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Biological Characteristics and Zooplankton-Phytoplankton Interactions of the Marshes on the Belene Island (the Danube River, Bulgaria)

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Abstract: The zooplankton species composition and strucrure as well as the relationship between zooplankton and phytoplankton were studied in comparison to water chemistry and high aquatic vegetation in three marshes on the Belene Island (Bulgarian sector of the Danube River) in June 1997, June 1998 and April 2000. The high plant aquatic vegetation was presented by 48 species belonging to 17 families and 39 genera, of which the helophytes were the dominant ecological group. A total of 131 zooplankton species were found, 72 of them Rotatoria, 36 Cladocera and 18 Copepoda. The subadult stages of Copepoda contributed to the bigger part of zooplankton biomass. Significant linear regression was observed between both zooplankton biomass and zooplankton: phytoplankton biomass ratio on one hand and the average weight of phytoplankton organisms on the other.

Key words: marshes, zooplankton, phytoplankton, chemistry, macrophytes

Introduction

The wetlands associated with a river are peculiar kind of water basins with alternating periods of drought and inundation (depending on the river level) corresponding with fast and unpredictable changes in the physical, chemical and biological conditions in the water body. They are with low depth and changeable area overgrown with emerged and submerged aquatic plants. Some of the wetlands along the Danube River are partly investigated mainly with regard to one or another component of their biota.

The zooplankton was studied by Naidenow who reported 41 species of Cladocera and 19 species of Copepoda species, most of them found mainly in the river (Naidenow, 1965, 1968, 1991). Among them there are species found only in basins adjoined to the river as *Polyphemus pediculus, E. transylvanicus, E. intermedius, Arctodiaptomus kerkyrensis*. One new species from Belene Island - *Latonopsis hospitus* has been described (Naidenow, 1969).

Despite of the many years' research of some authors of the Slovakian sector (Ertl *et al.,* 1961) and some Romanian islands (Negrea, 1962, 1983; Plesa, 1963), they have not reported many of the zooplankters ascertained for the Bulgarian islands.

The previous investigations of high vegetation in the marshes (Petkoff, 1911; Stojanov, 1948, Kochev, Jordanov, 1981) did not represent completely their species composition and cenological characteristics.

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The studies concerning the phytoplankton in different water basins associated with the Danube River are reported by Beshkova, Botev (in press).

There are no works on the mentioned water bodies covering simultaneously several components of the ecosystem or concerning the interactions between different levels of the trophic chain. By some objective reasons the marshes situated on the Belene Island have remained till now almost completely unstudied. Only the structure of phytoplankton was already reported (Beshkova, Botev, in press).

The goal of the present work is to compare the water chemistry, the high aquatic vegetation, the structure of zooplankton and the character of zooplankton – phytoplankton interactions in the marshes situated on the Belene Island (the Danube River).

Study Site

The Belene Island (Fig. 1) is the biggest in the Bulgarian and the Romanian sector of the Danube with regard to the area (451.5 ha). It is 15.5 km long and 7.2 km in wide, with longitude 25°10´E and latitude 43°40´N. Like the majority of the Danubian islands it is overgrown with *Salix* L., *Populus* L. and other trees. Big areas are covered with different kinds of shrubs (*Amorpha* L., *Rubus* L., *Clematis* L.).

The Belene swamps are three – Martvo blato, Pischene and Dyulova bara. They contain water only during moderate and high level of the river. Their hydrology is partially regulated by a water-gate.

Their water areas vary significantly depending on the river level. The Martvo blato – 122.6 ha, Pischene – 182.0 ha, and Dyuleva bara – 80.6 ha are accepted for average values.

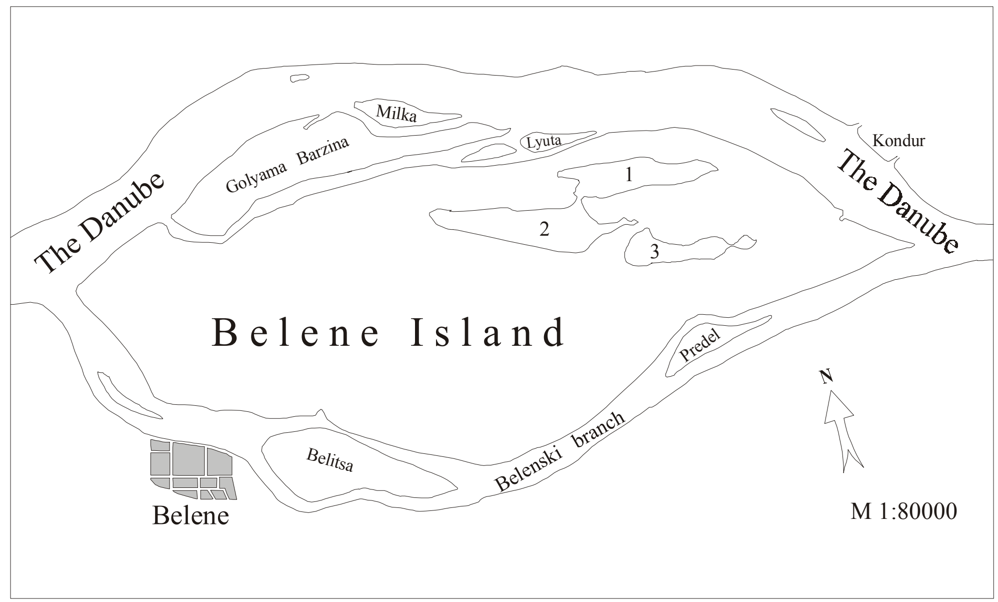

Fig. 1. Scheme of location of the three studied marshes: Martvo blato (1); Pischene (2); Dyulova bara (3).

Material and Methods

The investigations were carried out in June 1997, July 1998 and April 2000.The samples for water chemistry, phytoplankton and zooplankton analyses were taken simultaneously from the water surface.

Qualitative zooplankton samples were taken by scooping up and quantitative ones by filtering of 50 l water through a hand net with 47μm mesh size. Counting of the zooplankton species was performed in samples of 2-10 cm^3.

Phytoplankton sampling and treatment are described by Beshkova, Botev (in press).

The field measurement, filtering and fixation of the samples, as well as the methods of laboratory chemical analysis are already described by Botev (1998).

The ratio between zooplankton and phytoplankton biomasses (B_{zoo}:B_{phyto}) was estimated for a relative measure of transfer efficiency between zoo- and phytoplankton. The average zooplankton and phytoplankton weights (AIW_{zoo} and AIW_{phyto}) were calculated by dividing the biomass with the numbers. The non-parametric Spearman's correlation test was used to examine the relationships between the divers zooplankton and phytoplankton variables.

The principles and methodology of the investigation of high aquatic vegetation were based on Katanskaya (1956), Braun-Blanquet (1964) and Hejny (1960).

Results and Discussion

Chemical Conditions

The oxidability by potassium permanganate was very high (above 10 $mgO_2\ l^{-1}$) at the time of all our tests, the higher values we established in Pischene and Dyulova bara (Fig. 2b). These values are due to the presence of considerable quantities of organic substances (dissolved and finely suspended) in the water of all swamps. As it can be seen from the Fig. 2a, the absolute quantities of dissolved oxygen were lower in the spring of 2000, when the water level was higher than in the summer months of the previous two years. This is better expressed in Martvo blato. The reason may be that after spring flood a rapid process of organic substances decomposition begins (release from mud and dead marsh vegetation), for which a great deal of dissolved oxygen is spent. On the other hand, the higher amount of dissolved oxygen in summer is probably due to photosynthesis of primary producers (submerged macrophytes and algae).

In all marshes the values of alkalinity were considerably higher in April of 2000 in comparison with the summer months (Fig. 2c). This is a result of penetration of more bicarbonate from underground river water in this month (Fig. 2d).

Only in Pischene we ascertained considerable differences between ammonium nitrogen (NH_4-N) and nitrate nitrogen (NO_3-N) during the three years of study (Fig. 2e, 2f). In 1997 the high value of NH_4-N may be related to the existence of oxygen deficiency at that time (Fig. 2a). On the contrary, the differences between the two forms of nitrogen in the next two years could not be connected with the quantities of dissolved oxygen and are due to other biological processes probably.

Hydrophyte and Hygrophyte Vegetation

Forty eight species belonging taxonomically to 17 families and 39 genera participate in the structure of vegetation (Table 1). With regard to their relation with the surrounding water the helophytes were dominant ecological group. Most of them were in blossom during the spring.

To indicate different ecological assessments, the following marks were used: for, abundance 1–5; for occurrence I–V; for relation with water surrounding: hdr–hydrophytes; hel–helophytes; nei–neistophytes; the blossom: p–spring; s–summer.

Some associations related to different formations presented the water and marsh vegetation.

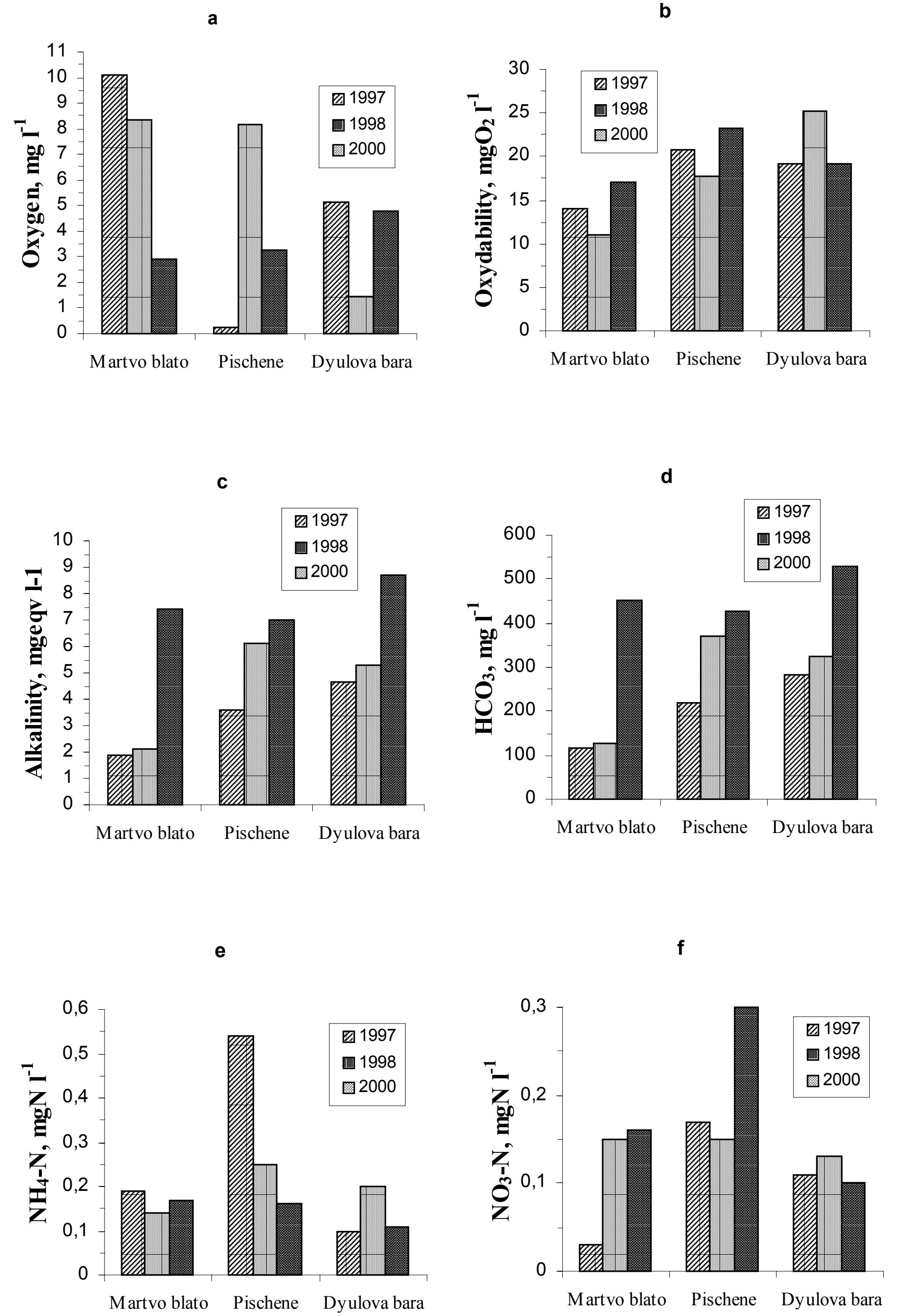

Fig. 2. Comparison of chemical values (mg liter^{-1}) of: **a)** dissolved oxygen; **b)** oxydability by $KMnO_4$; **c)** alkalinity; d)HCO_3^{1-}; **e)** NH_4-N and **f)** NO_3-N, between marshes of the Belene Island during 1997, 1998 and 2000 years

Table 1. Species composition, relative abundance, occurrence and ecological characteristics of high aquatic vegetation; hel–helophytes; nei–neistophytes; hdr–hydrophytes; p–spring; s–summer.

Species composition	Abundance	Occurrence	Relation to the water	Bloom
Phragmites australis /Cav./Trin ex Stend	4-5	V	hel	s
Typha angustifolia L.	1-2	IV	hel	p
Typha latifolia L.	1	IV	hel	p
Schoenoplectus lactularius /L/ Palla	1	II	hel	s
S. tebernimontanii /Gmel/ Palla	1	I	hel	s
Nymphoides peltata /S.G.Gmel/O.K.	3-5	V	nei	p
Trapa natans L.	1	I	nei	p
Sparganium erectum L.	1	I	hel	p
Rumex palustris Sm.	+	II	hel	s
Stachys palustris L.	+		hel	s
Salvinia natans /L./ All.	1	I	hel	p
Cyperus fuscus L.	1	II	nei	p
Oenanthe aquatica /L./ Poir	+	+	hel	s
Oenanthe banatica Heuff	+	+	hel	s
Stachus palustris L.	+	+	hel	s
Urticularia vulgaris L.	+	+	hel	s
Najas minor L.	1	I	hdr	s
Iris pseudacorus L.	1	I	hdr	s
Sagittaria sagittifolia L.	+	+	hel	p
Glyceria aquatica Wahlenb.	1	I	hel	s
Catabrosa aquatica /L./ P.P.	1	I	hel	s
Carex riparia Curt.	1	II	hel	s
Salvinia natans L.	1	II-III	hdr	p-s
Heleocharis palustris /L./ R.Br.	1	I	hel	s
Butomus umbelatum L.	+	+	hel	p
Lemna trisulca L.	1	III	nei	p
Lemna minor L.	1	II	nei	p
Spirodella polyrrhiza /L/ Scheid.	1	II	nei	p
Marsilea quadrifolia L.	+	+	nei	p
Potamogeton natans L.	1	I	nei	p-s
Potamogetum pusillus L.	1	I	hdr	p
Potamogetum pectinatus L.	1	I	hdr	p
Potamogetum crispus L.	1	I	hdr	p
Myriophyllum verticullatum L.	1	II-IV	hdr	p - s
Ceratophyllum demersum L.	1	II	hdr	s
Mentha pulegium L.	+	+	hel	p
Mentha aquatica L.	+	+	hel	p
Alisma plantago - aquatica L.	+	+	hel	p
Pycreus longus /L/ Hayek	1	I	hel	p
Sium latifolium L.	+	+	hel	p
Sium sisatum L.	+	+	hel	p
Epilobium palustre L.	+	+	hel	p- s
Persicaria hydropiper /L./ Opiz	+	+	hel	p
Galium palustre L.	1	I	hel	s
Myosotis palustris Lam.	1	I	hel	s
Hydrocharis masus - ranae L.	1	II	nei	p - s
Bolboschoenus maritimus /L./ Palla	1	I	hel	s
Scutelaria galericulata L.	+	+	hel	p-s
Lycopus europaeus L.	+	+	nei	s
Lythrum salicaria L	+	+	nei	s

Formation *Phragmiteta australi*

Association *Phragmitetum australiosum*

This association was the most widespread. It was established on large areas in the three marshes, but in Pischene and Martvo blato it was widely distributed. A total of 34 species were established as helophytes prevailed. The dominant species is *Phragmites australis* 5 V. Two floors were well differentiated. The average height of reed was 3.5–4.0 m. *Typha angustifolia* 1–2 IV was relatively better distributed in comparison with other species. The total projective coverage was 80-90%.

Association *Phragmitetum australi angustifoliosum*

It was distributed mainly in Dyulova bara and Pischene, but separate fragments were also found on the limited areas in Martvo blato. A total of 26 species was determined. The proportion of the dominant species was: *Phragmites australis* 3-4 V and *Typha angustifolia* 2 V. Two floors were distinguished. The former was average 3–4 m in height, composed mainly by dominant species. The total projective cover was 90–95 %.

Formation *Typhaeta angustifolii*

Association *Typhaetum angustifoliosum*

It was distributed on small areas in different parts of the marshes, bordered with reed cenosis and with reed and broad-leaved rush. *Typha angustifolia* dominated –2-3 V. Coexistent species were *Phragmites australis* 1 I-II, *Typha latifolia* 1 I, and *Schoenoplectus lacustris* 1 I, which formed the first floor with an average height of 3.5–4 m. The total projective cover was 70–80 %.

Formation *Schoenoplecteta lacustri*

Association *Schoenoplectetum lacustriosum*

The association was distributed on restricted areas. It was found fragmentarily in Dyulova bara and in Martvo blato. The main dominant species was *Schoenoplectus lacustris* 4 V. *Phragmites australis* 1 I, *Typha angustifolia* 1 I, and *Typha latifolia* 1 I were with lower participation. The rest of the species were found in single specimens. One floor was formed with average height of 2.5–3.0 m. Projective cover was 60-70 %.

Formation *Nymphoideta peltati*

Association *Nymphoidetum peltatiosum*

It was presented on comparatively limited areas and fragmentarily in some places. In the past this species covered dozens of hectares (Kochev, Jordanov, 1981). Together with the dominant *Nymphoides peltata* 3–4 V there were found also *Trapa natans* 1 I, *Potamogetum natans* 1 I; P. *pusilus* 1 II, *Myriophyllum verticullatum* 1, *Lemna trisulca* 1 II, *Lemna minor* 1 III, *Ceratophyllum demersum* 1 II, etc. One floor was formed mainly by hydrophyte and nymphea species. The projective cover is 80–90 %.

Formation *Oenantheta aquaticae*

Association *Oenanthetum aquaticosum*

It was of limited distribution mainly on the periphery of Dyulova bara. Beside the dominant *Oenanthe aquatica* 2-3 IV-V, other species - *Phragmites australis* 1 I, *Typha anguistifolia* 1, *Sagittaryia sagittifolia* 1 I, *Lemna minor* 1 II, *Lemna trisulca* 1 II, *Mentha aquatica* 1 I, *Pycreus longus* 1 I, *Sparganium erectum* 1 I, etc., were distributed in low percentages. The projective cover was 40-60 (70) %.

Some plant groups were distributed in the marshes, too.

Group of *Sparganium erectum*

It occurred in the shallow littoral part of Dyulova bara and Martvo blato. *Schoenoplectus lactularius* 1 I, *Typha latifolia* 1 I, *Typha angustifolia* 1 I, etc. grew together with the main species of the group. The projective cover was 40–50 %.

Group of *Oenanthe banatica*

It was established in separate places of Dyulova bara and Martvo blato. The cenoses were formed mainly by *Oenanthe banatica* 2-3 IV, but there occurred also some helophyte and nymphea species with very low abundance and cover. The average height of the dominant species was 50–60 cm. The projective cover is 40–60 %.

Group of *Trapa natans*

It was established in Martvo blato on limited areas. In the past *Trapa natans* had been quite widely distributed and it had formed separate associations (Kochev, Jordanov, 1981). Together with *Trapa natans* 2 IV some hydrophyte and nymphea species in very low abundance and frequency of occurrence were found, such as *Lemna trisulca* 1 I, *Lemna minor* 1 I, *Potamogetum crispus* 1 I, *Myriophyllum verticillatum* 1 I, etc. The projective cover was 50–60 %.

Group of *Carex ripari*

It had limited distribution mainly in Pischene. *Heleocharis palustris* 1 I, *Butomus umbellatus* 1 I, *Mentha puligium* 1 I, *Picreus longus* 1 I, *Epilobium palustre* 1 I, *Bolboschoenus maritimus* + I, etc., developed together with the dominant species. The projective cover was about 70 %.

Group of *Bolboschoenus maritimus*

It was distributed fragmentarily along the periphery of the marshes. The dominant species was accompanied by a few species as *Myosotis palustris* +, *Lycopus europaeus* +, *Lythrum salicaria* +, *Epilobium palustre* +, etc. The projective cover was 60–70 %.

Zooplankton

A total of 131 species was found during the investigation period, of them 77 Rotatoria, 36 Cladocera and 18 Copepoda (Table 2).

Dyulova bara was the richest in species – 97 (59 Rotatoria, 25 Cladocera and 13 Copepoda. In the second place comes Martvo blato (72) followed by Pischene with 58 species. The distribution of species number between the main groups of zooplankton is shown in Figure 3a.

Martvo blato. In 1997 the dominant complex consisted mainly of copepodites of Cyclopoida and cladocerian species *Chydorus sphaericus, Alona rectangula, Alonella excisa,* etc. Copepoda formed over 55 % of the abundance and 80 % of the biomass. The distribution of abundance and biomass of the three zooplankton groups are presented in Fig. 3b,c. The relative part of Rotatoria was under 0.5 %. Because of the fact that Cladocera participated with small size species, they constituted 44 % of abundance, but only 20 % of the biomass. In 2000 the subadult stages of Copepoda formed 90 % of the abundance and over 65 % of the biomass. Rotatoria were presented by single specimens *of Notolca aquminata* and *Testudinella patina.*

The rare for Bulgaria *Polyphemus pediculus, Arctodiaptomus kerkyrensis, Echinisca rosea, Tretocephala anbigua, Camptocercus rectirostris, Wlassicsia pannonica Squatinella cirrata, Squatinella rostrum* were found there.

Pischene. The smallest number of species - 58, was found in the biggest marsh during the whole period of investigation.

The quality composition was close to that of Martvo blato in 1997. With respect to the quantity the subadult stages of Cladocera prevailed, making over 90 % of the abundance and the biomass. In contrast to the previous year in 1998 the species *Arctodiaptomus kerkyrensis* and *Mixodiaptomus kupelviseri* were displaced by *Eudiaptomus vulgaris* with very high population density. The structure of zooplankton was characterized with dominance of subadult stages of Copepoda, *Polyarthra vulgaris* and *Trichocerca longiseta*. Rotatoria and Cladocera were very poorly represented (Fig. 3b,c). In this Pischene differed from others swamps in the same time. In 2000 the species composition of Rotatoria was highly reduced in comparison to the previous years. The domi-

Table 2. Species composition and distribution of zooplankton in the marshes during the studied period.

Taxa	**Martvo blato**	**Pischine**	**Dyulova bara**
1	2	3	4
Rotatoria			
Taphrocampa selenura Gosse, 1851		+	
Cephalodella gibba (Ehrenberg, 1832)			+
C. ventripes (Dixon - Nutall, 1901)			+
Monommata grandis Tessin, 1890			+
Scaridium longicaudatum (Müller, 1786)			+
Trichocerca (Diurella) bidens (Lucks, 1912)			+
Trichocerca (D.) vernalis (Hauer, 1936)	+		+
T. (D.) tenuior (Gosse, 1886)			+
T. (D.) dixon-nuttallii (Jennings, 1903)			+
T. (Trichocerca) rattus (Müller, 1776)	+		+
T. (T.) elongata (Gosse, 1886)		+	
T. (T.) pussilla (Lauterborn, 1898)	+		
T. (T.) cylindrica (Imhof, 1891)	+		
T. (T.) longiseta (Schrank, 1802)		+	
T. (T.) iernis (Gosse, 1887)		+	
Synchaeta sp.		+	+
Polyarthra vulgaris Carlin, 1943	+	+	+
P. dolichoptera Idelson, 1925			+
P. remata Skorikov, 1896			+
P. luminosa Kutikova, 1962			+
Dicranophorus longidactylum Fadeev, 1927			+
Asplanchna sp.	+	+	+
Lecane (Lecane) luna (Müller, 1776)	+	+	+
L. (L.) ungulata (Gosse, 1887)			+
L. (L.) ohioensis (Herrick, 1885)			+
L. (L.) tenuiseta Harring, 1914		+	
L. (L.) hornemanni (Ehrenberg, 1834)	+		
L. (Monostyla) bulla (Gosse, 1886)	+	+	+
L. (M.) arcuata (Bryce, 1891)	+	+	+
L. (M.) lunaris (Ehrenberg, 1832)	+	+	+
L. (M.) quadridentata (Ehrenberg, 1832)	+		+
L. (M.) closterocerca (Schmarda, 1859)	+	+	+
L. (M.) pyriformis (Daday, 1905)		+	+
L. (M.) hamata (Stokes, 1896)	+	+	+
L. (M.) styrax (Harring et Myers, 1926)	+		
L. (M.) opias Harring et Myers, 1926	+		
L. (M.) cornuta (Müller, 1786)			+
Trichotria similis (Stenroos, 1898)			+
T. truncata (Whitelegge, 1889)			+
T. pocillum ((Müller, 1776)			
Mytilina mucronata (Müller, 1773)	+	+	+
M. ventralis redunca (Ehrenberg, 1832)		+	+
M. trigona (Gosse, 1851)		+	
M. acantophora Hauer, 1938			+
M. videns (Levander, 1894)			+
Lophocharis oxysternon (Gosse, 1851)		+	+
Colurella adriatica Ehrenberg, 1831	+	+	+

Table 2. Continued

1	2	3	4
C. uncinata (Müller, 1773)			+
C. obtusa (Gosse, 1886)			+
C. colurus (Ehrenberg, 1830)			+
Lepadella ovalis (Müller, 1786)			+
L. patella (Müller, 1773)	+	+	+
L. p. biloba Hauer, 1958			
L. acuminata (Ehrenberg, 1834)		+	+
L. obtusa Van, 1961	+		
L. rottenburgi (Lucks, 1912)			+
L. cristata (Rousselet, 1893)			+
Squatinella rostrum (Schmarda, 1846)	+	+	+
S. cirrata (Müller, 1773)	+	+	
Euchlanis dilatata Ehrenberg, 1832	+	+	+
E. calpidia (Myers, 1930)			+
Dipleuchlanis propatula (Gosse, 1886)			
Eudactylota eudactylota (Gosse, 1886)	+	+	+
Brachionus quadridentatus Herrmann, 1783		+	+
B. rubens Ehrenberg, 1838		+	+
B. urceolaris Müller, 1773	+		
B. calyciflorus Pallas, 1766			+
B. angularis Gosse, 1851			+
B. a. bidens Plate, 1886		+	
B. leidigii tridentatus Zernov, 1901			
Keratella cochlearis (Gosse, 1851)	+		+
K. c. tecta (Gosse, 1851)			
K. quadrata (Müller, 1786)			+
K. tropica (Apstein, 1907)			
Notolca aquminata (Ehrenberg, 1832)	+		+
N. squamula (Müller, 1786)			
Platyias patulus (Müller, 1786)	+	+	+
P. quadricornis (Ehrenberg, 1832)		+	+
Anuraeopsis fissa (Gosse, 1851)	+	+	
Testudinella patina (Hermann, 1783)	+	+	+
T. mucronata (Gosse, 1886)		+	
Felinia terminalis (Plate, 1886)			
F. longiseta (Ehrenberg, 1834)			
Collotheca cornuta (Dobie, 1849)	+		+
Hexarthra mira (Hudson, 1871)	+		
Rotatoria g. sp.	+	+	+
Crustacea Cladocera			
Diaphanosoma brachyurum (Liévin,	+		
D. lacustris Korinek, 1981	+		
Latonopsis hospitus Naidenow, 1996			+
Daphnia magna Straus, 1820		+	+
D. curvirostris Eylmann, 1887	+	+	+
D. longispina O. F. Müller, 1785	+	+	+
Ceriodaphnia reticulata (Jurine, 1820)	+		+
C. laticaudata P. E. Müller, 1867	+	+	
C. quadrangula O. F. Müller, 1785			+
C. dubia Richard, 1894			+

Table 2. Continued

1	2	3	4
Moina brachiata (Jurine, 1820)			+
M. micrura Kurz, 1874			
Scapholeberis mucronata (O. F. Müller, 1785)	+	+	+
Sc. aurita (Fischer, 1849)	+		
Bosmina longirostris (O. F. Müller, 1785)	+	+	
Simocephalus vetulus (O. F. Müller, 1776)	+	+	+
S. exspinosus (Koch, 1841)	+		
Echinisca rosea Lievin, 1848	+		
Wlassicsia pannonica Daday, 1904	+	+	+
Camptocercus rectirostris Schoedler, 1862	+		
Acroperus harpae (Baird, 1834)	+	+	+
Tretocephala anbigua (Lilljeborg, 1900)	+		
Alona guttata Sars, 1862			+
A. rectangula Sars, 1862	+	+	+
A. quadrangularis (O. F. Müller, 1785)	+		+
A. affinis (Leydig, 1860)			
Alonella excisa (Fischer, 1854)	+		+
A. exigua (Lilljeborg, 1853)	+	+	+
A. nana (Baird, 1843)			+
Graptoleberis testudinaria (Fischer, 1848)	+		+
Oxyurella tenuicaudis (Sars, 1862)			+
Peracantha truncata (O. F. Müller, 1785)			+
Dunhevedia crassa King, 1853	+		
Pleuroxus laevis Sars, 1862		+	
P. trigonellus (O. F. Müller, 1785)	+		+
P. uncinatus (Baird, 1850)			+
Chydorus sphaericus (O. F. Müller, 1785)	+	+	+
Polyphemus pediculus (Linnaeus, 1761)	+	+	+
Copepoda			
Eurytemora velox (Lilljeborg, 18530)			
Eudiaptomus vulgaris (Schmeil, 1898)	+	+	
Arctodiaptomus kerkyrensis (Pesta, 1935)	+		+
Arctodiaptomus sp.		+	
Mixodiaptomus kupelviseri (Brehm, 1907)	+		+
Macrocyclops albidus (Jurine, 1820)			+
M. fuscus (Jurine, 1820)	+		+
Eucyclops serrulatus (Fischer, 1851)	+	+	+
Cyclops strennus (Fischer, 1851)	+		+
C. vicinus Uljanin, 1875			
Megacyclops viridis (Jurine, 1820)	+	+	+
Acanthocyclops robustus (Sars, 1863)	+		+
Diacyclops bicuspidatus (Claus, 1857)	+	+	+
D. bisetosus (Renberg, 1880)	+		
Metacyclops gracilis (Lilljeborg, 1853)	+	+	
Cryptocyclops bicolor (Sars, 1863)	+		
Thermocyclops dybowskii (Lande, 1890)		+	+
T. crassus (Fischer, 1853)			+
nauplii	+	+	+
copepodites	+	+	+

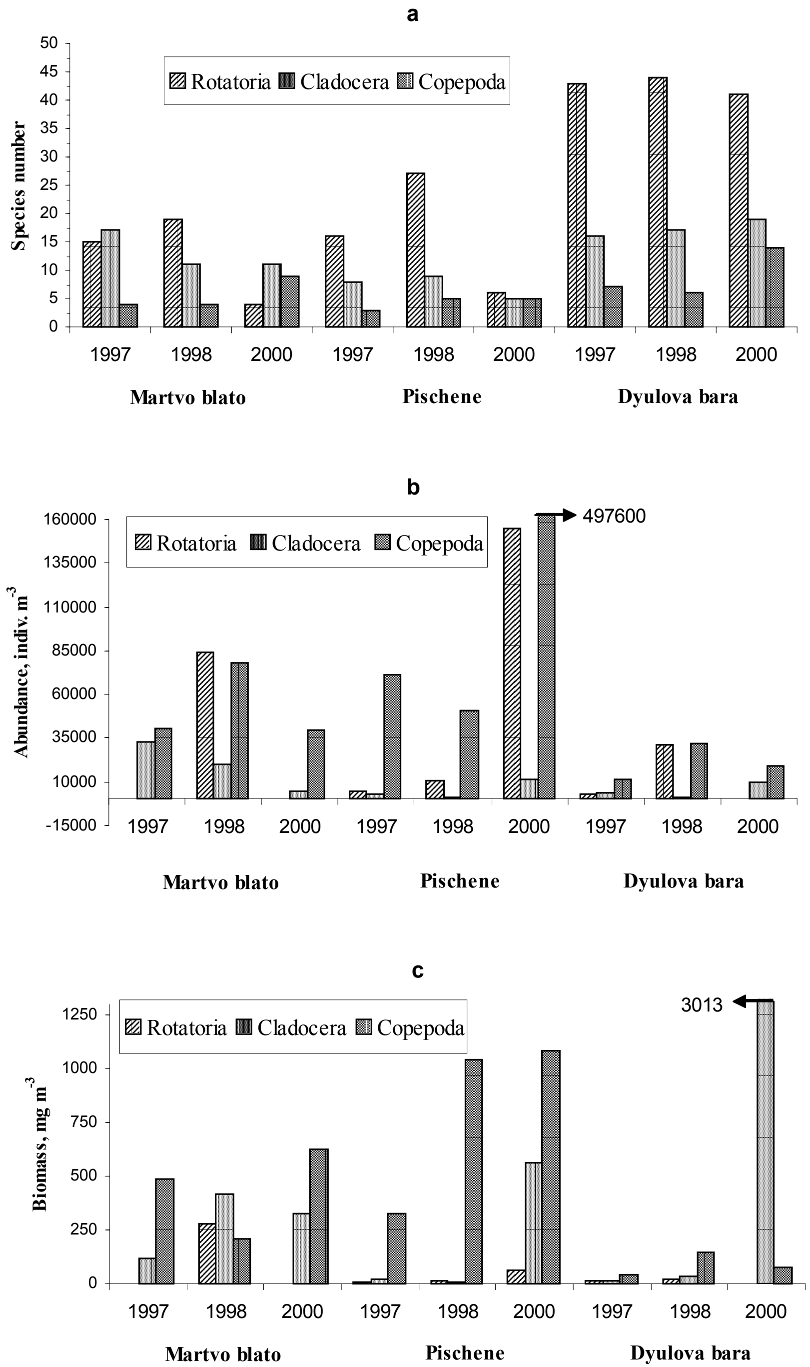

Fig. 3. Distribution of Rotatoria, Cladocera and Copepoda in the studied marshes of: **a)** species number; **b)** abundance, indiv. m^{-3}; **c)** biomass, mg m^{-3}

nants were again the nauplii and copepodites of Copepoda, *Polyarthra. vulgaris* and *Daphnia longispina,* as the last determined high relative part of biomass of Cladocera (Fig. 3c), while Rotatoria despite of its species richness and the high abundance of *P. vulgaris* constituted only 3.6 % of the total biomass. The highest values of the abundance and biomass (664000 indiv. m^{-3}; 1.7 g m^{-3}) were registered in this year.

Dyulova bara. In 1997 the subadult stages of Copepoda and *Alona rectangula* prevailed qualitatively. Despite of the obvious diversity of Rotatoria, they ranked in the last place regarding the density. Copepoda formed over 60% of both abundance and biomass. In the next year the subadult stages of Copepoda dominated again together with *Brachionus rubens,* but *A. rectangula* missed even qualitative samples. The abundance and biomass were about three times higher than the previous year, but Rotatoria reached high density (Fig. 3b), close to this of Copepoda. In 2000 the dominant complex included *D. longispina* and *Pleuroxus trigonellus* besides subadult stages of Copepoda. Rotatoria participated with only two species represented by single specimens, which sent them to the last place regarding abundance and biomass (Fig. 3b,c). Owing to *D. longispina* the biomass of Cladocera exceed 97 %.

Zooplankton-Phytoplankton Interactions

The interaction between zooplankton and phytoplankton has been an object of many limnological works, as most of them deal mainly with the relation with trophic status of water basins (McCauley, Kalff, 1981; McQueen *et al.*, 1986; Sager, Richman, 1991; Kalchev *et al*., 1993, 2002; Lacroix *et al*., 1999). These publications concern mainly permanent water basins, but almost nothing is known for these interactions in temporary wetlands such as Belene marshes. Significant correlation was obtained between relative biomass of diatoms and Rotatoria (Rsp=-80, P=0.009, n=9) and between diatoms and crustaceans (R_{sp}=0.80, P=0.009, n=9). Other two correlations were observed between the biomass of crustaceans on one hand and the relative biomass of Chlorophyta and flagellates on the other, which were close, but above the threshold of significance (R_{sp}= -0.65; P=0.058, n=9). The total biomasses of zooplankton and phytoplankton were found to correlate negatively (R_{sp}= -0.65), but the significance of the correlation was also a little bit above the probability threshold of 0.05. The significance of the correlation did not change when the zooplankton biomass was restricted only to crustacean zooplankton (without Rotatoria). This correlation is opposed to the obtained for other authors, who have established a positive relationship between zooplankton and phytoplankton biomass in different lakes (McCauley, Kalff, 1981; Lacroix *et al.*, 1999). If the insufficient significance of some of correlations is disregarded, we may assume that the positive sign of correlation between B_{zoo} and B_{phyto} is an indicator for existence of a top down effect by zooplankton on phytoplankton and that diatoms are better grazed by rotifers, wail crustaceans prefer greens and flagellates. Higher (R_{sp}=-0.80) and more significant (P=0.009) correlation was obtained between the biomass of zooplankton (B_{zoo}) and the average individual weight of phytoplankton (AIW_{phyto}). It is evident from Table 3 that in Dyulova bara and Martvo blato there are well expressed differences in the size of individuals between the low water summer months and spring (Table 3), which are reverse for zooplankton and phytoplankton. The phytoplankton was presented by large individuals in summer and by small ones in spring, while the zooplanktonoin the opposite - by smaller organisms in summer and by larger in spring (Table 3). In Pischene this tendency is not so clear. The functional relationship between logarithms of B_{zoo} and AIW_{phyto} was found to be significantly close to the linear relationship (Fig 4a).

Table 3. Depth, average weight of phytoplankton (AIW_{phyto}) and zooplankton (AIW_{zoo}) and ratio between biomasses of zoo and phytoplankton (B_{zoo}:B_{phyto}) of the three studied marshes.

Marsh	Martvo blato			Pischene			Dyulova bara		
Month, Year	June 1997	June 1998	April 2000	June 1997	June 1998	April 2000	June 1997	June 1998	April 2000
Depth, m	1.00	0.60	1.50	0.80	0.50	1.40	0.80	0.30	1.00
AIW_{phyto}, ng	9.00	4.00	0.92	6.00	1.00	1.03	9.20	9.00	1.15
AIW_{zoo}, µg	8.3	4.9	20.0	4.4	20.0	2.6	3.6	3.2	100.0
B_{zoo}:B_{phyto}, rel. units	0.15	0.66	2.89	0.15	0.50	6.56	0.06	0.004	11.00

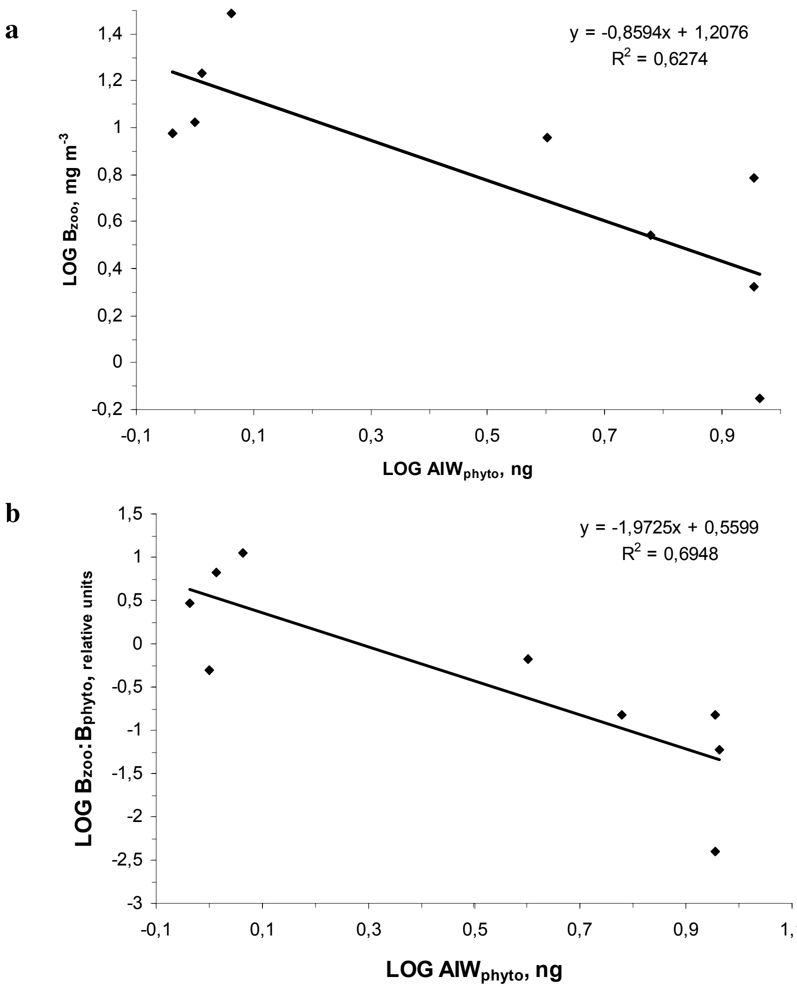

Fig. 4. Relationship between logarithms of: a) zooplankton biomass (B_{zoo}) and phytoplankton average individual weight (AIW_{phyto}); b) zooplankton phytoplankton biomass ratio (B_{zoo}:B_{phyto}) and AIW_{phyto}

Factors Influencing the B_{zoo}:B_{phyto} Ratio

The ratio between zooplankton and phytoplankton biomass, which is a relative measure of zooplankton-phytoplankton interactions, also differed between summer and spring (Table 3). Significant correlation (R_{sp}=0.70, P=0.026, n=9) was found between depth and B_{zoo}:B_{phyto} ratio. The low summer values of this ratio indicate a low efficiency of consumption of phytoplankton by zooplankton which may explain the weak correlation between the biomasses of phyto- and zooplankton. These low values might be due to two reasons. The first is the prevalence of larger and not edible phytoplankton forms in summer. The significant correlation (R_{sp}=-0.76, P=0.017, n=9) and the linear relationship (Fig 4b) between Log B_{zoo}:B_{phyto} ratio and Log AIW_{phyto} is an evidence for that and shows that smaller organisms are grazed more effectively by zooplankton. Similar correlation but with positive sign, was obtained by Kalchev *et al.* (2002) for the shallow Durankulak Lake (1.4 mean depth), but in the deeper Shabla and Ezerets Lakes it did not appear. When we compared the AIW of phytoplankters of the mentioned water basins, we ascertained that these were very different. The AIW_{phyto} in Belene marshes is higher than in Shabla and Ezerets, but considerably smaller in comparison with those in Durankulak. Probably the differences in the size structure of phytoplankton in Belene marshes and in Durankulak are one of the reasons for the different sign of the two mentioned relationships. It is clear however that the size structure of phytoplankton has a big influence on the zooplankton-phytoplankton interactions. The second reason for the low efficiency between zooplankton and phytoplankton might be the involving of detritus as alternative source of food for zooplankton in summer. The significance of the additional sources is typical of the shallow waters (Lacroix *et al.*, 1999) and in a concrete case they are available mainly in summer when the process of decomposition of dead aquatic vegetation is sufficiently advanced. The B_{zoo}:B_{phyto} ratio was not found to correlate with the AIW of zooplankton in the studied marshes. Kalchev *et al.*, (2002) found such relation in Shabla and Ezerets, but it disappeared in zones influenced by macrophytes. The same authors report that B_{zoo}:B_{phyto} ratio is significantly smaller in macrophyte overgrown stations. Our data are not suitable to examine the quantitative influence of macrophytes, but it seems that this factor, together with the low depth of water basin, causes a decrease of the transfer efficiency between zooplankton and phytoplankton.

Conclusion

The macrophytocenosis consisted of considerable number of species. These belong mainly to the group of helophytes. From the other ecological groups a smaller number of plants was ascertained. Some of them were represented by separate groups, which had restricted distribution. In the near past they were spread more widely (for instance *Trapa natans*, *Nymphoides peltata,* etc.). Some species as *Nymphea alba* and *Nuphar lutea* have completely disappeared. The group of euhydrophyte had comparatively more limited distribution. This is a reason to consider that the ecological conditions have become worse for their distribution.

The zooplankton community was quantitatively dominated mainly by subadult stages of Copepoda, as only in Dyulova bara (April 2000) and Martvo blato (June 1998) Cladocera had a leading role in respect to the biomass. In general, Rotatoria showed higher species richness, especially in Dyulova bara. Considerable differences exist between the low water summer period and spring, regarding both taxonomic and size structure of phytoplankton and zooplankton. The size of phytoplankton individuals is larger in summer and smaller in spring, the opposite is characteristic of zooplankton. The negative correlation between the total zooplankton and phytoplankton biomass is an indicator for prevailing top-down influence by zooplankton on phytoplankton, which however applies mainly to the spring. The low B_{zoo}:B_{phyto} ratio in summer indicates a low transfer efficiency between zoo and phytoplankton. This ratio was found to depend in a great extend on AIW_{phyto}. The bigger size of phytoplankton organisms and the involving of alternative food sources are the probable reasons for the low B_{zoo}:MB_{phyto} ratio in summer. In this respect the presence of macrophytes might also be a factor diminishing the transfer efficiency between zooplankton and phytoplankton.

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Биологични характеристики и връзка между зоопланктона и фитопланктона на блатата на остров Белене (река Дунав, България)

М. Бешкова, В. Найденов, Х. Кочев, И. Ботев

(Резюме)

Изследвани са съставът и структурата на зоопланктона както и връзката между зоопланктона и фитопланктона във връзка с химичните фактори на водата и висшата водна растителност в три блата на остров Белене (българският сектор на река Дунав) през м. юни 1997 г., юни 1998 г. и април 2000 г. Блатната растителност е представена от 48 вида, принадлежащи към 17 семейства и 39 рода, от които хелофитите бяха доминираща екологична група. Установени са 131 зоопланктонни вида от които 72 Rotatoria, 36 Cladocera и 18 Copepoda. Субадултните стадии на Copepoda съставляваха по-голямата част от биомасата на зоопланктона. Установена е достоверна линейна зависимост на биомасата на зоопланктона и на отношението зоопланктон-фитопланктон от средния размер на фитопланктонните организми.