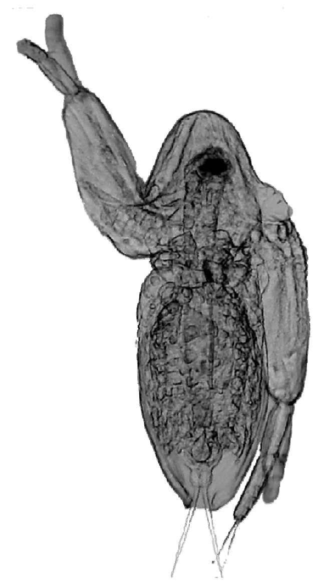
THE “BABEŞ-BOLYAI” UNIVERSITY
FACULTY OF BIOLOGY AND GEOLOGY
DEPARTMENT OF TAXONOMY AND ECOLOGY

Study of structure, dynamics and biomass of zooplanktonic crustacean community, with emphasis on common species from Lake Ştiucii, Nature Reserve, Cluj County

~Abstract of the PhD thesis~



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KEY WORDS:

- ✓ **zooplankton;**
- ✓ **cladocerans;**
- ✓ **cyclopoid copepods;**
- ✓ **qualitative structure;**
- ✓ **density;**
- ✓ **biomass;**
- ✓ **vertical distribution;**
- ✓ **gut content;**
- ✓ **assessment of lake ecological status.**

Introduction

In a lentic ecosystem, a true microcosm, composed of well-defined components connected through a complicated network, any factor acting on one species will affect, sooner or later, the whole system. The zooplankton community, because of its structure and functions, is indispensable to an efficient matter and energy flow in a lake system. It includes different taxonomic groups, having different requirements and variation limits. It represents the middle link in lacustrine food chains, connecting all the other biotic links, assuring their survival and sustainability.

This is the reason why one of the zooplankton compartments was chosen as main focus for the present paper, which had the following objectives:

- *study of the qualitative structure of planktonic microcrustacean community (cladocerans and cyclopoid copepods);*
- *illustrating the seasonal dynamics of the microcrustacean density and biomass, together with the abiotic factors;*
- *testing the vertical migration patterns of microcrustaceans populations from Lake Ştiucii;*
- *study of the occurrence of planktonic microcrustaceans in fish diets from Lake Ştiucii;*
- *assessment of the ecological status of Lake Ştiucii (considered to be an unaffected water body) compared to the Ţaga Mare fish pond (an aquatic ecosystem created for intensive fish farming), based on planktonic microcrustacean community characteristics.*

Even if the focus of the present paper was the planktonic microcrustacean community from Lake Ştiucii, I had the opportunity to include this topic into a greater framework, thanks to the financial support of the TD CNCSIS grant (no. 155/2003-2005). Thus, I was able to compare the structure and functions of the plankton microcrustacean community of this natural lake with the one from the Ţaga Mare fish pond, which belongs to the numerous man-made lakes from the Fizeş River catchment area.

Lake Ştiucii was declared a Nature Reserve in 1966 and it was confirmed in 1974. Its total surface was increased in 1994 and 2004. Since 2001, Lake Ştiucii was included in the EMERALD network. Lake Ştiucii was declared a protected area because (i) according to some authors, it is one of the deepest natural lakes in the continental part of Romania; (ii) it represents one of the few Transylvanian aquatic ecosystems not heavily affected by human activities and (iii) it is the only lake outside the Danube Delta characterized by floating reeds. On the other hand, Lake Ţaga Mare is part of the man-made water bodies created for intensive fish farming.

During the conception of the present paper, I enjoyed the support of several people, whom I want to say thanks.

First, my sincere thanks go to Mr. Professor Leontin Ştefan Péterfi, the scientific supervisor of the thesis, because he accepted me as a PhD student and for his useful advice during the final part of the thesis.

I owe my orientation to aquatic sciences to Mr. Professor Claudiu Tudorancea. I want to thank him for giving me the opportunity to work in a modern limnological laboratory and with a team of extraordinary and motivated people.

I also want to thank Ms. Associated Professor Laura Momeu for her continuous support, not only on this particular thesis, but on all the projects we have worked on.

My thanks are also given to the two specialists that were kind enough to help me with the taxonomical identifications of this paper: Mr. Ştefan Negrea and Mrs. Danielle Defaye.

For my dear colleagues, who helped me in the field work, in the long hours spent in the laboratory and in many other things, many thanks: Mirela Cîmpean, Claudia Pavelescu, Levi Nagy, Daniel Ţura, Anca Avram-Timar, Mugur Bogătean, Ionuţ Stoica, Leo Modan, Istvan Zsok, Radu Sălcudean, Ioana Meleg, Alin David. I couldn't forget Mr. Cristian Gudasz for his help in the chemical analyses of the water.

Last but not least, my thanks are given to my parents, for their strong and constant support that made possible the completion of this thesis. As a matter of fact, my whole work is dedicated to them.

I. Hydrological and geomorphological characteristics of the study area

Lake Ştiucii is located 46..9676 North and 23.9015 East (from the center of the water body), at 274.5 m a.s.l., on the Bonţ River valley, a tributary of the Fizeş River. The formation of the lake is due to a combination of neotectonic events and salt dissolution processes. A dense mud layer isolated the salt, thus the water became fresh. However, the groundwater can be enriched by the contact with the salt deposits, altering the chemical composition of lake water (Gudasz, 2004).

Regarding the hydrological regime, the water source of the lake is represented mainly by superficial runoff, which accounts for about 70-80% from the total water supply (Sorocovschi *et al.,* 2000). The groundwater source can become significant during summer or autumn, reaching about 50% from the total supply (Şerban şi Sorocovschi, 2003). The lake thermal regime is strongly influenced by the air temperature. Spring warming starts once the air temperature starts to increase and once the ice cover melts away (end of February / beginning of March). This period represents the transition from the winter inverse stratification to spring water mixing period. Summer warming begins in the middle of May; it has high amplitudes in Lake Ştiucii. By the end of September the autumn cooling occurs, once the temperatures drop, cold rains appear and cold winds start to blow.

Morphometrical characteristics of Lake Ştiucii are depicted in table I.1.

Table I.1. Morphometrical elements of Lake Ştiucii (Şerban & Sorocovschi, 2003)

Parameter	Value (according to the analyses from the year 2000)
Area	57.35 ha
Length	1.555 km
Mean width	0.369 km
Maximum width	0.662 km
Mean depth	3.123 m
Maximum depth	6.8 m
Shoreline length	4.263 km
Mean slope	31.84 m/km
Total volume	1 780 000 m^3

The human impact in Lake Ştiucii is represented by a small dam (50-70 cm high) whose purpose was to control the runoff regime after the floods from the 70's. It lead to alterations in water levels and favored the spread of paludal vegetation. However, the human impacts are not intense in Lake Ştiucii; they are mostly represented by runoffs from the agricultural and pasture fields near the lake, tourism and fish stocking.

The Ţaga Mare fish pond (46.9334 North and 24.0764 East – measured at the sampling site) is located on the middle course of the Fizeş River, at 280 m a.s.l. The natural origin of the depression that today includes the Ţaga Mare and Ţaga Mică fish ponds is related to neotectonic movements. At present, the pond water sources come mostly from superficial runoff, while groundwaters represent a low percentage (15-20%), due to impermeable substratum of the lake. The water levels in the pond are controlled by water inputs. The maximum water levels are recorded in March/April, while minimum water levels in September/October. The thermal regime in the Ţaga Mare fish pond has low amplitudes, because the lake is shallow.

On the basis of the morphometrical characteristics (table I.2.), the Ţaga Mare fish pond can be considered a wetland with a depth lower than 6 m (Holland *et al.*, 1990).

Table I.2. Morphometrical data of the Ţaga Mare fish pond (Pandi, 2000, from Sorocovschi, 2005)

Parameter	**Value (according to the analyses from the year 1997)**
Length	3.3 km
Shoreline length	2.8 km
Mean width	0.31 km
Maximum width	0.45 km
Mean depth	1.95 m
Maximum depth	2.50 m
Area	1.03 km^2
Volume	2 010 000 m^3

The Ţaga Mare fish pond is affected by many human impacts, like: dam modifications, fish stocking, fish removal etc., that derives from the very purpose of the lake. The pollution sources include animal husbandry, domestic wastes, runoff coming from the agricultural fields near-by etc. (Floca *et al.*, 1998).

II. Material and methods

Three sampling sites were considered for Lake Ştiucii (fig. II.1.). The fist one, site **S1,** was located in the center of the lake (46.9676 North; 23.9015 East), in the region of maximum depth (about 6.75 m), where no influences of the lake shores are present. Site **S2** (46.9675 North; 23.9040 East) was situated in the East part of the lake, near the reed belt that surrounds the lake, the maximum depth at this point being 2 m. Sampling site **S3** was located in the Southern gulf of the lake (46.9621 North; 23.8969 East), in a region completely surrounded by reed, having a shallow depth (up to 2 m).

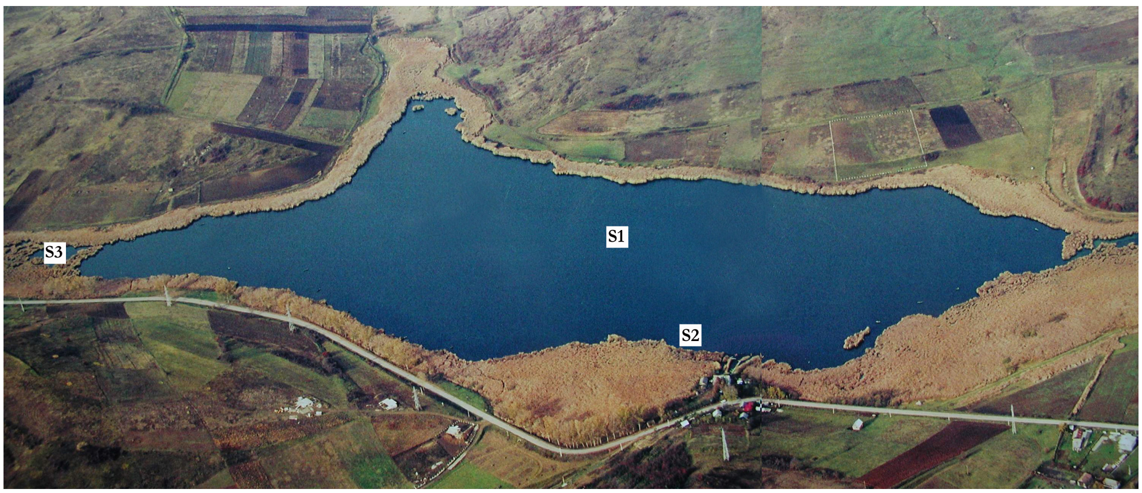


Fig. II.1. The location of the three sampling sites in Lake Ştiucii (**S1**, **S2** and **S3**)
(photo: Mihuţ S., 2001, modified from David, 2008)

Only one sampling site was considered on the Ţaga Mare fish pond – **T1** (fig. II.2.). It was located in the North part of the lake (46.9334 North; 24.0764 East), where the maximum depth did not exceed 2 m.

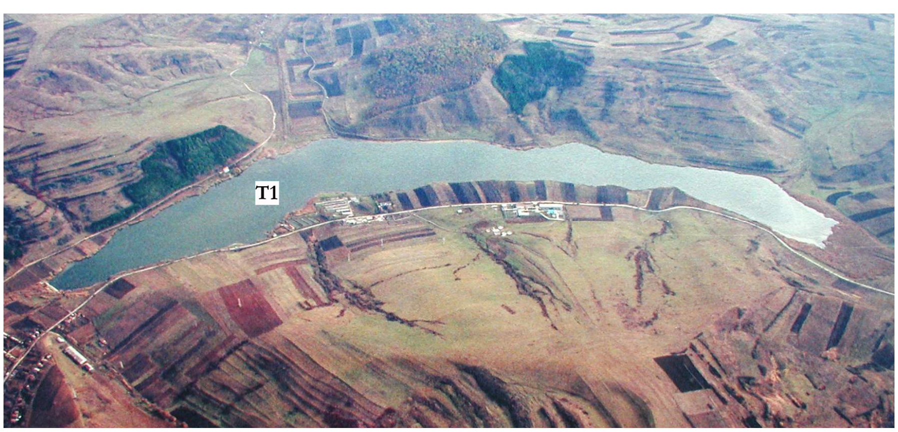


Fig. II.2. The location of the sampling site in the Ţaga Mare fish pond (**T1**)
(photo: Mihuţ S., 2001, modified from David, 2008)

The samples were collected every one meter, to the maximum depth characteristic to each site. Lake Ştiucii was sampled monthly for two years, from May 2003 to April 2005. The Ţaga Mare fish pond was sampled monthly for one year, from September 2003 to August 2004. For the testing of diel vertical migration of planktonic crustaceans in different seasons in Lake Ştiucii, samples were collected every 4 hours (in 24 hours) in October 2004, January, April and July 2005. A total of 1173 samples were collected and processed. Fish community was sampled in July 2004 in Lake Ştiucii in order to establish the stomach content of the main fish species. Three gill nets were used, having 14 mm, 20 mm and 45 mm mesh sizes. The fish sampling lasted for 12 hours, during night. The sampling procedures of the plankton community were carried out using standardized methods in both lakes (Clesceri *et al.* (ed.), 1998; Haney & Hall, 1973).

Physical and chemical parameters of water (pH, conductivity, salinity, temperature and dissolved oxygen) were measured at every sampling date. Chemical water analyses included total phosphorus and total nitrogen estimations (the Menzel & Corwin method (1965) and the *Tentative* method (Standard Methods, 1976), respectively). In order to assess the trophicity state of the two water bodies, the **T**rophic **S**tate **I**ndex – **TSI**) was calculated (according to Carlson, 1977).

The qualitative analysis of zooplankton referred to taxonomical identifications to the species level for cladocerans and cyclopoid copepods. Rotifers were considered as a group and identified up to the genus level. Identification of the main microcrustacean species was carried out using the following keys: Negrea (1983); Dumont & Negrea (2002); Damian-Georgescu (1963) and Dussart & Defaye (2001).

Counting zooplankton organisms and density estimations were made according to standardized methods Clesceri *et al.* (ed.), 1998.

Biomass estimation was made using length-weight regression equations taken from the literature (Dumont *et al.,* 1975; Bottrell *et al.,* 1976; McCauley, 1984; Culver *et al.*, 1985; Rosen, 1981; Bird & Prairie, 1985 etc.). 28620 cladocerans and cyclopoid copepods were measured in Lake Ştiucii and 1577 in the Ţaga Mare fish pond in order to use the regression equations for the estimation of biomass. Other 11499 individuals were measured in order to calculate microcrustacean biomass for the study of the diel vertical migration. The **I**ndex of **C**enotic **S**ignificance - ICS) (Rogozin, 2000) was calculated for the identification of the most important cladoceran and copepod species as regards their biomass and frequency.

The Shannon-Wiener index (Shannon & Weaver, 1949; Wiener, 1948) was used to calculate the microcrustacean community diversity, on the basis of biomass values for every species at the sampling dates.

The diel vertical migration in the four seasons from 2004 and 2005 was tested at site **S1** in Lake Ştiucii, by comparing the biomass distributions of the considered species along the 7 depth levels, according to the nonparametric Kolmogorov-Smirnov test (Kolmogorov, 1941; Smirnov, 1939). The weighted mean depth during day and night was also calculated according to Frost & Bollens, (1992). This parameter showed the depth at which the large majority of zooplankton individuals resided during daytime and during night. The amplitude of migrations was then calculated as the differences between the weighted mean depth values, positive results indicating normal migration pattern (descendent movements during the day and ascendant during the night), while negative results pointing out inverse migration patterns.

Two indices of dietary preferences were calculated: the selection index **w** and Manley's **α** (Manley *et al.,* 1972).

Correlations between biotic parameters (microcrustacean diversity, biomass) and the **T**rophic **S**tate **I**ndex were considered for the assessment of ecological status of the two water bodies, together with saprobity (according to the Zelinka & Marvan (1961) index) and a biotic index based on the ratio between large cladocerans and the total cladoceran density (Moss *et al.,* 2003).

III. Structure and the quantitative parameters of planktonic microcrustacean communities from Lakes Ştiucii and Ţaga Mare

III.1. Physical and chemical parameters

Water temperature represents one of the most important factors influencing the growth of aquatic organisms. Lake Ştiucii has a general pattern of temperature variation characteristic to temperate dimictic lakes (fig. III.1.1.). The same pattern of variation was observed in the Ţaga Mare fish pond, but with lower amplitudes due to the lower water depth.

The dissolved oxygen concentration decreased from the surface to deeper waters in almost all sampling dates. At the end of spring and at the beginning of summer 2003 the oxygen variation was characterized by a metalimnetic maximum, explained by lower concentrations above and below this water stratum and by the rapid development of the algal community at that particular depth (Wetzel, 2001). In November 2003 and 2004, equal dissolved oxygen values were recorded in the water column. In the Ţaga Mare fish pond the variation of this parameter recorded a similar pattern. During summer (July and August 2004) oxygen concentrations near the bottom of the pond indicated anoxia (as for Lake Ştiucii).

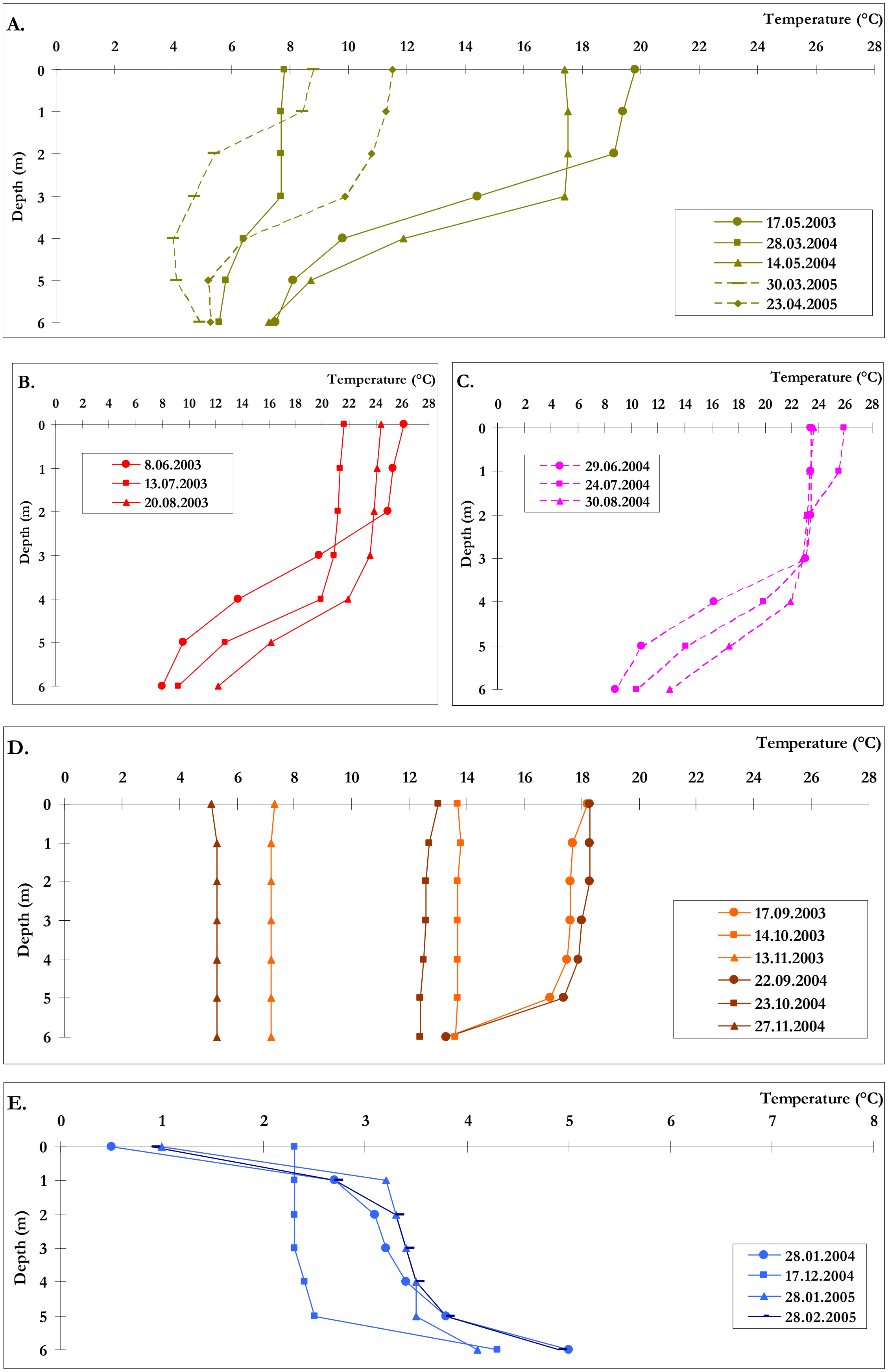


Fig. III.1.1. Water temperature values in the water column in Lake Ştiucii: spring (**A**), summer (**B** and **C**), autumn (**D**) and winter (**E**)

The **pH** values in Lake Ştiucii ranged from 4.79 (17.09.2003, 6 m) to 9.78 (23.10.2004, surface). Most values varied between 7 and 8, with no significant differences from one depth to another. In the Ţaga Mare fish pond, the pH values were higher (alkaline), ranging from 8.52 (24.07.2004, maximum depth) to 11.13 (17.09.2003, 1 m).

Conductivity values varied between 778 μS/cm (13.11.2003, 4-6 m) and 1539 μS/cm (22.09.2004, 6 m), with an average of 1062.80 μS/cm ± 42.73 in 2003 and 1156.41 μS/cm ± 55.81 in 2004.

Salinity had a similar variation. The average salinity values in Lake Ştiucii were 566.33 mg/l ± 22.87 in 2003 (May – November) and 617.67 mg/l ± 29.70 in 2004 (January – September). Salinity values for the Ţaga Mare fish pond had an average of 509.96 mg/l ± 31.42 between September 2003 and August 2004. Slightly higher values compared to Lake Ştiucii might be explained by the salt deposits in the region, influencing the groundwater (Şerban & Sorocovschi, 2003).

The total nitrogen (TN) concentration in Lake Ştiucii was more or less constant throughout the study period (May 2003 – April 2005), with an average of 598.42 μg/l ± 50.2, except for August and September 2004, when the total nitrogen concentration exceeded 2500 μg/l (fig. III.1.2.). These high values could be explained by the heavy rainfall from July 2004 (the average mean was 174.5 mm - source: the Fizeşu Gherlii meteorology station). The high precipitations could wash the agricultural and pasture regions near the lake, leading to large inputs of nutrients.

The total nitrogen concentration can be related to the zooplankton community dynamics (composed of cladocerans, cyclopoid copepods and rotifers larger than 50/55 μm), even if the correlation is not significant (according to the Spearman rank correlation coefficient). Figure III.1.2. shows the total nitrogen peak in August 2004, bordered from both sides by two peaks in zooplankton density: one caused by rotifers and cladocerans (May 2004) and one caused exclusively to rotifers (October 2004). The values of total nitrogen measured in the Ţaga Mare fish pond between September 2003 and August 2004 were higher compared to those from Lake Ştiucii, having an average of 1173.97 μg/l ± 323.72 for the first 8 sampling dates, while in August 2004 the TN concentrations exceeded 5500 μg/l.

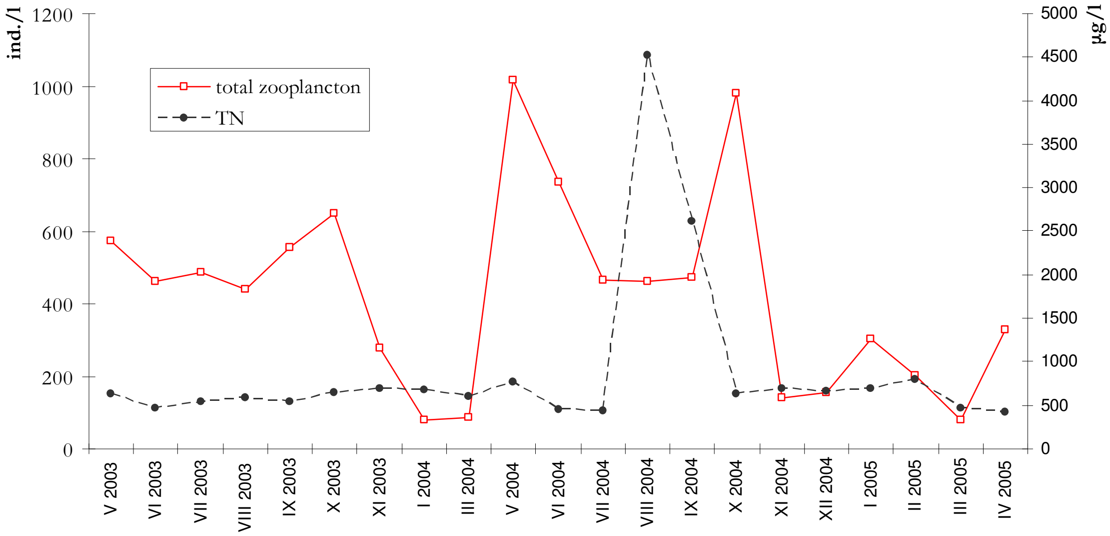


Fig. III.1.2. Variation of total nitrogen concentration (TN) and the total zooplankton density in Lake Ştiucii at the 21 sampling dates

Total phosphorus values (TP) measured in Lake Ştiucii recorded on the average 19.82 µg/l ± 3.78. The minimum concentrations were recorded in August and September 2004, in opposition to the maximum total nitrogen values recorded in the same months. Total phosphorus values recorded in the Ţaga Mare fish pond were much higher, having on the average 179.5 µg/l ± 50.32 during September 2003 – August 2004.

The trophic state of water bodies can be accurately assessed considering the total nitrogen and the total phosphorus concentrations. Lake Ştiucii is characterized as a meso – eutrophic ecosystem, considering the total phosphorus concentration during the spring mixing (March 2004, 31.788 µg/l) (OECD**,** 1982). The Ţaga Mare fish pond was considered to be hyper-eutrophic, due to the average total phosphorus concentration during spring mixing (May 2004, 127.85 µg/l).

A strong negative correlation was observed between the mean temperature values and the mean dissolved oxygen at the 21 sampling dates, because at low temperatures the oxygen concentrations are usually high. The total phosphorus concentration in Lake Ştiucii was negatively correlated with the average temperature (fig. III.1.3.).

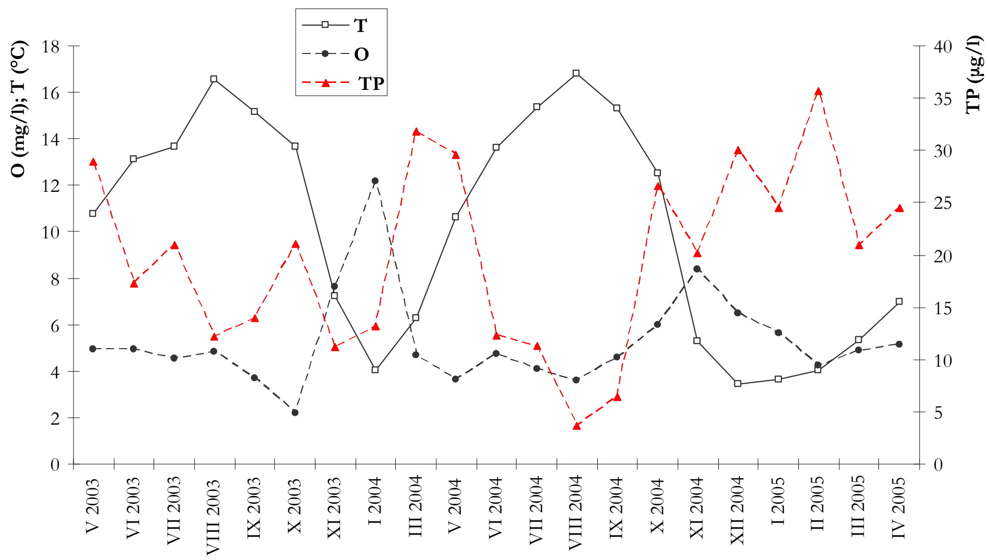


Fig. III.1.3. Variation of the average temperature (T), the dissolved oxygen (O) and the total phosphorus (TP) at the 21 sampling dates in Lake Ştiucii

III.2. Qualitative composition of planktonic crustacean communities

26 cladoceran and cyclopoid copepod species were identified in Lake Ştiucii during the study period between May 2003 and April 2005, while 19 microcrustacean species were found in the Ţaga Mare fish pond. 5 species were common to both water bodies (table III.2.1.).

15 cladoceran species were present in the two water bodies, 10 species in Lake Ştiucii and 9 in the Ţaga Mare fish pond: *Alona rectangula, Bosmina longirostris* (fig. III.2.1.), *Ceriodaphnia pulchella* (fig. III.2.2.), *Chydorus sphaericus, Daphnia cucullata* (fig. III.2.3.), *Daphnia galeata, Diaphanosoma orghidani, Graptoleberis testudinaria, Ilyocryptus sordidus, Leydigia acanthocercoides, Moina brachiata, Pleuroxus aduncus, Pleuroxus laevis, Scapholeberis mucronata* and *Simocephalus vetulus.* Most of the cladocerans were parthenogenetic females, with or without eggs. Males and gamogenetic females also appeared, but in lower numbers.

11 species of cyclopoid copepods were found in the two lakes, 9 in Lake Ştiucii and 3 in the Ţaga Mare fish pond: *Acanthocyclops vernalis, Cryptocyclops bicolor, Cyclops vicinus* (fig. III.2.5.), *Eucyclops macruroides, Eucyclops serrulatus, Macrocyclops albidus, Macrocyclops distinctus, Megacyclops viridis, Mesocyclops leuckarti, Thermocyclops crassus* (fig. III.2.6.) and *Thermocyclops oithonoides* (fig. III.2.7.). Only *Cyclops vicinus* was common in the two water bodies. Generally speaking, the number of immature cyclopoid copepods can exceed 10 to 20 times the number of adult copepods (Pleşa & Müller, 2002). This was also the case of both lakes, where nauplii and copepodites (fig. III.2.4.) represented an important part of zooplankton community at every sampling date and depth. They were processed as a group, because identifications to the species level are impossible.

8 rotifer genera were found in Lake Ştiucii and 6 in the Ţaga Mare fish pond, but due to the sampling net that had a mesh size of 50/55 μm, only the rotifers that exceeded that body size were collected and thus considered.

Table III.2.1. List of cladoceran and cyclopoid species identified in Lake Ştiucii (sampling sites **S1**, **S2**, **S3**) and the Ţaga Mare fish pond (site **T1**) during 2003 and 2005

TAXA	S1	S2	S3	T1
Suborder CLADOCERA*				
Infraorder Ctenopoda				
Family Sididae				
Diaphanosoma orghidani Negrea, 1982	-	-	-	✓
Infraorder Anomopoda				
Family Daphniidae				
Ceriodaphnia pulchella Sars, 1862	✓	✓	✓	✓
Daphnia cucullata Sars, 1862	✓	✓	✓	-
Daphnia galeata Sars, 1864	-	-	-	✓
Scapholeberis mucronata O.F. Müller, 1776	-	-	✓	-
Simocephalus vetulus O.F. Müller, 1776	✓	✓	✓	-
Family Moinidae				
Moina brachiata Jurine, 1820	-	-	-	✓
Family Bosminidae				
Bosmina longirostris O.F. Müller, 1776	✓	✓	✓	✓
Family Eurycercidae				
Alona rectangula Sars, 1862	✓	✓	✓	✓
Chydorus sphaericus O.F. Müller, 1776 (emend. Frey, 1980)	✓	✓	✓	✓
Graptoleberis testudinaria Fischer, 1848	-	✓	✓	-
Leydigia acanthocercoides Fischer, 1854	-	-	-	✓
Pleuroxus aduncus Jurine, 1820	✓	✓	✓	-
Pleuroxus laevis Sars, 1862	✓	✓	✓	-
Family Macrothricidae				
Ilyocryptus sordidus Liévin, 1848	-	-	-	✓
Subclass COPEPODA**				
Family Cyclopidae				
Subfamily Eucyclopinae				
Eucyclops macruroides Lilljeborg, 1901	-	✓	✓	-
Eucyclops serrulatus Lilljeborg, 1901	-	-	✓	-
Macrocyclops albidus Jurine, 1820	-	✓	✓	-
Macrocyclops distinctus Richard, 1887	-	✓	✓	-
Subfamily Cyclopinae				
Acanthocyclops vernalis Fischer, 1863	-	-	-	✓
Cryptocyclops bicolor Sars, 1863	-	✓	✓	-
Cyclops vicinus Ulianine, 1875	✓	✓	✓	✓
Megacyclops viridis Jurine, 1820	-	✓	✓	-
Mesocyclops leuckarti Claus, 1857	✓	✓	✓	-
Thermocyclops crassus Fischer, 1853	✓	✓	✓	-
Thermocyclops oithonoides Sars, 1863	-	-	-	✓

* according to Negrea, 2007; the order of the families according to Negrea *et al.,* 1999; species are ordered alphabetically within families;

** according to Dussart & Defaye, 2006 and Iepure, 2007; species are ordered alphabetically within subfamilies.

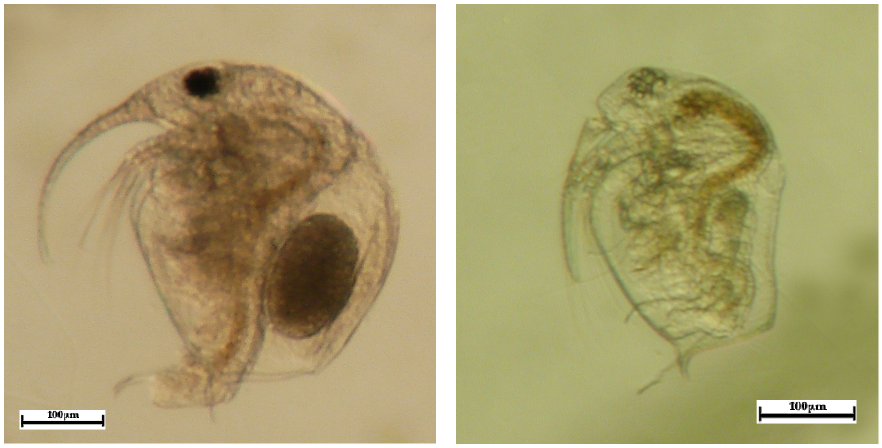


Fig. III.2.1. *Bosmina longirostris* from Lake Ştiucii: left – gamogenetic female (17.12.2004); right – male (27.11.2004)

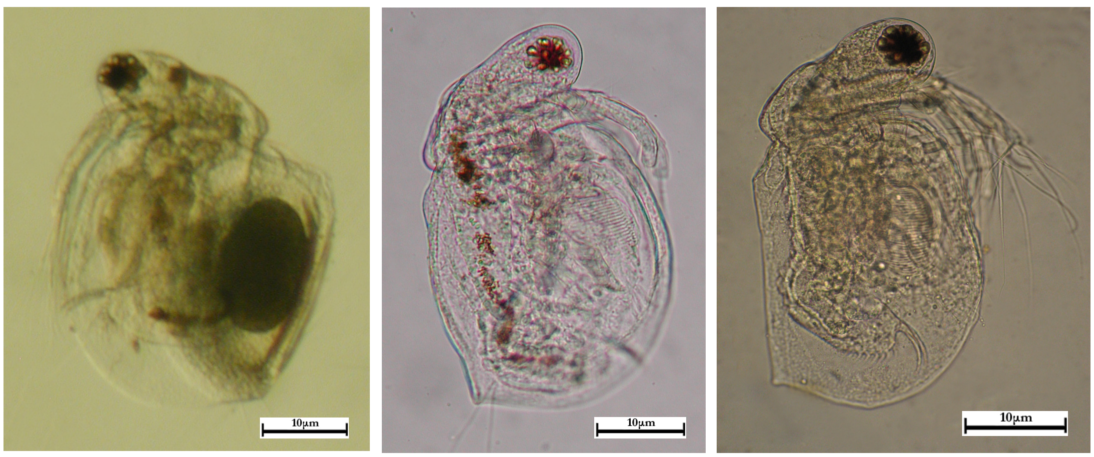


Fig. III.2.2. *Ceriodaphnia pulchella* from Lake Ştiucii: left – gamogenetic female (14.10.2003); middle – nonovigerous parthenogenetic female (14.10.2003); right – male (23.10.2004)

Fig. III.2.3. *Daphnia cucullata* from Lake Ştiucii: left - nonovigerous parthenogenetic female, 17.12.2004; middle - gamogenetic female, 17.12.2004; right – male, 14.10.03

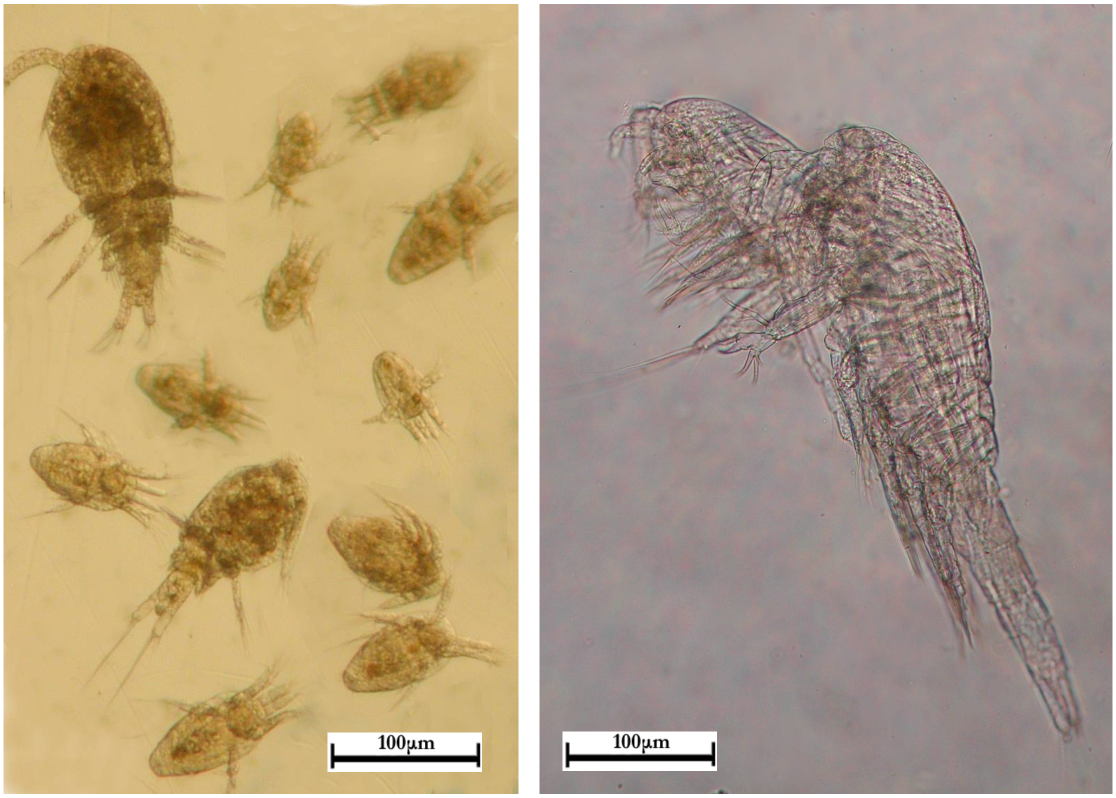


Fig. III.2.4. Nauplii and copepodites from Lake Ştiucii, 28.01.2005 (left); copepodite feeding on another copepodite in Lake Ştiucii, 20.08.2003 (right)

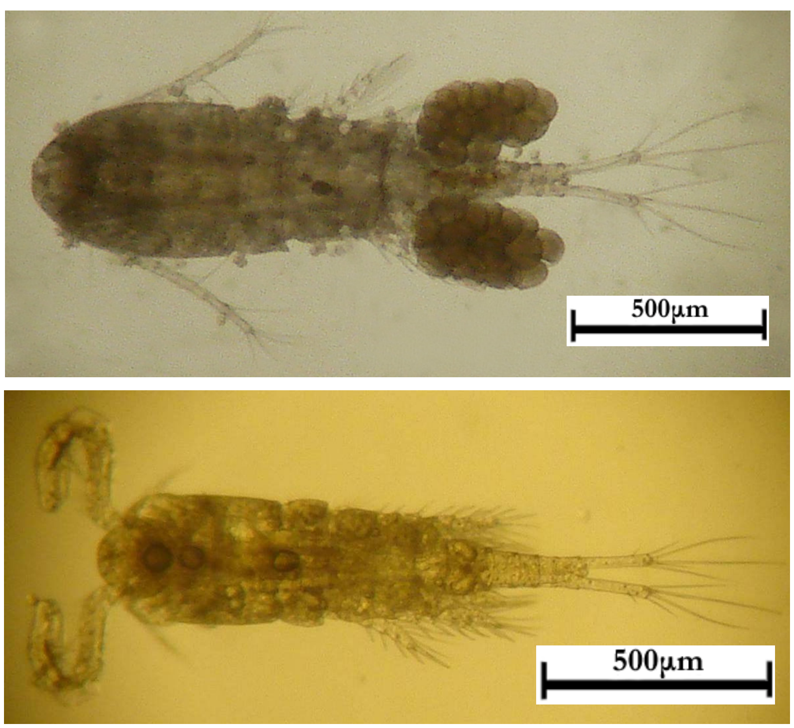


Fig. III.2.5. *Cyclops vicinus*: ovigerous female in Lake Ştiucii, 17.12.2004 (up); male from the Ţaga Mare fish pond, 21.11.2003 (down)

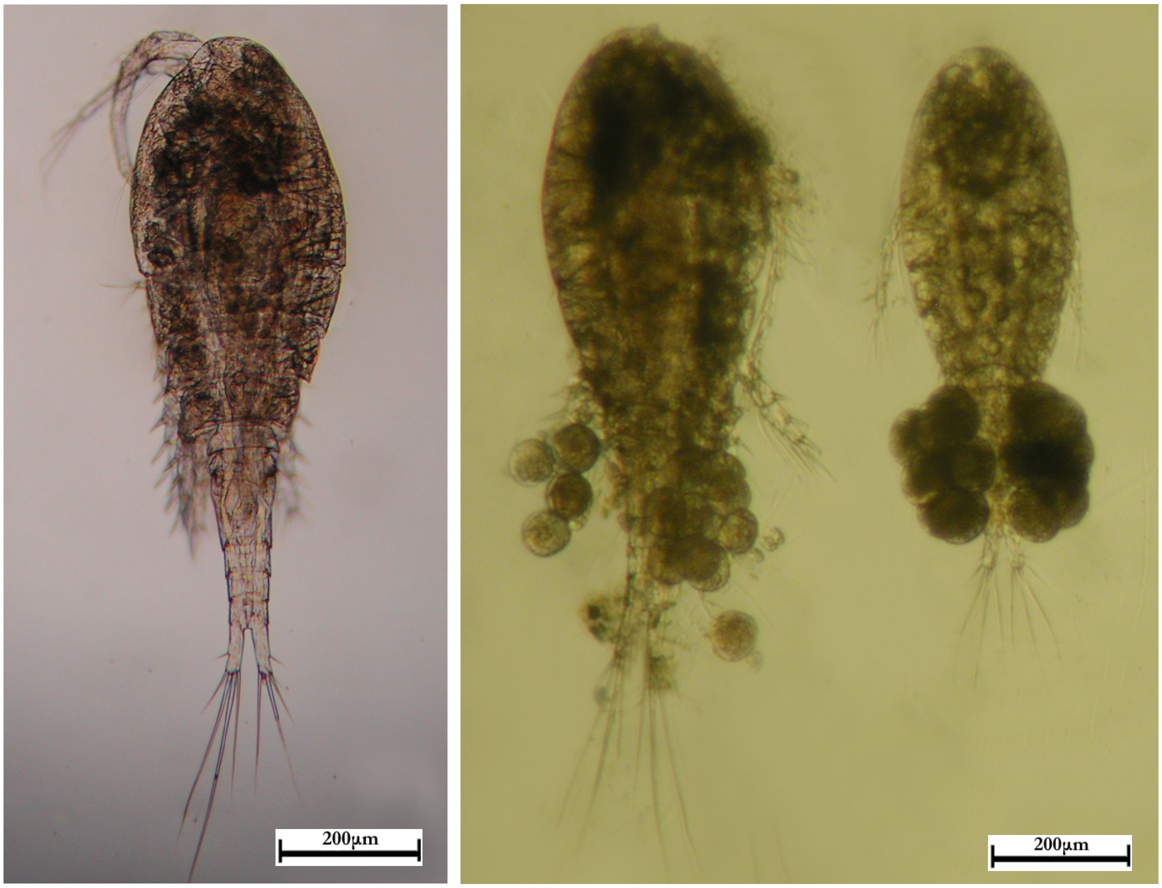


Fig. III.2.6. *Mesocyclops leuckarti*, nonovigerous female, 23.04.2005, Lake Ştiucii (left picture); *Mesocyclops leuckarti* (on the left) together with *Thermocyclops crassus* (on the right), ovigerous females, Lake Ştiucii, 30.08.2004 (right picture)

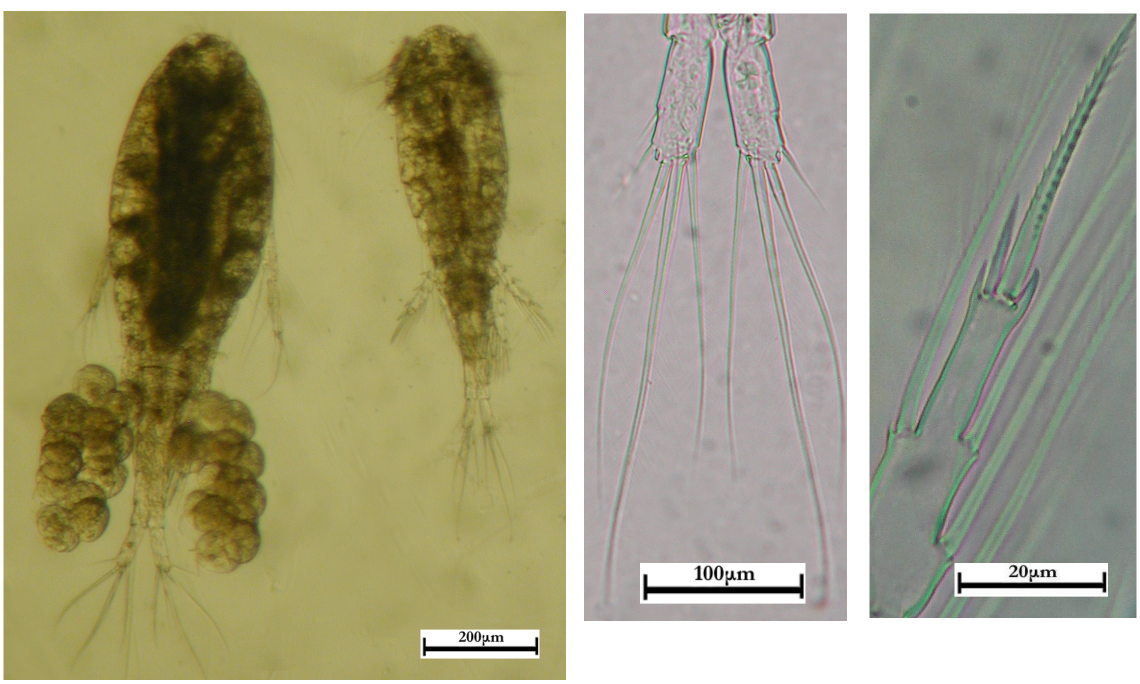


Fig. III.2.7. *Thermocyclops oithonoides* from the Ţaga Mare fish pond: ovigerous female and male, 29.06.2004 (left); male, furcal rami, 29.06.2004 (middle); the 4th pair of legs – last segment of the endopodite: an important identification character (right)

Regarding **the structure of zooplankton community from the two lakes recorded before the present study (2003-2005)**, **Lake Ştiucii** was not found in the old works of Daday, or in the chorology synthesis published by Negrea (1962). The fist data on cladocerans and cyclopoid copepods from Lake Ştiucii were included in two master thesis defended at the “Babeş-Bolyai” University, Cluj-Napoca (Echim, 2000; Mara, 2000). Six cladoceran species and three copepod species were identified, during November 1998 and October 1999. A review of the common microcrustacean species was carried out by Gudasz (2004) for a study period that stretched from January 2001 to December 2002. *Daphnia galeata galeata* and *Tropocyclops prasinus prasinus* were not found in the present paper, but **four new cladoceran species were identified (*Simocephalus vetulus, Graptoleberis testudinaria, Pleuroxus aduncus* şi *Pleuroxus laevis*), together with six cyclopoid copepod species (*Eucyclops macruroides, E. serrulatus, Macrocyclops albidus, M. distinctus, Cryptocyclops bicolor* and *Megacyclops viridis*).**

For the **Ţaga Mare fish pond,** the first microcrustacean data come from the end of the 19th century, when Daday published several papers, including 27 cladoceran species and 8 cyclopoid copepods in *“Czegei tó”* (meaning Lake Ţaga Mare) (Daday, 1884 etc.). These data were revised by Negrea for cladocerans Negrea (1966) and by Pleşa (1957) for cyclopoid copepods. Next information regarding zooplankton community from this water basin came from the 80’s, due to the unpublished results of a study conducted by the Aquaculture and Aquatic Ecology Laboratory, Piatra-Neamţ. **Considering all these previous data, four new cladoceran species *(Diaphanosoma orghidani, Ceriodaphnia pulchella, Leydigia acanthocercoides* and *Ilyocryptus sordidus),* together with two new copepod species *(Cyclops vicinus* and *Thermocyclops oithonoides)* were found in the Ţaga Mare fish pond.**

III.3. Dynamics of zooplankton density

The density (number of individuals per volume) represents an essential parameter of zooplankton communities. The density of microcrustaceans was calculated for the two lakes, Lake Ştiucii and the Ţaga Mare fish pond, together with the density of rotifers larger than 50/55 µm.

The dynamics of common species density from Lake Ştiucii confirms the general patterns described in the literature for planktonic communities. There are a few species that record high densities and high frequencies throughout the year in zooplankton communities. We called these species “common”. The rest of the species, that appeared only in a few sampling dates with lower densities were called “sporadic”. Five common species were defined in Lake Ştiucii, three cladoceran ones (*Bosmina longirostris, Ceriodaphnia pulchella, Daphnia cucullata)* and two copepod species (*Cyclops vicinus, Thermocyclops crassus*). The criteria that represented the basis for this differentiation were the following: (i) the „common" species were present at all three sampling sites (**S1**, **S2** and **S3**); (ii) they were found in at least half of all the sampling dates and (iii) the mean density value recorded for all sampling months and depths exceeded 1 ind./l.

The cladoceran *Bosmina longirostris* was identified at all sampling sites from Lake Ştiucii, at all sampling depths, recording high densities that exceptionally exceeded 500 ind./l (May 2004, **S1**, 2 m). Figure III.3.1. depicts the variation of the species density at the three sampling sites from Lake Ştiucii. The plotted values represent the averages for all depth levels at every site. Two density maxima can be observed at site **S1** during one year: one in spring and one in autumn. At sites **S2** and **S3** the spring maximum is present, but the autumn one is delayed: the species records the highest densities during colder months, apparently gaining the competition with another perennial species, *Daphnia cucullata* that recorded lower densities.

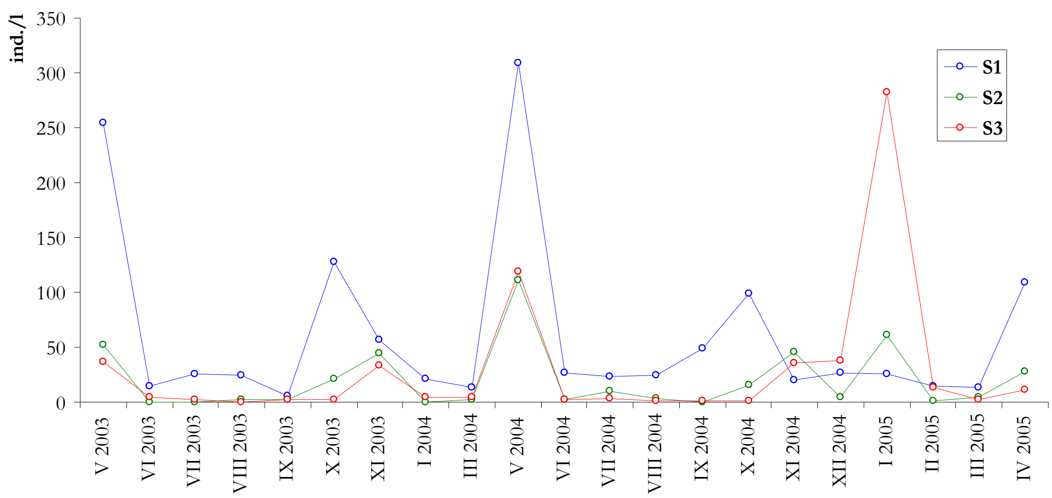


Fig. III.3.1. Dynamics of the average density for the common cladoceran *Bosmina longirostris* in Lake Ştiucii at the 21 sampling dates

A similar variation was observed for *Daphnia cucullata* (fig. III.3.2.), whose monthly average density values were also high during spring and autumn. However, *D. cucullata* recorded increased density values in summer too. The third common cladoceran species, *Ceriodaphnia pulchella*, is an "estival" species, never found during winter (fig. III.3.3.). Its maximum development was recorded in summer, but high density values were also recorded in spring and autumn.

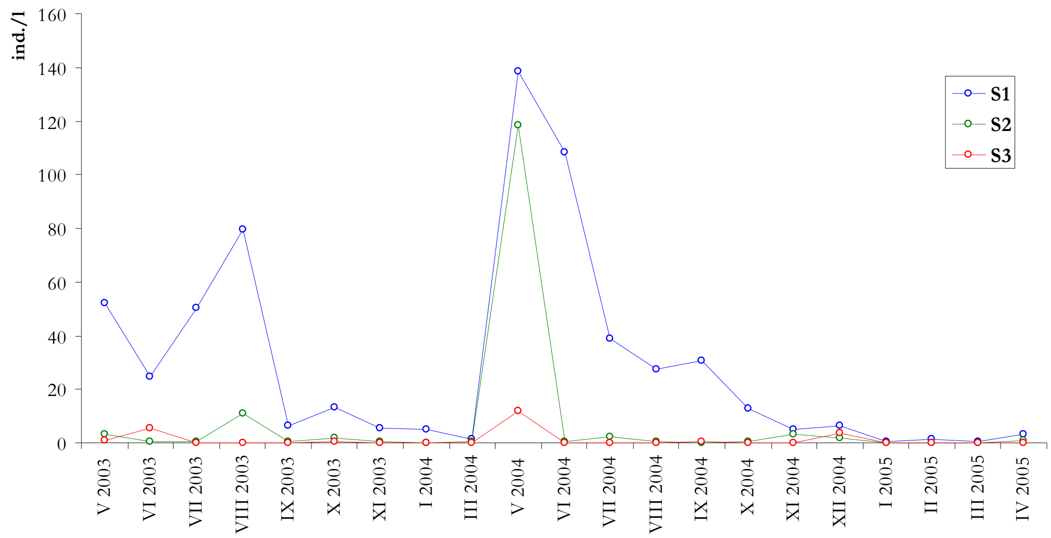


Fig. III.3.2. Dynamics of the average density for the common cladoceran *Daphnia cucullata* in Lake Ştiucii at the 21 sampling dates

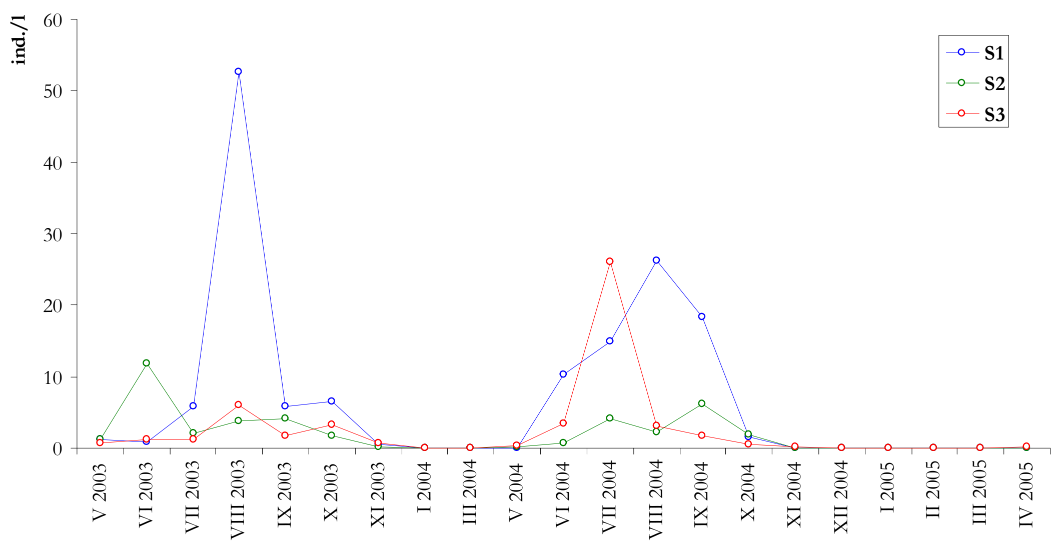


Fig. III.3.3. Dynamics of the average density for the common cladoceran *Ceriodaphnia pulchella* in Lake Ştiucii at the 21 sampling dates

The common species of cyclopoid copepods *Cyclops vicinus* is a stenothermal element, found in cold waters. Adults were identified from the end of autumn until spring (fig. III.3.4.). This variation of density is also described in the literature. A diapause period, lasting from the end of spring to the beginning of autumn is also characteristic to this species according to the literature (Hansen & Santer, 2003).

An opposite dynamics was recorded by the second common species of copepods from Lake Ştiucii, *Thermocyclops crassus*. It is also a stenothermal element, but common for warm waters. Adults were identified only during spring, summer and at the beginning of autumn (fig. III.3.5.). This species is known to enter diapause during winter.

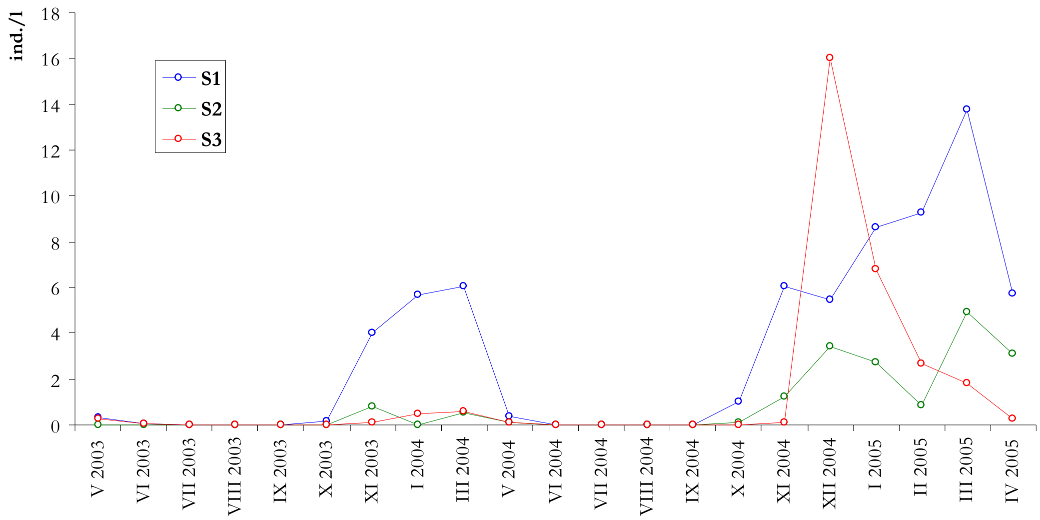


Fig. III.3.4. Dynamics of the average density for the common cyclopoid copepod *Cyclops vicinus* (adults) in Lake Ştiucii at the 21 sampling dates

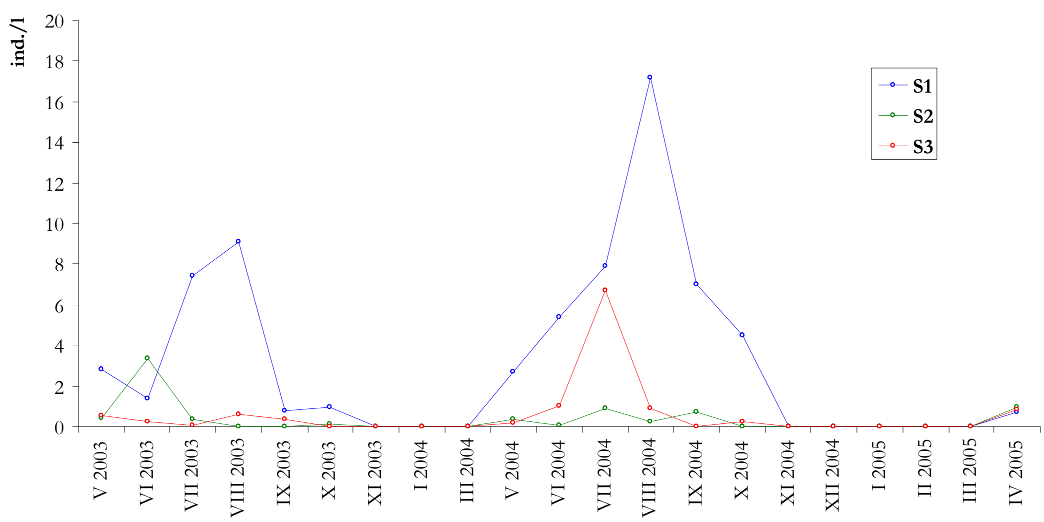


Fig. III.3.5. Dynamics of the average density for the common cyclopoid copepod *Thermocyclops crassus* (adults) in Lake Ştiucii at the 21 sampling dates

Ceriodaphnia pulchella and *Daphnia cucullata* recorded a significant positive correlation with the mean monthly water temperature, and a negative correlation with the mean concentration of dissolved oxygen. The correlation is stronger for *C. pulchella* (the estival species) because temperature represents in this case the major limiting factor for its growth (fig. III.3.6.).

Thermocyclops crassus also recorded a strong positive correlation with the mean water temperature, while *Cyclops vicinus* recorded a significant negative correlation with this parameter (fig. III.3.7.).

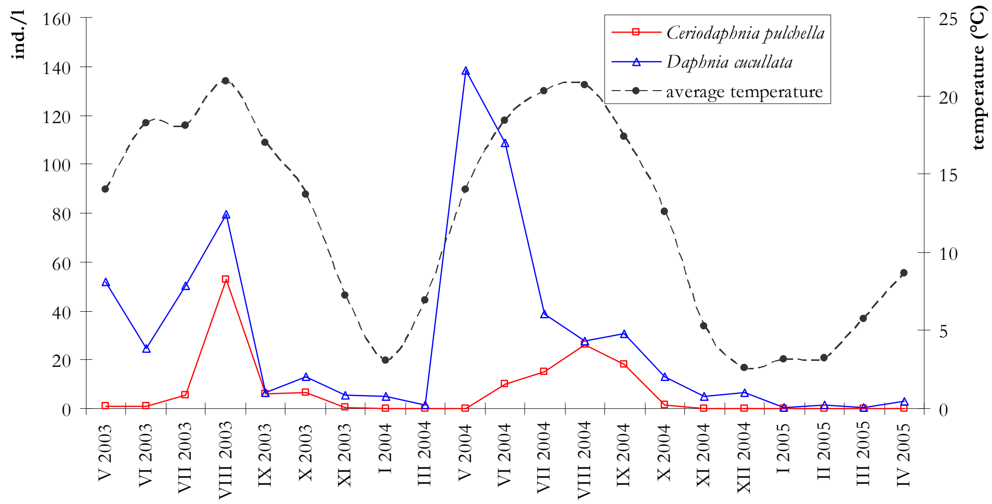


Fig. III.3.6. Variation of the average monthly densities of common cladoceran species in Lake Ştiucii, at site **S1**, together with the average water temperatures at the sampling dates

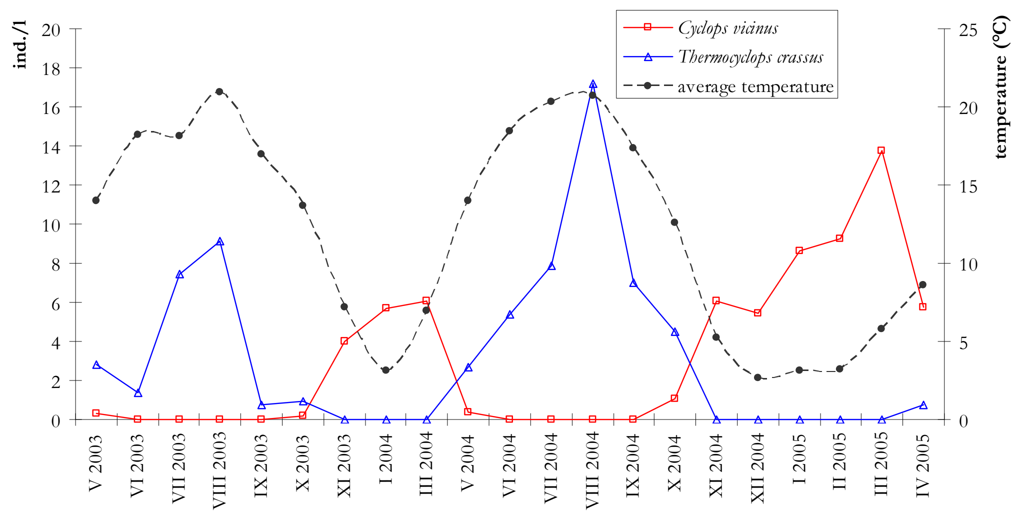


Fig. III.3.7. Variation of the average monthly densities of common cyclopoid copepod species in Lake Ştiucii, at **S1** site, together with the average water temperatures at the sampling dates

An interesting aspect regarding the correlations between species densities and physical and chemical parameters is the significant negative correlation between total phosphorus and herbivore densities (*Ceriodaphnia pulchella)* or herbivore/carnivore species (*Thermocyclops crassus*) (fig. III.3.8.). Total phosphorus (TP) represents one of the main limiting factors for algal growth. Algae are the food source for herbivory zooplankton (Mcqueen *et al.,* 1986). Thus, low TP values can reflect an algal proliferation that could sustain high herbivore densities. However, nutrients do not influence directly the zooplankton organisms, so their effects are somewhat less important than temperature.

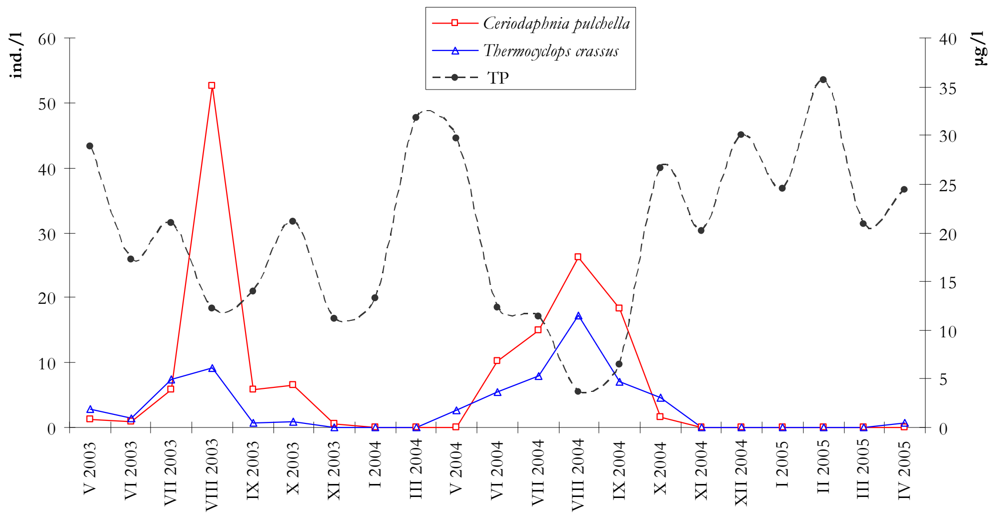


Fig. III.3.8. Variation of the average densities of herbivory species *Ceriodaphnia pulchella* and *Thermocyclops crassus* in Lake Ştiucii, together with the variation of the total phosphorus (TP)

Immature copepods dominated numerically at all sampling sites, depths and months, a typical situation for temperate lakes.

As regards **the common species from the Ţaga Mare fish pond**, they were also defined according to quantitative criteria. The common species were present at more than half of the total number of sampling dates, with mean densities that exceeded 5 ind./l. One cladoceran species (*Bosmina longirostris*) and two copepod ones (*Cyclops vicinus; Thermocyclops oithonoides*) met the criteria. Only one copepod species reached high densities during winter (*Cyclops vicinus*), while *Thermocyclops oithonoides* was identified only in warm seasons. The alternating life cycles of copepods living in the same water body represent a way to diversify their ecological niches in order to survive in the same habitat.

Zooplankton species distribution along the gradients of environmental variables is easy to visualize by means of Canonical Correspondence Analysis (CCA) ordination diagram. For the present study the ordination diagram was constructed for the species and environmental factors considered at the 21 sampling dates from site **S1** in Lake Ştiucii (fig. III.3.9.).

Daphnia cucullata, *Ceriodaphnia pulchella, Thermocyclops crassus, Pleuroxus laevis, P. aduncus, Alona rectangula, Mesocyclops leuckarti* were present usually at the sampling dates characterized by high temperatures, while *Cyclops vicinus* was identified at the dates with low temperatures. *C. pulchella* and *T. crassus* reached high densities at low total phosphorus concentrations. The positive correlation between conductivity values and the density of *Ceriodaphnia pulchella*, *Thermocyclops crassus, Pleuroxus laevis* and *Alona rectangula* might be caused by the evaporation processes occurred during summer, that could increase the conductivity in the warm season due to salt concentration.

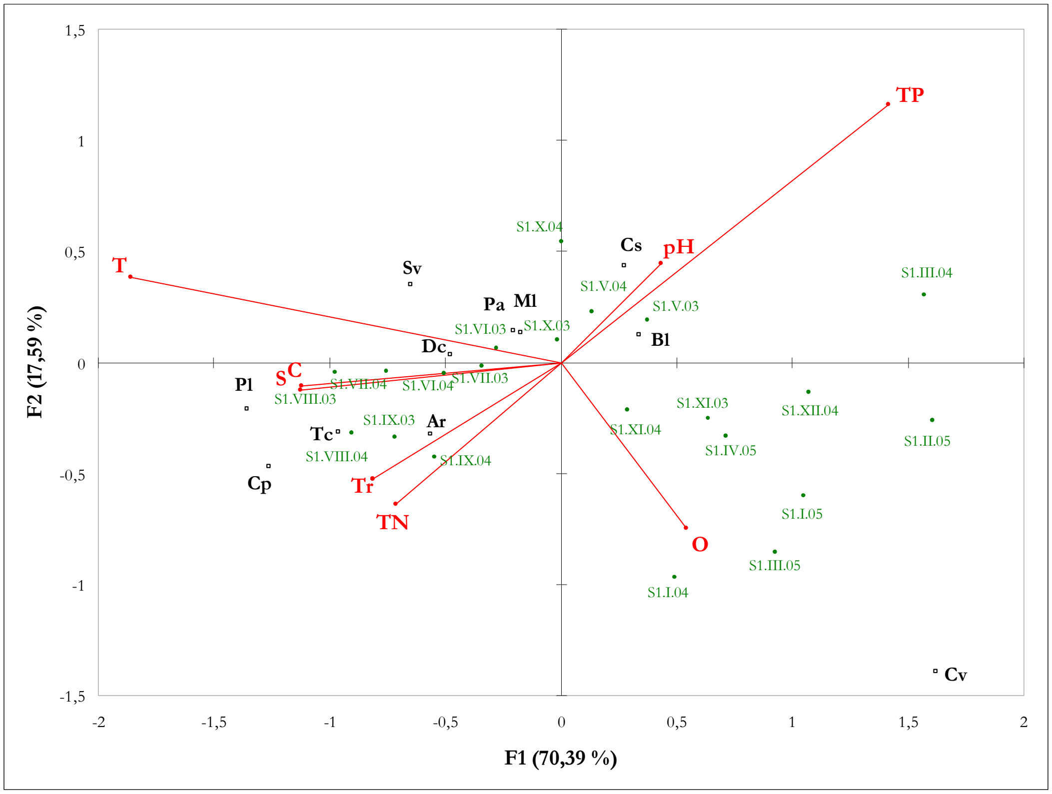


Fig. III.3.9. Canonical Correspondence Analysis (CCA) ordination diagram based on the physical and chemical parameters and the average monthly density values for the species present at site **S1** from Lake Ştiucii at the 21 dates (Roman numbers) (**S1** – site 1, **T** – temperature; **O** – dissolved oxygen; **C** – conductivity; **S** – salinity; **TP** – total phosphorus; **TN** – total nitrogen; **Tr** – transparency; ***Ar*** - *Alona rectangula;* ***Bl*** - *Bosmina longirostris;* ***Cp*** - *Ceriodaphnia pulchella;* ***Cs*** - *Chydorus sphaericus;* ***Dc*** - *Daphnia cucullata;* ***Pa*** - *Pleuroxus aduncus;* ***Pl*** - *Pleuroxus laevis;* ***Sv*** - *Simocephalus vetulus;* ***Cv*** - *Cyclops vicinus;* ***Ml*** - *Mesocyclops leuckarti;* ***Tc*** - *Thermocyclops crassus*); **axes F1 and F2: 87.98 %**

III.4. Estimation of planktonic crustacean biomass

The biomass of microcrustacean species collected at the 21 sampling dates from Lake Ştiucii and 9 dates from the Ţaga Mare fish pond was estimated using the length-weight regression equations from the literature. The biomass was expressed as dry weight for all the species.

The low values of individual weight for the common cladoceran *Bosmina longirostris* were compensated by the large number of individuals present in the water samples in Lake Ştiucii. Thus, in spite of the fact that *B. longirostris* is a small-bodied species (its length ranged between the minimum 0.175 and the maximum 0.575 mm), it recorded the highest cladoceran biomass values, exceeding occasionally 300 µg/l (January 2005, site **S3**), having an average of 52.40 µg/l at **S1**, 16.84 µg/l at **S2** and 29.12 µg/l at **S3** (fig. III.4.1.).

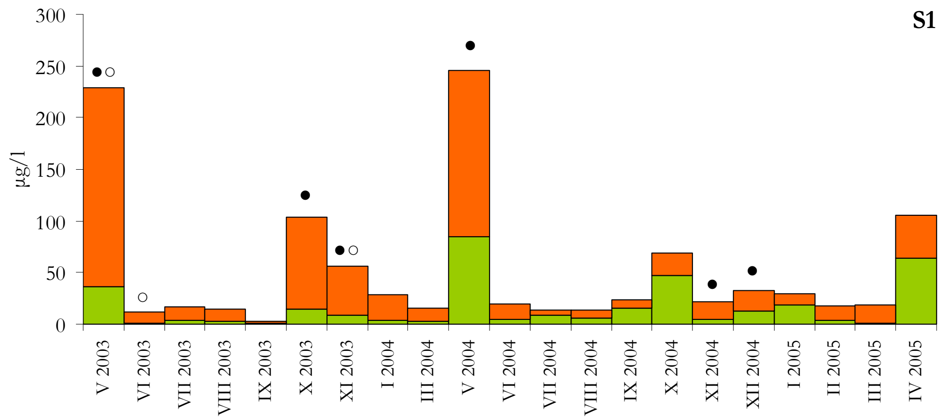


Fig. III.4.1. Variation of biomass values for the common cladoceran *Bosmina longirostris* (dry weight; µg/l) in Lake Ştiucii at **S1;** ■ nonovigerous parthenogenetic females; ■ ovigerous parthenogenetic females; ● gamogenetic females present; ○ males present

Daphnia cucullata, a larger-body species (its total length reaching 1.3-1.4 mm) recorded lower biomass values compared to *B. longirostris*, having an average of 34.31 µg/l at **S1**, 4.76 µg/l at **S2** and only 1.29 µg/l at **S3**. *D. cucullata* recorded maximum biomass values in spring/summer at the three sampling sites from Lake Ştiucii, even if it was also identified under ice.

For the estival species *Ceriodaphnia pulchella*, the maximum biomass values were the same with the density ones (during summer).

The biomass values recorded by copepods followed the density dynamics and different individual weights of the species. *Cyclops vicinus* recorded high biomass values during cold months, while no adult was found in summer. An interesting situation was revealed in the second year of the present study (December 2004 - March 2005), when the biomass values reached by *C. vicinus* were higher compared to the previous year (November 2003 - March 2004), even if the values were not significantly different from a statistical point of view (fig. III.4.2.).

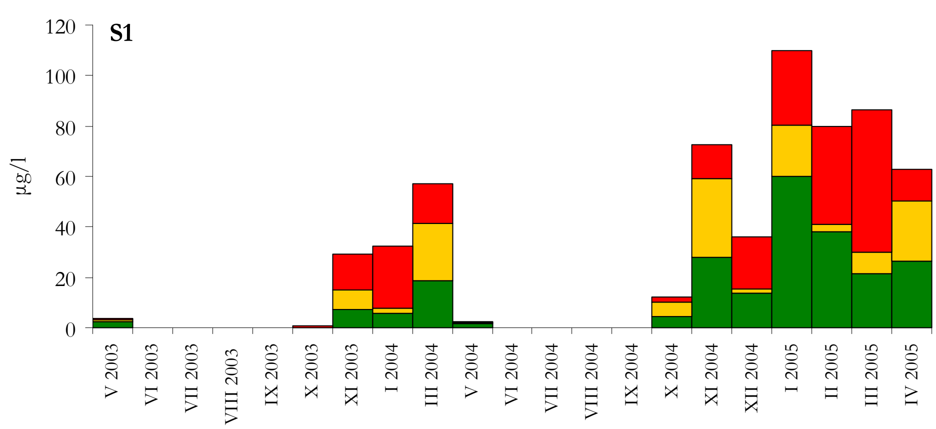


Fig. III.4.2. Variation of biomass values for the common copepod species *Cyclops vicinus* (dry weight; µg/l) in Lake Ştiucii at **S1;** ■ nonovigerous females; ■ ovigerous females; ■ males

Large *C. vicinus* copepodites and adults represent the main predators in the ecosystems with high rotifer densities (Walz, 1995). A significant negative correlation was observed in Lake Ştiucii between the *C. vicinus* density and the rotifers at all three sampling sites (according to the Spearman rank coefficient; p=0.004) (fig. III.4.3.). Thus, the higher biomass values recorded by *C. vicinus* at the beginning of 2005 could be caused by the density peaks reached by rotifers in May and October 2004.

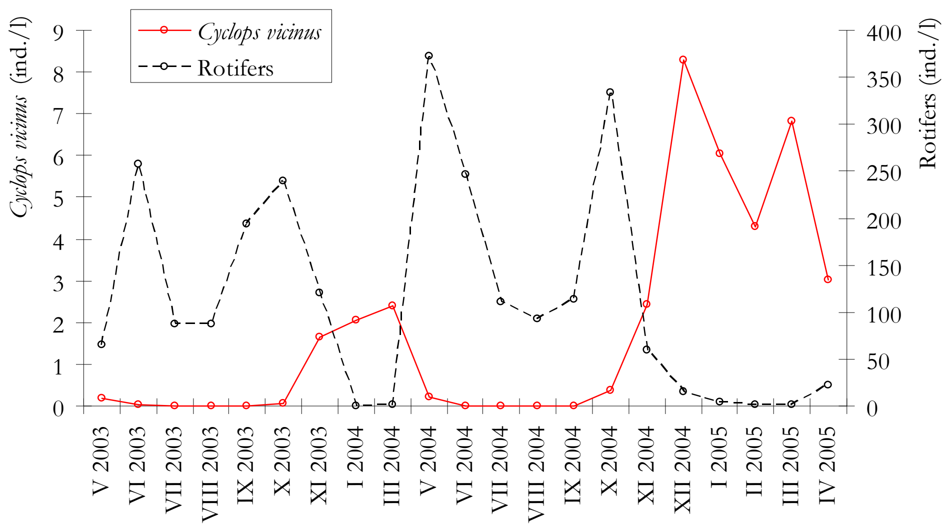


Fig. III.4.3. Density dynamics of cyclopoid copepod *Cyclops vicinus* and rotifers at the 21 sampling dates (mean values for the three sampling sites in Lake Ştiucii)

The biomass of the copepod *Thermocyclops crassus* recorded an opposite variation compared to the previous species, with maximum values in May and October and with total absence during winter. Biomass values are much lower because of the smaller size of this species (the maximum length being 0.825 mm, without furcal rami). *T. crassus* shares the same feeding patters with *C. vicinus* (Brandl, 2005), being an opportunistic species, herbivory and predatory, feeding also on rotifers. Figure III.4.4. depicts the relationship between the densities of *T. crassus* and rotifers considering the mean values recorded at the three sampling sites **S1**, **S2** and **S3**.

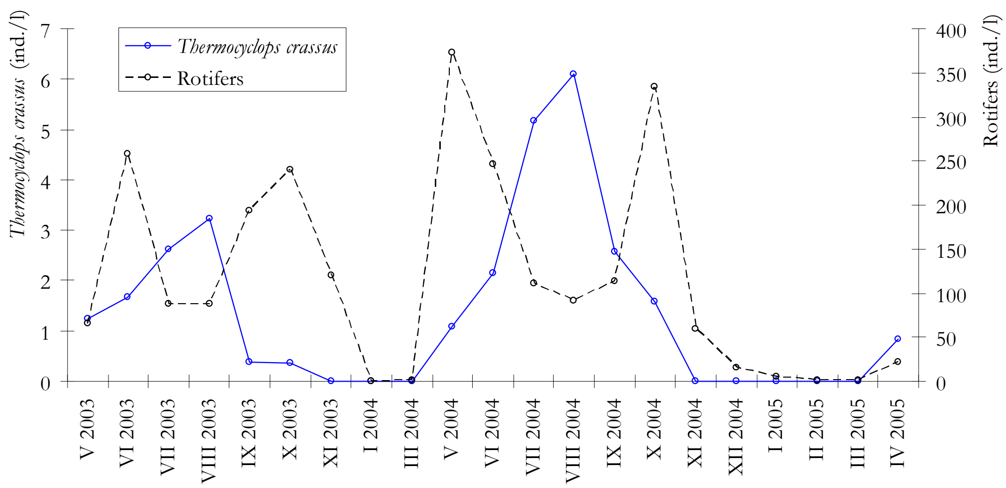


Fig. III.4.4. Density dynamics of cyclopoid copepod *Thermocyclops crassus* and rotifers at the 21 sampling dates (mean values for the three sampling sites in Lake Ştiucii)

A very efficient method to categorize the microcrustacean species according to their biomass and frequency is calculation of the **I**ndex of **C**enotic **S**ignificance (**ICS**), also called Index of Dominance) (Metodika izucheniya, 1975, from Rogozin, 2000). The classification of species according to their dominance (in dominant, codominant and subdominant species) (table III.4.1.) is very important for the characterization of the planktonic crustacean community.

Table III.4.1. List of dominant, codominant and subdominant microcrustacean species at the four sampling sites from Lake Ştiucii and the Ţaga Mare fish pond, according to the **I**ndex of **C**enotic **S**ignificance (**ICS**)

Lake/site	**Dominant species**	**Codominant species**	**Subdominant species**
Lake Ştiucii, **S1**	*Bosmina longirostris*	*Daphnia cucullata*	*Cyclops vicinus* *Thermocyclops crassus* *Ceriodaphnia pulchella*
Lake Ştiucii, **S2**	*Bosmina longirostris*	*Daphnia cucullata*	*Cyclops vicinus* *Simocephalus vetulus* *Ceriodaphnia pulchella*
Lake Ştiucii, **S3**	*Bosmina longirostris*	*Cyclops vicinus*	*Simocephalus vetulus* *Daphnia cucullata* *Ceriodaphnia pulchella*
The Ţaga Mare fish pond	*Bosmina longirostris*	*Cyclops vicinus*	*Thermocyclops oithonoides* *Moina brachiata* *Daphnia galeata*

III.5. Diversity of planktonic crustacean communities

The Shannon-Wiener index was calculated for the estimation of diversity in Lake Ştiucii and in the Ţaga Mare fish pond, considering the biomass values for microcrustacean species, without immature copepods (nauplii and copepodites). Because the three sampling sites in Lake Ştiucii had different numbers of species, the Shannon-Wiener index was calculated for each site separately (fig. III.5.1.). At most sampling dates, the highest diversity was recorded at site **S3**, located in the Southern gulf of the lake, completely surrounded by a reed curtain that isolates it from the main water body. The macrophytes are common in this sampling site during the vegetation season, thus numerous different hiding places are created for the microcrustacean species. The equitability values followed a similar pattern.

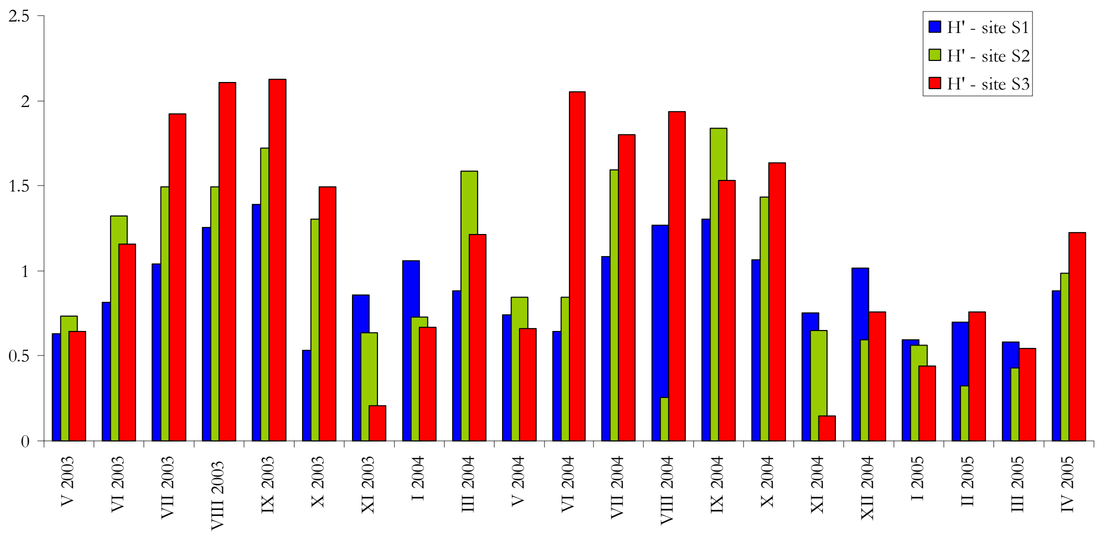


Fig. III.5.1. The Shannon-Wiener index (H') for the microcrustacean communities from the three sampling sites from Lake Ştiucii at the 21 sampling dates

A significant negative correlation was recorded in Lake Ştiucii between the Shannon-Wiener diversity and the total microcrustacean biomass (obtained by summing the biomass values for each species, except for the nauplii and copepodites) (according to the Spearman rank coefficient; p=0.001) (fig. III.5.2.). This opposite variation is explained by the fact that high values of biomass can only be recorded by one or two species at a time, thus creating an unevenness that decreases the Shannon-Wiener diversity values.

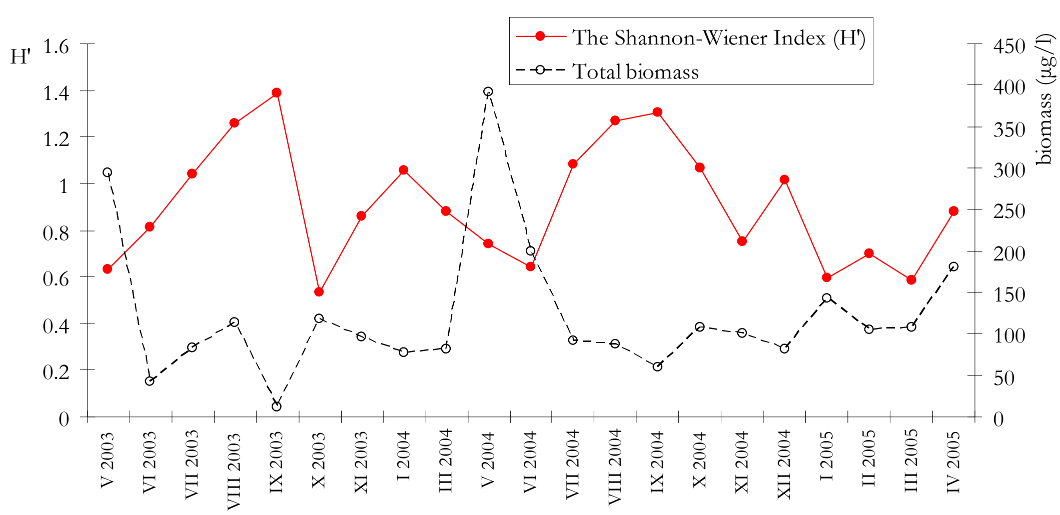


Fig. III.5.2. The variation of the Shannon-Wiener diversity (H') and of the total microcrustacean biomass at the 21 sampling dates in Lake Ştiucii, site **S1**

A significant positive correlation was calculated between the Shannon-Wiener diversity and the mean water temperature (according to the Spearman rank coefficient; p=0.019). The high diversity values in warm months are explained by the large number of cladocerans and cyclopoid copepods with optimal development at high temperatures. A negative correlation was observed between diversity values and the total phosphorus concentration (according to the Spearman rank coefficient; p=0.02). This opposite dynamics can be explained by the algal communities that need high values of nutrients to develop. Thus, low TP concentrations might reflect algal proliferation and also zooplankton high density and diversity values.

In the Ţaga Mare fish pond, the Shannon-Wiener diversity and equitability were comparable with those in Lake Ştiucii, site **S1**, considering the amplitude of variation. However, the mean diversity value was lower in Lake Ţaga Mare compared to Lake Ştiucii.

IV. The vertical distribution of planktonic crustaceans from Lake Ştiucii

Zooplankton individuals occupy different depth levels in different moments of the day. Thus, we can define the diel vertical migration, a common phenomenon occurring in plankton communities (Pearre, 2003). The diel migration patters are very diverse, they can vary from one species to another but also for the same species from one season to another (Lampert & Sommer, 2007).

Six microcrustacean species were considered for the study of diel vertical migration, together with the copepodites, at four different sampling dates: October 2004; January, April and July 2005. In order to test the diel vertical migration the nonparametric test Kolmogorov-Smirnov was used. The distributions in the water column were compared during daytime (as the average between the biomass values recorded at 08:00, 12:00 and 16:00 o'clock) and nighttime (as the average between the biomass values recorded at 20:00, 00:00 and 04:00 o'clock). The weighted mean depth was also calculated according to Frost & Bollens, 1992.

Generally speaking, no clear diel vertical migration was observed in Lake Ştiucii, due to the shallow depth of the water body (the maximum depth is 6,75 m). However, the nonparametric tests used showed significant differences in species distributions during night and day.

For most cladoceran species considered for this diel migration study, a minimum biomass value was recorded at 16:00 o'clock (during the day). This unevenness between day and night in Lake Ştiucii can be due to the retreat of most of the animals at the bottom of the lake, near the sediments (thus escaping the sampling gear), probably to avoid predators that hunt visually (like fishes).

The cladoceran *Bosmina longirostris* is the only species with diel vertical migrations in all four seasons sampled. Significant results were obtained by applying the Kolmogorov-Smirnov test

(D=0.714; p=0.05 in October 2004; D=0.714; p=0.05 in January 2005; D=0.857; p=0.008 in April 2005; D=0.857; p=0.008 in July 2005). Figure IV.1. presents the differences between the weighted mean depths during nighttime and daytime in the four sampling dates. During the day the species prefers the deeper layers and during the night it moves up into the water column, thus following a "normal" migration pattern. The migration amplitudes are small: 0.42 m in October 2004; 0.86 m in January 2005; 0.32 m in April 2005 and 1.13 m in July 2005.

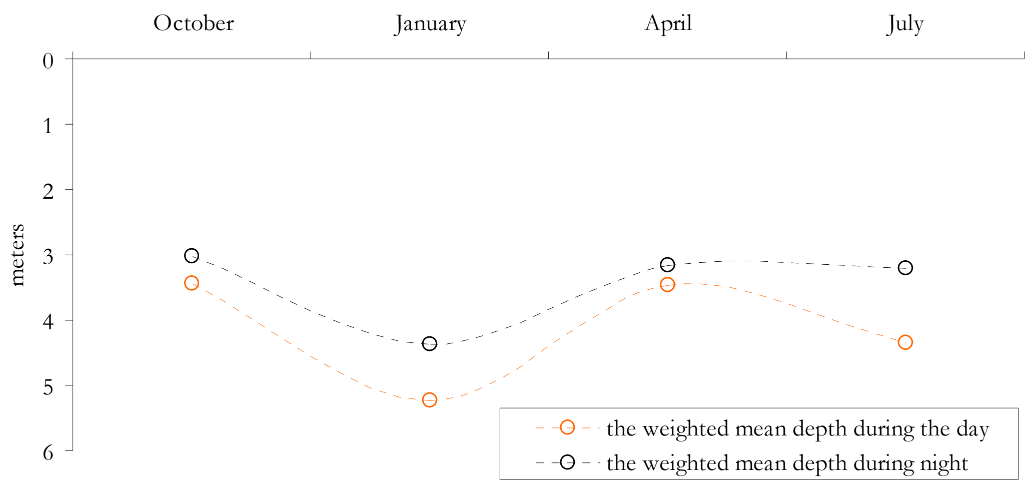


Fig. IV.1. Variation of the weighted mean depth for the cladoceran *Bosmina longirostris* in the four sampling months in Lake Ştiucii

Using the same methods, the diel vertical migration was proved for the cladoceran *Ceriodaphnia pulchella* in October 2004 and July 2005, but also for the cladoceran *Daphnia cucullata* in October 2004 and January 2005.

The copepod species *Cyclops vicinus* recorded significant differences from day to night only in April 2005. The other two copepod species considered for the migration study, *Mesocyclops leuckarti* and *Thermocyclops crassus* had different distributions during day compared to nighttime only in July 2005. The migration amplitudes were generally higher for adult copepods, probably due to the higher swimming velocities compared to the filter-feeding cladocerans. The migration pattern was in all cases discussed above a normal one.

In case of copepodites, significant differences in their distributions were recorded in January and April 2005. In April they had a "normal" vertical migration with an amplitude of 0.58 m, while in January they followed an inverse vertical migration, with a very low amplitude (-0.16 m) (fig. IV.2.). The explanation of this inverse vertical migration could be the advantage of feeding near the surface during daytime, but also the invertebrate predator pressure (like the dipteran larvae *Chaoborus* sp.).

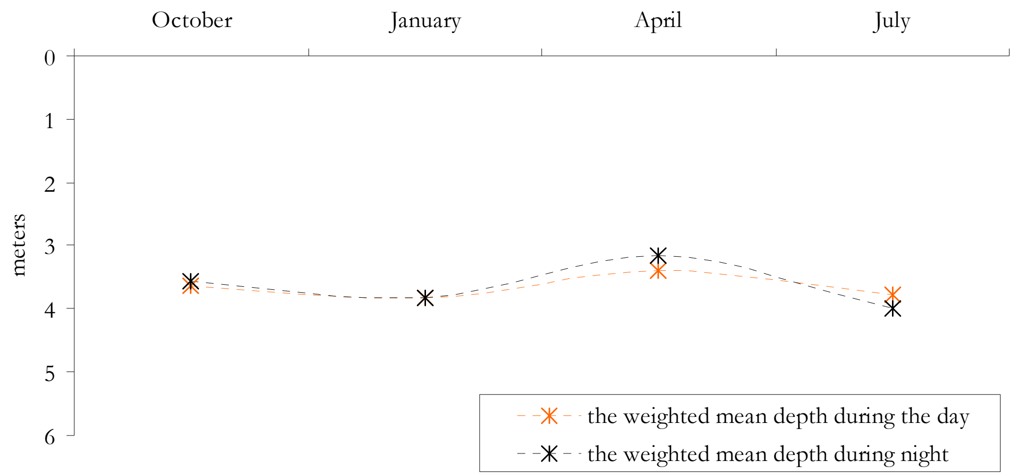


Fig. IV.2. Variation of the weighted mean depth for cyclopoid copepodites in the four sampling months in Lake Ştiucii

A negative correlation was observed in January 2005 between nauplii and copepodites on the one hand and the number of *Chaoborus* larvae on the other hand (fig. IV.3.).

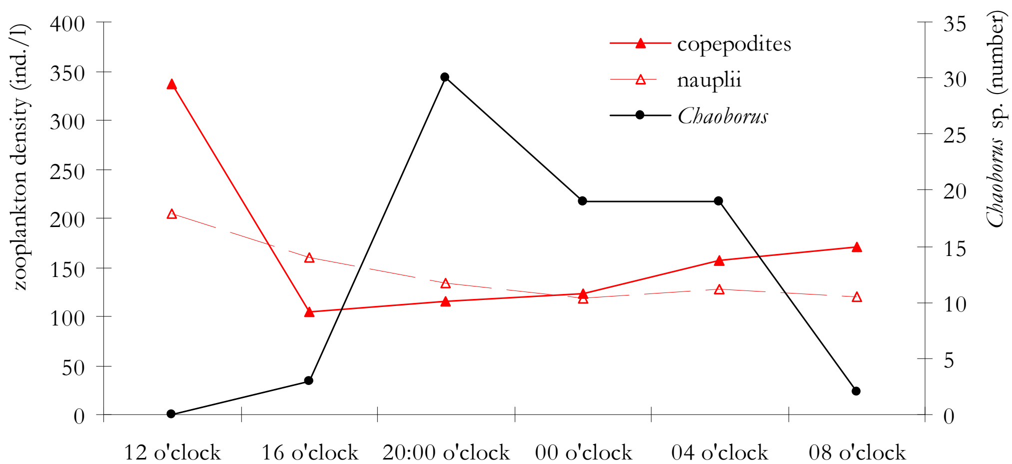


Fig. IV.3. The mean density variation of nauplii and copepodites together with the variation of the number of *Chaoborus* sp. larvae identified at different times in January 2005, Lake Ştiucii, site **S1**, (density refers to average values for all depth layers)

V. The occurrence of planktonic crustaceans in the diet of fish populations from Lake Ştiucii

Zooplankton community represents food for numerous fish species, both adults and juveniles. Ten fish species were identified in the fishing campaign from July 2004. Only goldfish was not captured with the gill nets due to the small size of the individuals dwelling shallow waters. Rudd was the most abundant and frequent species. It was followed by roach and bleak. Large-bodied species were well represented too (bream and tench). The herbivore species (like rudd) had the highest abundance values, due to the rich aquatic vegetation from Lake Ştiucii. Omnivore species (bleak) and detritivore species (roach) had also favorable feeding conditions.

These numerous species assured the presence of a well represented carnivorous population (of pike or perch), that represented about 15% from the existing biomass (K.W. Battes & Stoica, 2006).

The 56 fishes whose gut content was analyzed for the present study had different ages, mostly 3+ and 4+ (3 and 4 years and one summer). The individual age was calculated based on scales (K.W. Battes & Stoica, 2006).

Several groups of organisms were observed in the fifty-six fish stomachs: algae, macrophytes, rotifers, nematodes, mollusks, water mites, crustaceans, insects and fishes. The identification and counting of some of these taxonomic groups was difficult due to their intense fragmentation.

All eight fish species stomachs contained zooplanktonic microcrustaceans. Figure 1 presents the percentage of fish guts that included cladocerans and copepods. In case of bleak, bream, tench and crucian carp the percentage of occurrence for these groups exceeded 50%, while the lowest value was recorded for perch.

Eight species of microcrustaceans were identified in fish stomachs from Lake Ştiucii: 6 cladocerans (*Alona rectangula, Bosmina longirostris, Ceriodaphnia pulchella, Chydorus sphaericus, Daphnia cucullata* and *Simocephalus vetulus*) and 2 copepods (*Mesocyclops leuckarti* and *Thermocyclops crassus*).

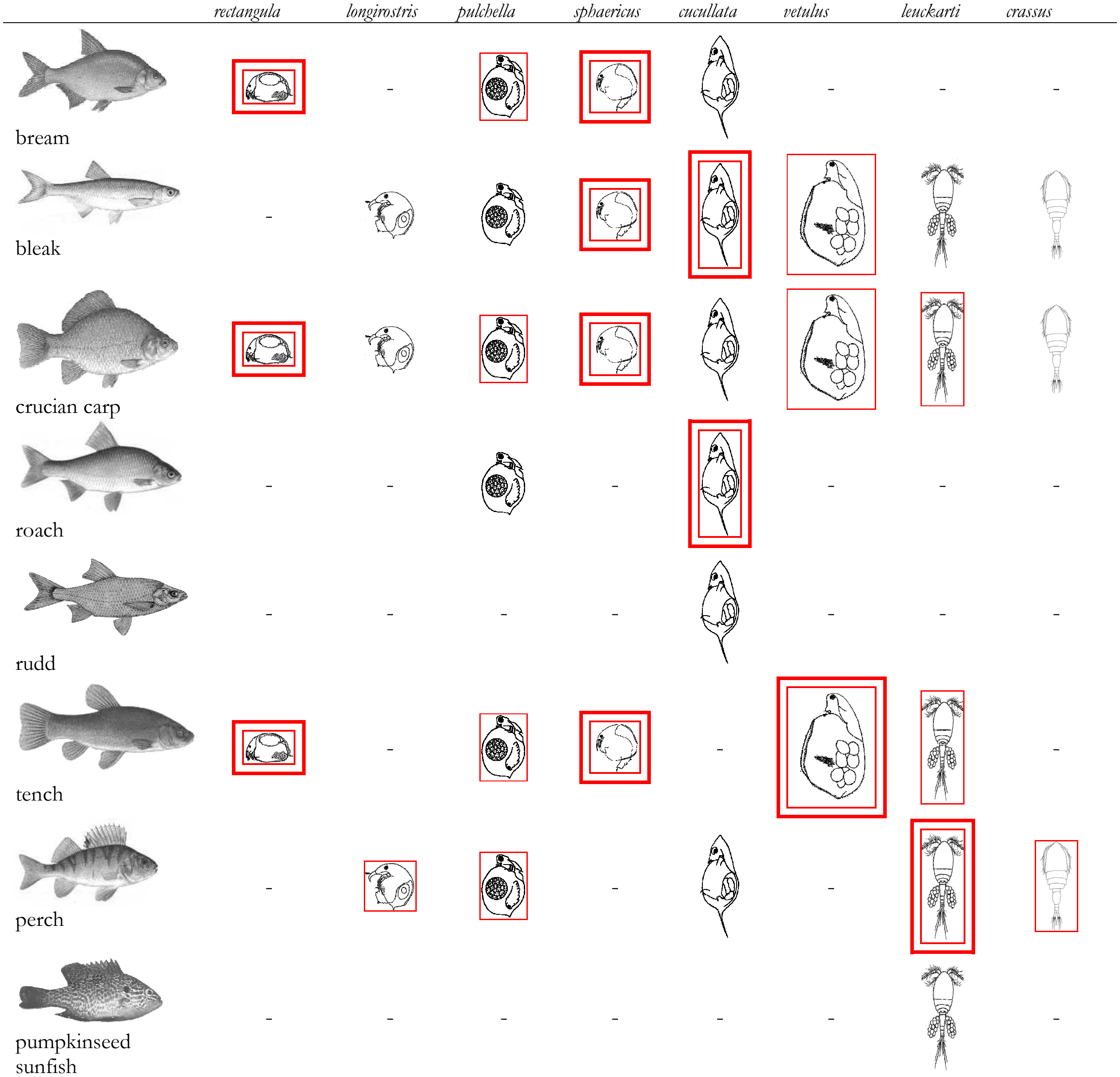
Most of the cladoceran individuals were well preserved and easy to recognize. All of them were parthenogenetic females. The majority of copepod individuals were partly destroyed probably due to their particular body morphology. Nauplii were not observed.

Two indices of dietary preferences were calculated: the selection index w and the Manley's α. The basic principle of the both indices is the comparison between the availability of the prey species in the environment and the presence in the predator's stomachs. The density of the microcrustacean species was calculated as the average values of the density for the summer 2004 (ind./l).

Table V.1. presents the dietary preferences of the eight fish species from Lake Ştiucii, according to the indices considered. Generally speaking, fishes prefer middle and large-bodied microcrustacean species, like *Ceriodaphnia pulchella, Daphnia cucullata, Simocephalus vetulus* or *Mesocyclops leuckarti*, as stated in the literature (Werner, 1974; Lampert, 1987 etc.).

However, small bodied species like *Alona rectangula* and *Chydorus sphaericus* were declared preferred according to the indices used in every fish stomach they appeared into. This result might be somewhat erroneous because the index values are influenced by the availability of the species in the environment. In this particular case, the densities of *A. rectangula* and *C. sphaericus* were extremely low during that summer (0.0183 ind./l for the first species and 0.0178 ind./l for the second one).

Table V.1. Synthetic list of microcrustacean species eaten by the eight fish species from Lake Ştiucii (the fine red border shows the food categories preferred according to the **w** selection index; the bold red border depicts the dietary preferences according to the Manley's **α**)



FISH SPECIES	PLANKTONIC MICROCRUSTACEAN SPECIES *Alona rectangula*	*Bosmina longirostris*	*Ceriodaphnia pulchella*	*Chydorus sphaericus*	*Daphnia cucullata*	*Simocephalus vetulus*	*Mesocyclops leuckarti*	*Thermocyclops crassus*
bream		-				-	-	-
bleak	-							
crucian carp								
roach	-	-		-		-	-	-
rudd	-	-	-	-		-	-	-
tench		-			-			-
perch	-			-		-		
pumpkinseed sunfish	-	-	-	-	-	-		-

VI. Assessment of lake ecological status based on planktonic crustacean communities

Including the zooplankton community in studies of assessing water ecological status generates a complete image of water quality, because it represents an important link in lentic food chains, feeding on algae, detritus and bacteria and being eaten by invertebrate and vertebrate predators.

All dominant and codominant species in both water bodies (according to the **I**ndex of **C**enotic **S**ignificance ICS) (Metodika izucheniya, 1975, from Rogozin, 2000) are known to indicate relatively clean waters considering the saprobity (oligo- to β mesosaprobic systems). In the Ţaga Mare fish pond, one of the subdominant species, the cladoceran *Moina brachiata,* indicates waters with large quantities of decomposing organic matter (even polisaprobic waters) The saprobic index according to Zelinka & Marvan (1961) recorded 1.57 for Lake Ştiucii ("slightly polluted") and 1.8 for the Ţaga Mare fish pond ("moderated pollution").

Similarly, most dominant, codominant and subdominant species from Lake Ştiucii develop in meso-eutrophic waters (*Daphnia cucullata, Cyclops vicinus, Thermocyclops crassus*), while most species from the Ţaga Mare fish pond prefers eutrophic waters (*Bosmina longirostris, Moina brachiata, Daphnia galeata*).

A negative relationship was observed between the **T**rophic **S**tate **I**ndex (**TSI**) and the Shannon-Wiener diversity, based on biomass values, for both water bodies. This confirms the hypothesis that states that the lower the trophic state of la lake, the more complex its structure and diversity (Margalef, 1958).

High biomass values together with low Shannon-Wiener diversity usually reflect the development of only a few species from the community (table VI.1.).

Table VI.1. The main structure and functional parameters of planktonic microcrustacean community from the four sampling sites, together with the **T**rophic **S**tate **I**ndex (**TSI**)

Lake; site	**TSI**	**B (μg/l)**	**H'**	**ICS for the dominant species**	**Σ ICS**
Lake Ştiucii **S1**	45.42±3.51	221.4706	0.91	723.8604	2019.689
Lake Ştiucii **S2**	-	63.46148	1.02	410.3912	1161.908
Lake Ştiucii **S3**	-	130.6041	1.19	539.6441	1339.071
Lake Ţaga Mare	77.8±4.22	300.0001	0.69	956.6986	2096.178

TSI – The **T**rophic **S**tate **I**ndex – **TSI**); **B** – total biomass (dry weight); **H'** – the Shannon-Wiener diversity; **ICS** – The **I**ndex of **C**enotic **S**ignificance –**ICS**;
Σ ICS – the sum of **ICS** values for all the species at the sampling site

The **T**rophic **S**tate **I**ndex (**TSI**) (calculated according to the total phosphorus values) could be related to the total biomass values (calculated as the averages of the biomass recorded by different species at the sampling dates). In Lake Ştiucii this correlation was positive and statistically significant (according to the Spearman rank coefficient; $p = 0.019$). The higher the nutrient concentration, the higher the possibility for algae to develop, thus allowing a diverse and rich zooplankton community. In the Ţaga Mare fish pond, a negative correlation was observed between these parameters (however not statistically significant according to the Spearman rank coefficient; $p = 0.108$). The **TSI** values for this water body exceeded 70 in most of the sampling dates, indicating hypertrophy. Thus, in these conditions (favoring algal blooms, decreases in oxygen concentrations, decreased transparency etc.) the microcrustacean biomass decreases (fig. VI.1.).

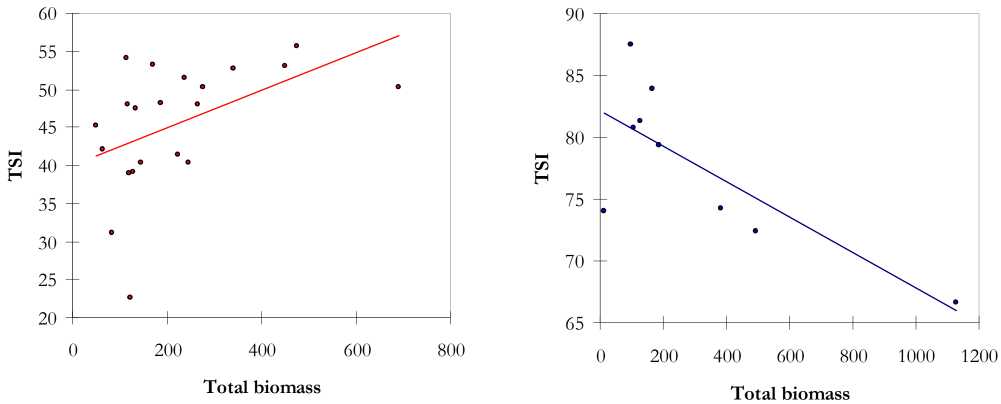


Fig. VI.1. The correlation between the **T**rophic **S**tate **I**ndex (**TSI**) and the total biomass for the 21 sampling dates in Lake Ştiucii, **S1** (left) and for the 9 sampling sites from the Ţaga Mare fish pond (right)

Table VI.1. also shows that increases of **T**rophic **S**tate **I**ndex are happening at the same time with increases of the **I**ndex of **C**enotic **S**ignificance for the dominant species, but also the sum of **ICS** values for all the species present in the community. Thus, the zooplankton structure simplifies and the dominance of a small number of species becomes prevalent once the trophicity of aquatic ecosystems increases.

One **biotic index** was calculated for the present study: the ratio between large cladocerans (C_l) and the density of all cladoceran species (C_t) (Moss *et al.,* 2003, din Török *et al.,* 2008). The Cl/C_t ratio recorded 0.299 for Lake Ştiucii, indicating moderate ecological status; and 0.021 for the Ţaga Mare fish pond, showing bad ecological status. Another way to analyze these results would be the following: small bodied species become more and more abundant in spite of the large ones once the waters become more eutrophic (Hillbricht-Ilkowska, 1977).

The results obtained during the present study from the **Ţaga Mare** fish pond were compared with certain data gathered during 1984 and 1986 by M.I.A.A.P.A., C.P.I.P. Bucureşti, C.C.P.P.P.I.P. Galaţi and the Research and Fish Production Station Podu Iloaiei, represented by the Aquaculture and Aquatic Ecology Laboratory, Piatra-Neamţ.

A calanoid copepod (*Calanipeda aquae-dulcis*) was identified in 1984 in the Ţaga Mare fish pond. The fact that in 2003/2004 this species was not found might reflect the gradual eutrophication of this water body. The calanoid copepod biomass decreases once the trophicity of the system increases, and cyclopoid copepods take over. Nicholls & Tudorancea (2001) relate the disappearance of some calanoid species to lower oxygen concentrations and to significantly higher total phosphorus concentrations. These tendencies can be observed also in the Ţaga Mare fish pond during 20 years (table VI.2.).

Table VI.2. Abiotic parameters and the biomass of planktonic microcrustaceans in different years

Years	TP (µg/l)	O (mg/l)	Cladoceran and copepod biomass (µg/l)
1984	90	14.4	1410.533
1985	170	13.42	-
1986	180	6.65	1062.079
2003/2004	180	7.17	300.0001

VII. Conclusions

The following synthetic conclusions can be drawn in the present study:

1. The qualitative structure of the microcrustacean communities included 19 species in Lake Ştiucii (out of which 10 was first cited for the lake) and 12 species in the Ţaga Mare fish pond (6 cited for the first time for the region);
2. Microcrustacean density and biomass recorded a pronounced seasonal dynamics in both water bodies. Not only the qualitative composition and the quantitative parameters were influenced mainly by temperature, nutrient concentration and predator pressure;
3. The diel vertical migration was proved for 3 cladoceran species and 3 cyclopoid copepod species, but also for the copepodites in Lake Ştiucii;
4. Stomach content analyses for eight fish species in Lake Ştiucii showed fish dietary preferences for middle and large-bodied microcrustaceans, but also for small-bodied ones;
5. Cladoceran and cyclopoid copepod communities were successfully used to assess the ecological status of Lakes Ştiucii and Ţaga Mare. Several population parameters were used (biomass, diversity, cenotic significance of species), together with biotic indices (saprobic index, large cladocerans / total cladocerans ratio).

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