloaia, Fundu Mare and Piatra Fetii). Frequently, the diversity of the benthic communities remained at a low level, only two invertebrate groups being present.

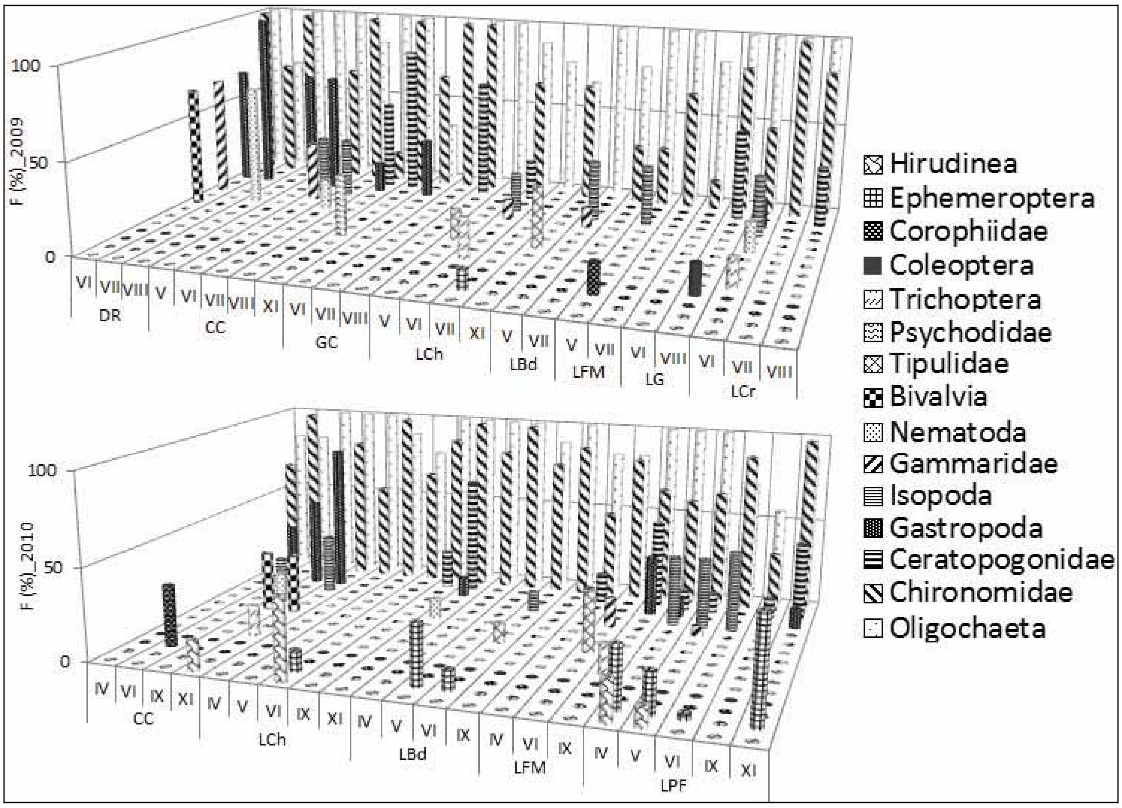

Figure 2. Spatial-temporal distribution and occurrence frequencies of taxa groups identified in the benthic fauna from the IDD during 2009-2010. DR – the Danube riverbank; CC – Chiriloaia Channel; GC – Gâsca Channel; LCh – L. Chiriloaia; LBd – L. Bordeiele; LFM – L. Fundu Mare; LG – L. Gâsca; LCr – L. Curcubeu; LPF – L. Piatra Fetii. / Figura 2. Distribuţia spaţio-temporală şi frecvenţele de apariţie în probe ale grupelor de organisme identificate în cadrul comunităţilor bentonice din delta interioară a Dunării în perioada 2009-2010. DR – mal Dunăre; CC – canal Chiriloaia; GC – canal Gâsca; LCh – lac Chiriloaia; LBd – lac Bordeiele;LFM – lac Fundu Mare; LG – lac Gâsca; LCr – lac Curcubeu; LPF – lac Piatra Fetii.

Particularly this was the case in five out of seven systems sampled in July 2009 (Gâsca channel and lakes Chiriloaia, Bordeiele, Fundul Mare and Curcubeu). Dynamics of the taxa richness at the level of benthic communities may be related with the hydrological regime and the morphology of the aquatic systems that favour development of aquatic weeds and high level of hypoxia or anoxia at the sediment water interface during the summer time. Similar results were reported also by BOTNARIUC *et al*. (1987) and RÎŞNOVEANU *et al*. (1997) in aquatic systems of the Danube Delta.

The spatiotemporal distribution of the identified taxa revealed that 8 benthic groups had occurrence frequencies of over 50% being constant components of benthic communities. They are represented by Nematoda, Oligochaeta, Gastropoda, Bivalvia, Gammaridae, Ephemeroptera, Chironomidae and Ceratopogonidae. Among that, Oligochaeta and Chironomidae were the most frequent components of the bottom fauna across the entire study area. Oligochaeta recorded values between 56 and 100%, except in June and July 2009 in the Gâsca Channel (F - 33%). Chironomidae recorded occurrence frequencies over 50%. Nevertheless, in some samples they were absent or did not fulfil the constancy criteria (F≥ 50%): April and July 2009 in channel and lake Chiriloaia, L. Bordeiele and L. Gâsca and September 2010 in Chiriloaia Channel and L. Piatra Fetii. This could be related to their life cycles.

Gastropoda and Bivalvia were the groups that meet the constancy criteria in the Danube riverbank and C. Chiriloaia. Nematoda and Gammaridae, were generally absent in lakes and accessory or even accidental in lotic ecosystems (channels Chiriloaia and Gâsca, and the Danube riverbank). Ceratopogonidae met the constancy criteria in C. Gâsca, August 2009, C. Chiriloaia, November 2009 and L. Chiriloaia, November 2010. In the same time, they were accessory or even accidentally present in both lakes and channels. Ephemeroptera reaches occurrence frequency of 56% in L. Piatra Fetii in November 2010. All other taxonomic groups were sporadic (Fig. 2).

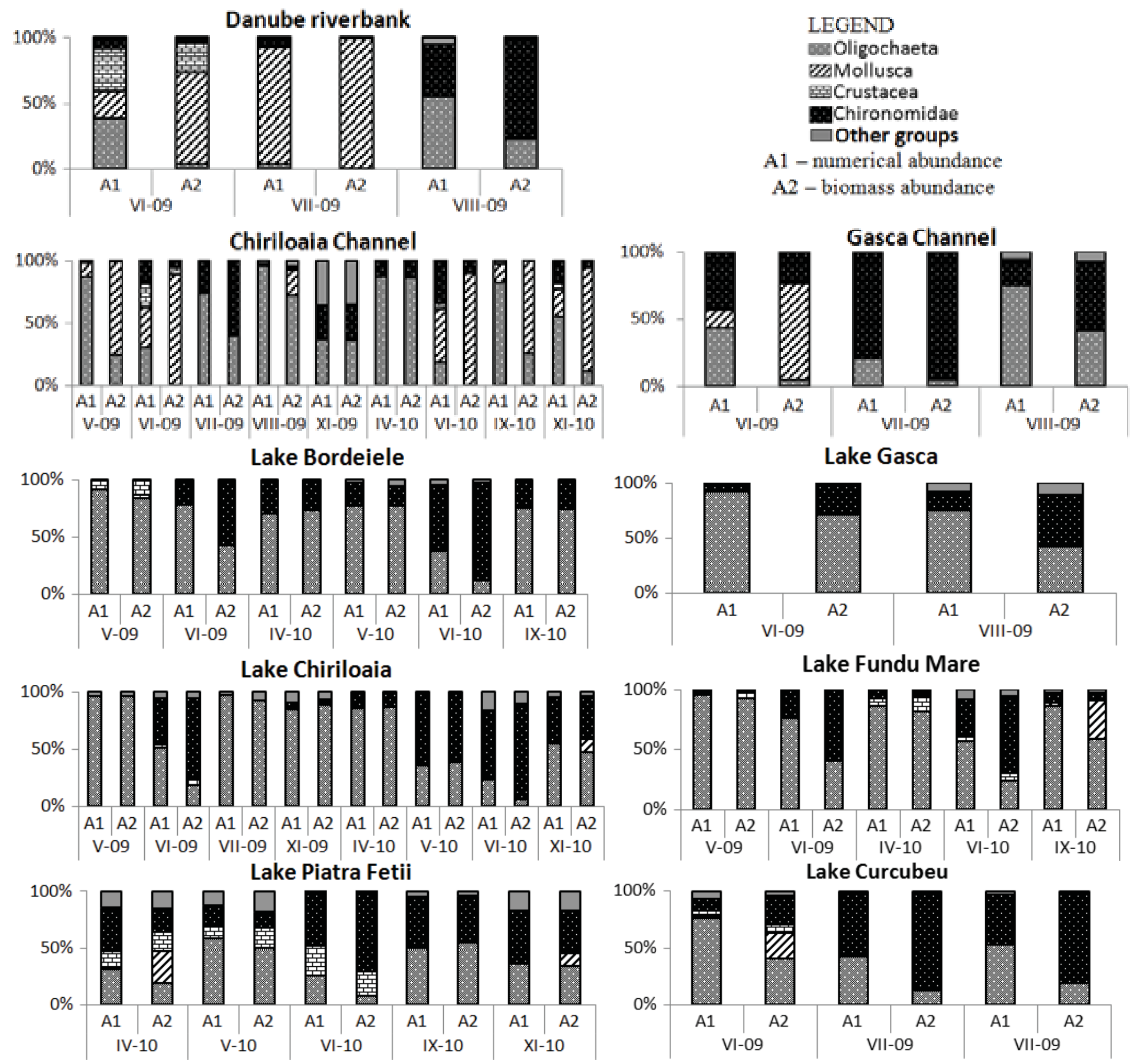

Figure 3. Dynamics of the relative abundances (%) (number: A1 and biomass: A2) of the main taxa group from the IDD during 2009-2010. / Figura 3. Abundenţa relativă (%) (numerică: A1 şi în biomasă: A2) înregistrată de principalele grupe bentonice la nivelul deltei interioare a Dunării, pe parcursul anilor 2009-2010.

The relative abundances (%) of the different zoobenthic groups recorded fluctuations across space and time. Two to four different invertebrates groups (Oligochaeta, Mollusca, Crustacea and Chironomidae) fulfill the dominance criteria in every freshwater system (Fig. 3). Oligochaeta met the criteria of dominance in all aquatic ecosystems with a few exceptions as biomass in summer (June and July 2009 in the Danube riverbank and C. Gâsca, June 2009 and 2010 in C. Chiriloaia and June 2010 in lakes Chiriloaia and Piatra Fetii). Also, Oligochaeta recorded an exception in the numerical abundances in the Danube riverbank (July 2009). Chironomidae reached their highest values of the relative abundances in the channel Gâsca and lakes Curcubeu and Piatra Fetii. As well, Chironomidae fulfill the dominance criteria with some exception in the Danube riverbank, channel and lake Chiriloaia and lakes Bordeiele, Fundu Mare and Curcubeu.

When were presented in the structure of communities, with a good frequency of occurrence, Mollusca – represented by Gastropoda and Bivalvia – fulfill the dominance criteria just in biomass. Nevertheless, few exceptions were noticed in lotic systems (June and July 2009 in the Danube riverbank and June 2009 and 2010 in Channel Chiriloaia) where they recorded numerical relative abundances of over 21%. With a sporadic frequency of occurrence (less than 38%), Crustacea (represented by Isopoda, Gammaridae and Corophiidae) met the criteria of dominance in the Danube riverbank and channel Chiriloaia (June 2009), lakes Fundu Mare (April 2010) and Piatra Fetii (April, May and July 2010).

In lakes (e.g. Gâsca, Chiriloaia, Bordeiele), Oligochaeta and Chironomidae recorded the highest relative abundances. Together they represent over 83% of the total main taxa groups as both number and biomass. Generally, the lotic ecosystems are characterized by a higher diversity of the benthic fauna (higher number of taxonomic groups that fulfill the criteria of dominance, better equitability) as compared to lakes. Lake Piatra Fetii, located in the riparian zone, has a higher benthic diversity as compared to the lentic systems from inland of SIB (Fig. 4). During 2009-2010, Shannon diversity index varies between 0.5185 in L. Gâsca and 1.1759 in L. Piatra Fetii and the values of equitability are between 0.4718 in L. Gâsca and 0.7593 in C. Gâsca (Fig. 4) indicating a low diversity of the studied communities.

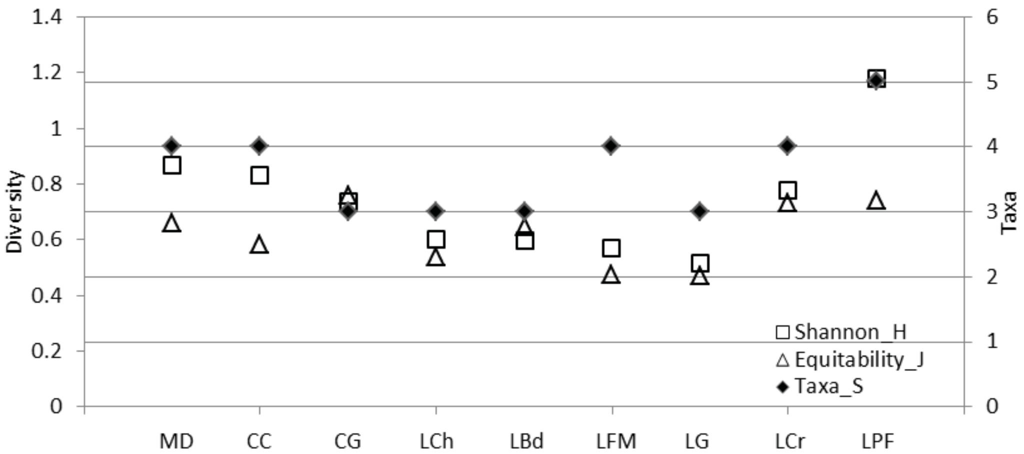

Figure 4. Taxa richness, Shannon diversity and equitability of the benthic taxonomic groups in the IDD during 2009-2010. /
Figura 4. Bogăţia taxonilor, diversitatea şi echitabilitatea grupelor bentonice la nivelul deltei interioare a Dunării, în perioada 2009-2010.

The main changes in the composition of benthic invertebrates and fluctuations in the density of the dominant taxonomic groups are represented in figures 3 and 5. The highest numerical density values were recorded for Oligochaeta, and they represent the predominant taxa from the numerical point of view. A similar situation was noticed in the structure of benthic fauna of the shallow lakes in the Danube Delta between 1984 and 1986, when the maximum abundance of Oligochaeta was about six times higher than the abundance of Chironomidae (BOTNARIUC *et al*., 1987; VĂDINEANU *et al*., 2000). In SIB, the numerical densities of Oligochaeta ranged between 407 and 20.461 ind./m^{-2} and the biomass densities between 0.05 and 2.7 g. dry mass/m^{-2} in the Danube riverbank (July 2009) and channel Chiriloaia (August 2009), respectively (Fig. 5). In August 2009 in the lotic ecosystems, the numerical densities of Oligochaeta were over 5000 ind./m^2 whereas the biomass values remained at low values. Considering these data and the peculiarities of the life cycle of oligochaetes reported in the area (RÎŞNOVEANU & VĂDINEANU, 2002) this fact could be explained by hatches of new individuals in those communities.

The numerical densities of Chironomidae were between 68 ind./m^{-2} (L. Gâsca, June 2009) and 14.634 ind./m^{-2} (the Danube riverbank, August 2009) and the biomass densities was within 0.02 – 9.06 g. dry mass/m^{-2}. Mollusca and Crustacea reached the lowest numerical densities values with an exception in the Danube riverbank (June and July 2009). The molluscs biomass densities were between 0.3 g. dry mass/m^{-2} (L. Piatra Fetii, November 2010) and 50.7 g. dry mass/m^{-2} (the Danube riverbank, July 2009) and those of crustaceans between 0.02 g. dry mass/m^{-2} (L. Chiriloaia, June 2009) and 8.5 g. dry mass/m^{-2} (the Danube riverbank, June 2009) (Fig. 5).

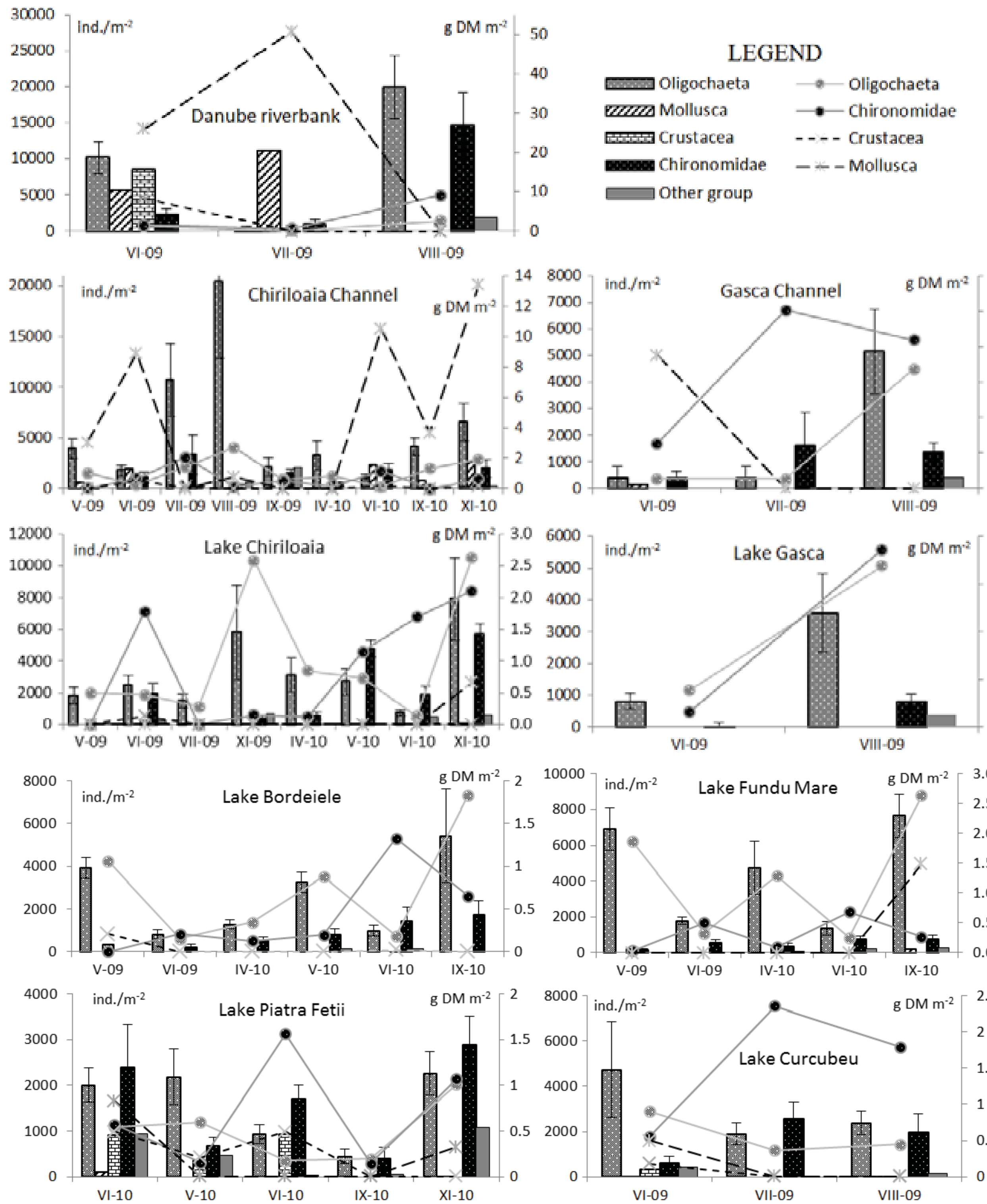

Figure 5. Dynamics of the abundance (number with Standard Error) of the main taxa groups (histogram) and biomass dynamics (lines) of Oligochaeta, Chironomidae Mollusca and Crustacea in the IDD, during 2009-2010. / Figura 5. Densitatea numerică (cu eroare standard) la grupe bentonice (histograme) şi densitatea în biomasă (linii) a grupelor de Oligochaeta, Chironomidae, Mollusca şi Crustacea din delta interioară a Dunării, în perioada 2009-2010.

A similar structure of benthic fauna, dominated by Oligochaeta and Chironomidae was also registered in the same area (***RFB, 1998; ***REDI, 2001) and the costal Danube Delta (RÎŞNOVEANU *et al.*, 1997). The authors relieve that the simplification of the benthic fauna structure is a consequence of eutrophication.

CONCLUSIONS

During 2009-2010, Oligochaeta and Chironomidae were both constant and dominant groups in the bottom fauna of all studied systems and Mollusca fulfilled the criteria of dominance just as biomass and only in the lotic systems.

The abundances of Oligochaeta and Chironomidae were significantly higher than those of other taxa groups. These groups reached up to 63% in L. Piatra Fetii and up to 95% in L. Bordeiele from the overall biomass of the community.

The maximum biomass abundance of Mollusca, about 19 times higher than the Oligochaeta and seven times higher than the Chironomidae, was recorded in the Danube riverbank (July, 2009). The lotic ecosystems (Danube riverbank and channel Chiriloaia) showed the largest range of benthic invertebrates densities (407 – 19919 ind./m^{-2}, 0.1 – 50.7 g. dry mass/m^{-2} and 68 – 20461 ind./m^{-2}, 0.1 – 13.4 g. dry mass/m^{-2} respectively).

In these conditions, the Oligochaeta and Chironomidae, with their well-adapted biological and behaviour mechanisms, and the Mollusca in some ecosystems remained the key components of the benthic fauna, representative for achieving its role within the integrating ecosystems.

The results sustain the conclusion that the composition and structure of the benthic fauna in the network of aquatic systems in the IDD is in an advanced degree of simplification.

More researches are required in order to identify the main driving forces structuring the benthic communities and to estimate their value in the resources and services flows through the studied aquatic ecosystems.

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