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Qualitative and quantitative investigation of the zooplankton in fish ponds

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ABSTRACT

Investigations on two Hungarian pond systems aimed to evaluate zooplankton species as a utilizable feed source for common carp of different age-groups. Eight samples from six ponds were taken during the rearing season; number and biomass were determined per species and taxonomic group. Traditional quantitative analysis is based on taxonomic grouping. Zooplankton species were assigned to two size-groups of below and above 500 microns. Altogether 38 species were identified: 6 of above 75% incidence, 6 between 50 and 75% and 8 between 10 and 50%. For practical reasons relating to production biology only 7-8 species have a determinant role in carp feeding. The biomass data show that the incidence of Rotatoria-size plankton - according to taxonomic grouping and according to size – was lower than that of the other two groups. In our grouping - abundance - species smaller than 500 microns represented the larger part of zooplankton throughout the entire rearing period. In the group above 500 microns Copepoda proved more important as natural feed for the different age-groups of carp than Cladocera (except carp-grass carp biculture). Grouping of zooplankton according to size seems to be a much more informative method for evaluating available carp feed than taxonomic classification. The latter also has to be maintained as an important source of information on the biological water quality and the production biology status of fish ponds.
(Keywords: zooplankton, fish pond, natural yield)

ÖSSZEFOGLALÁS

Kvalitatív és kvantitatív zooplankton vizsgálatok halastavakban
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Kísérleteink során azt vizsgáltuk két magyarországi halastórendszerben, hogy a tavakban található zooplankton szervezetek a különböző ponty korosztályok számára mennyi felvehető, hasznosítható táplálékot biztosítanak. A hagyományos, rendszertani besoroláson alapuló módszerrel szemben - a korábban az előnevelt, egy-, két-, háromnyaras pontyokon elvégzett béltartalom analízisek alapján - 500 µm alatti és feletti mérettartományba soroltuk a talált zooplankton fajokat. A halastavakban összesen 38 fajt azonosítottunk, 75% előfordulási gyakoriság felett 6 faj, 50-75% között 6 faj, 10-50% között 8 faj volt jellemző. A dominancia viszonyokat szemlélteti, hogy 50% felett mindössze 5 faj található. Gyakorlati termelésbiológiai szempontból, figyelembe

véve a béltartalom analízisek eredményeit, valamint azt a tényt, hogy a ponty nem szelektív planktonfogyasztó, a halastavakban 7-8 faj meghatározó. Vizsgálataink szerint a biomassza alapján a Rotatoria méretű (500 µm-nál kisebb) zooplankton fajok mind rendszertani besorolás, mind a méret szerinti felosztás alapján az egész vegetációs időszakban kisebb részarányt képviseltek a másik két csoporthoz viszonyítva. Az egyedszámot tekintve azonban az 500 µm alatti zooplankton az egész vegetációs időszakban lényegesen meghaladja a Cladocera és Copepoda fajokét. Az 500 µm feletti mérettartományban a Cladocera fajok lényegesen kisebb szerepet játszanak, mint a Copepodák, kivéve a ponty-amur bikulturás telepítést. Ebből adódik, hogy a vizsgált tórendszerekben a Copepodák a legfontosabb táplálékszervezetei az egy-, két- és háromnyaras pontyállományoknak. Eredményeink alapján a hagyományos, rendszertani felosztás szerinti zooplankton feldolgozási metodikával szemben előnyben kell részesíteni a mérettartományok szerinti csoportosítást, mert így pontosabb képet kaphatunk a pontyok számára ténylegesen hasznosítható táplálék mennyiségéről. A faj szerinti meghatározás továbbra is szükségszerű, mert ennek alapján kapunk információt a biológiai vízminőségről és tó termelésbiológiai állapotáról.
(Kulcsszavak: zooplankton, halastó, természetes hozam)

INTRODUCTION

A major part of Hungary's approx. 23,000 ha fish pond area was constructed several decades ago. The intensive production methods used since then have caused eutrophication and accelerated natural succession processes. The privatisation of the state farms and the co-operatives has created a new situation in many respects. Ecological investigations of fish ponds are inspired by the new need for more economical and environmentally friendly technologies based on maximum exploitation of the biological capacity of fish ponds.

Fish yield can be divided into 'natural' and 'feed' yield in the traditional eastern European culture system. The ratio of the natural yield, as a result of the consumption of fish feed organisms, mainly from the plankton and benthon, is the critical point in economical production. The available 'natural feed', the essential protein source, depends on population dynamics and on the size and weight relations of zooplankton and benthos species. Zooplankton consumption of different common carp age-groups has been investigated extensively (*Zaret and Kerfoot*, 1975; *Grigierek and Wasilewska*, 1978; *Fry and Osborn*, 1980; *Prikryl and Janacek*, 1982; *Stenson*, 1982; *Pejler*, 1995; *Specziár et al.*, 1997, among others). In these studies the methodology of gut content analysis applied was that described by *Hyslop* (1980) and *Windell and Bowen* (1978).

Zooplankton of consumable size was also investigated in relation to fish length and weight, and some information on the effect of fish feeding on the zooplankton community has come to light (*Prikryl*, 1986; *Murtaugh*, 1989; *Körmendi and Varga*, 1998).

Evaluation of the zooplankton of fish ponds has a long history in Hungarian fish culture. The most frequently applied method is based on the volume and/or weight determination of settled samples, which measures the seston. Hence, this method cannot be considered accurate even for measuring real total zooplankton quantity (*Tasnádi*, 1983).

The main species of Hungarian fish culture is the common carp (*Cyprinus carpio L.*), thus, qualitative and quantitative analyses of zooplankton were made on samples from carp monoculture ponds or where the strong dominance of carp characterised polyculture. The aim of these investigations was to evaluate zooplankton species as an

available food source for common carp of different age-groups and to develop a new method of evaluation for zooplankton which would provide the fish breeder with more practical information on zooplankton of consumable size, rather than traditional taxonomic classification. This information may be useful in better timing of the fertilisation or manuring of fish ponds, and in the planning of fish feeding.

MATERIALS AND METHODS

The investigations were carried out on two different Hungarian pond systems. System 1 is situated at the southern shore of Lake Balaton and was built several decades ago on peat-bog soil. System 2 was built 10 years ago in the catchment area of the Danube on clay-sand soil. 3 ponds in each system, of different size and stock (see *Table 1*), were sampled 7-8 times during the rearing season from late April to October.

Table 1

Stocking structure of the fish ponds investigated

Pond(1)	Area(2) (ha)	Species stocked (%) (3)		Mean weight (g) (4)	
		C.carp(5)	Sc (6), Gc (7), Bc (8)	C.carp (5)	Sc (6), Gc (7), Bc (8)
System 1					
1.1	62	90	10 (Bh, Gc)	150	480
1.2	45	90	10 (Sc)	150	100
1.3	60	90	10 (Gc)	20	20
System 2					
2.1	69	90	10 (Bh, Sc, Gc)	300	350
2.2	19	100	-	1	-
2.3.	55	90	10 (Bh, Sc, Gc)	50	40

Common carp: *Cyprinus carpio L.(5),* Silver carp: *Hypophthalmichthys molitrix Val.(6)*, Grass carp: *Ctenopharyngodon idella Val.(7*), Bighead carp: *Hypopthalmichthys nobilis Rich.(8)*

1. táblázat: A kísérleti tavak telepítési szerkezete

Halastó(1), Tóterület(2), Népesítési szerkezet(3), Átlagos testsúly(4), Ponty(5), Fehérbusa(6), Amur(7), Pettyes busa(8)

Fish were fed according to the traditional technology with mixed feed (i.e. grains). The water quality parameters were determined by traditional Hungarian hydrochemical methods (*Felföldy*, 1987) from mean samples for each pond.

Zooplankton samples were taken by column sampler in the open water zone, by means of a stripe method. 30-litre water samples were collected from each pond, which corresponds to 6-9 sampling sites, due to changing water depth. Samples were filtered through a net of 25 microns mesh size. Number of species and number of individuals per species were determined from each sample. Measurements were taken of the dominant taxa for biomass determination, according to *Gulyás* (1974), *Dumont et al.* (1975), *Bottrell et al.* (1976) and *Ruttner-Kolisko* (1977). Means of length and width were calculated on 50 individuals which originated from 3 samples collected at different

times. The data for abundance and biomass were grouped and analysed according to taxonomic classification (Rotatoria, Cladocera, Copepoda). Biomass was calculated on the basis of the dry weight of the organisms. The abundance and the biomass were expressed in units of individuals/10 l and mg/10 l respectively. The ratio of the number of individuals and the corresponding biomass per unit volume of pond water (I/B) was also calculated and analysed; here, biomass was calculated on the basis of live weight.

Based on the findings of *Spataru* (1977) and *Spataru et al.* (1983) and on our previous unpublished results of intestine content analyses on common carp the consumable size of zooplankton is above 500 microns for carp age-groups above one year. Hence, zooplankton species were assigned to two size-groups of below and above 500 microns and data analysis performed according to this classification.

Statistical analyses of the data were carried out by means of SPSS 8.0 software, using t-test and two-way ANOVA with factors for the ponds and the sampling time.

RESULTS AND DISCUSSION

The chemical analyses of the water samples showed appropriate inorganic P and N levels, characterising good conditions with respect to production biology (*Horváth et al., 1992*). The means of PO_4-P and inorganic N forms varied between 0.1-0.2 and 1.0-2.0 mg/l respectively. Oxygen consumption (measured by COD-$KMnO_4$) increased during the rearing season and in August exceeded the 30 mg/l level allowed. The COD of the ponds of System 1 was generally twice as high as that of the ponds of System 2. This was due to the greater age and/or to the peat-bog soil type of the former.

Altogether 38 zooplankton species were found in the investigated fish ponds: 6 of above 75% incidence, 6 between 50 and 75% and 8 between 10 and 50%. With reference to dominance relations, only 5 species showed incidence above 50% in the samples. For practical reasons relating to production biology, and since common carp is not a selective zooplankton consumer, only 7-8 species have a determinant role in fish ponds (*Table 2*).

The absolute and relative (%) abundance and biomass data of the differently classified (taxonomically and by size) zooplankton groups were analysed by two-way ANOVA with factors for the ponds and the sampling time. The effect of the ponds was not significant, except in the case of the Copepoda abundance ratio (%). The effect of sampling time was found to be significant ($P<0.01$-0.05) in most cases, except in the absolute and relative abundance of Cladocera and Copepoda and the biomass of Rotatoria and Cladocera.

The results for the size measurements show that the zooplankton group smaller than 500 microns included all Rotatoria (except *Brachionus calyciflorus* and *Asplanchna priodonta*), juvenil *Bosmina longirostris*, *Chydorus sphaericus*, *Alona affinis, Alonella nana*, from *Cladocera* and nauplii forms of *Copepoda*. Dominant species larger than 500 microns were *Moina macrocopa*, *Daphnia longispina* and *Cyclops sp*..

The means for the relative abundance and the biomass of zooplankton groups calculated for the whole season per pond are summarised in *Tables 3 and 4*. Grouping by taxonomy and by size shows great differences. Zooplankton smaller than 500 microns represent a significant ratio by number (74.3%) and by biomass (35.1%) which varies within a wide range (2.0-84.3% for biomass). The difference between the mean of the absolute Rotatoria biomass (0.82±2.65 mg/10 l) and that of the group smaller than 500 microns (4.78±11.51 mg/10 l) was significant ($P<0.05$), as was proved by two-sample t-test.

Table 2

Zooplankton species and occurrence frequency of zooplankton

	Pond system (1) 1			Pond system 2		
	1.1.	1.2.	1.3.	1.1.	1.2.	1.3.
Rotatoria						
Asplanchna priodonta	++	++	++	+++	++	++
Anuraeopsis fissa	+	-	-	-	-	+
Brachionus angularis	++	+++	++	+++	++	++
Br. calyciflorus	+++	+++	++	++	++	++
Br. budapestinensis	++	-	-	-	-	-
Br. diversicornis	+++	++	++	+++	++	++
Br. falcatus	-	++	-	+	-	+
Br. leydigi	++	-	-	-	-	-
Br. urceolaris	+++	++	++	+	+	-
Br. quadridentatus	++	++	+	-	+	+
Bdelloidea sp.	+	-	+	-	-	-
Cephalodella exigua	-	-	+	-	-	-
Colurella uncinata	+	+	-	+	+	-
Epiphanes clavulata	+	+	-	-	-	+
Euchlanis dilatata	+	++	++	-	-	-
Filinia longiseta	+	+	+	+	+	+
Hexarthra mira	+	++	-	+	-	+
Keratella cochlearis	++++	++++	++++	++++	+++	++++
K. quadrata	++	+++	+++	++	++	++
Lecane closterocerca	+	++	+	+	+	+
Lepadella patella	+	+	-	-	+	-
Polyarthra vulgaris	++++	+++	+++	++++	+++	+++
Pompholyx complanata	++	++	+	+	-	-
Trichhocerca sp.	+	+	+	+	+	-
Synchaeta sp.	+	+	-	+	-	+
Cladocera						
Bosmina longirostris	++++	++++	++++	++++	++++	++++
Alona affinis	++	++	+	+	+	-
Alonella nana	+	-	-	-	-	+
Ceriodaphnia reticulata	++	++	-	++	++	++
Chydorus sphaericus	+++	+++	+++	++	+	++
Daphnia longispina	++	+++	++++	+++	+	++
Daphnia pulex	+	+	++	+	+	+
Leydigia leyidigi	-	+	++	-	-	-
Moina macrocopa	+++	++	++	++	+	+
Pleuroxus trigonellus	-	+	-	-	+	-
Scapholeberis mucronata	+	+	+	-	+	-
Simocephalus vetulus	-	+	-	-	+	-

Continued. *A táblázat a következő oldalon folytatódik.*

Continued from previous page. *Folytatás az előző oldalról.*

Copepoda						
Nauplius	++++	++++	+++	++++	+++	++++
Cyclops sp.	++++	++++	++++	++++	++++	++++

előfordulási gyakoriság (*occurrence frequency*): + 10% alatt (*below 10%*), ++ 50% alatt (*below 50%*), +++ 75%-a alatt (*below 75%*), ++++: 75% felett (*above 75%*)

2. táblázat: A vizsgált halastavakban talált zooplankton fajok és előfordulási gyakoriságuk

Halastórendszer(1)

Table 3

Means of relative abundance data for the differently classified zooplankton groups (%)

Pond (2)	Zooplankton groups (1)					
	A	*B*	*C*	*D*	*E*	*F*
1.1	47.1	79.4	29.2	4.0	23.7	16.6
1.2	37.9	74.0	20.9	2.0	47.4	24.0
1.3	30.2	66.0	34.2	12.9	35.6	21.1
2.1	31.9	74.1	27.8	4.1	40.3	21.8
2.2	15.0	66.2	29.3	15.2	55.7	18.6
2.3	44.0	84.3	31.4	3.9	24.2	11.8
Mean (3)	35.6	74.3	28.5	7.0	35.9	18.7

A: Rotatoria, D: Cladocera>500 microns, B: Zoopl.<500 microns, E: Copepoda, C: Cladocera, F: Copepoda>500 microns

3. táblázat: A különböző zooplankton csoportok egyedszám átlagainak alakulása halastavakban

Zooplankton csoport (1), Halastó(2), Átlag(3)

Table 4

Means of relative biomass data for the differently classified zooplankton groups (%)

Pond (2)	Zooplankton groups (1)						
	A	*B*	*C*	*D*	*E*	*F*	*D+F*
1.1	7.3	47.5	59.5	20.1	33.2	32.4	52.5
1.2	2.9	28.8	38.1	13.4	59.0	57.8	71.2
1.3	1.7	27.1	67.9	43.3	30.4	29.6	72.9
2.1	1.9	35.5	46.6	14.2	51.5	50.3	64.5
2.2	0.5	21.6	50.4	32.2	49.1	46.2	78.4
2.3	3.6	47.2	59.0	16.5	37.4	36.6	53.1
Mean(3)	3.2	35.1	53.5	22.9	43.3	42.0	65.4

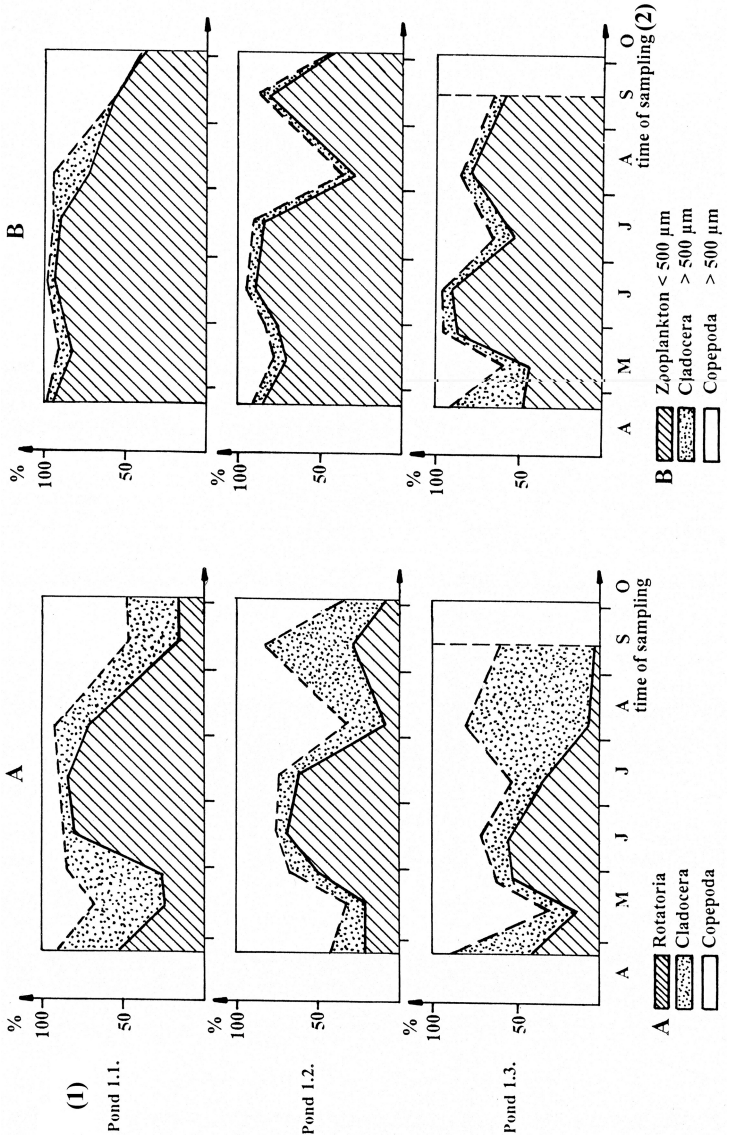
A: Rotatoria, D: Cladocera>500 microns, B: Zoopl.<500 microns, E: Copepoda, C: Cladocera, F: Copepoda>500 microns

4. táblázat: A különböző zooplankton csoportok biomassza átlagai a halastavakban

Zooplankton csoportok(1), Halastó(2), Átlag(3)

Figure 1

Changes of zooplankton abundance investigated by taxon (A) and by size (B) in pond system 1

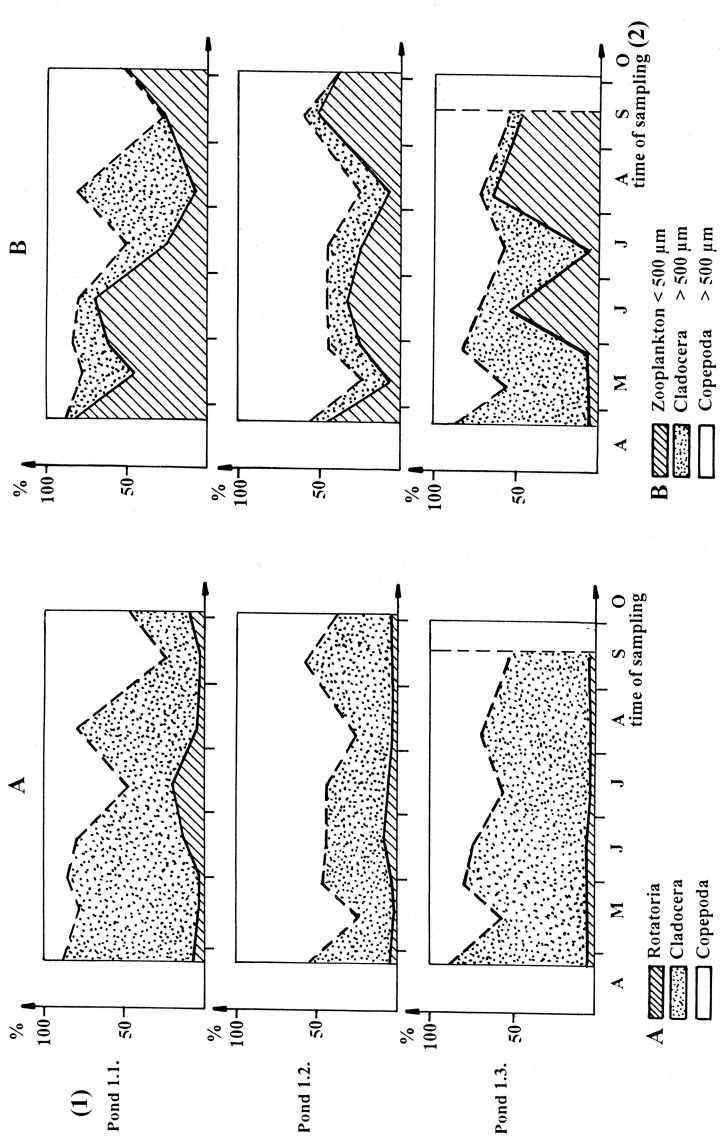


1. ábra: A rendszertani kategóriák (A) és a méret szerint vizsgált (B) zooplankton egyedszám alakulása az 1. tórendszerben

Kísérleti tavak(1), Mintavételi idő(2)

Figure 2

Changes of zooplankton biomass investigated by taxon (A) and by size (B) in pond system 1

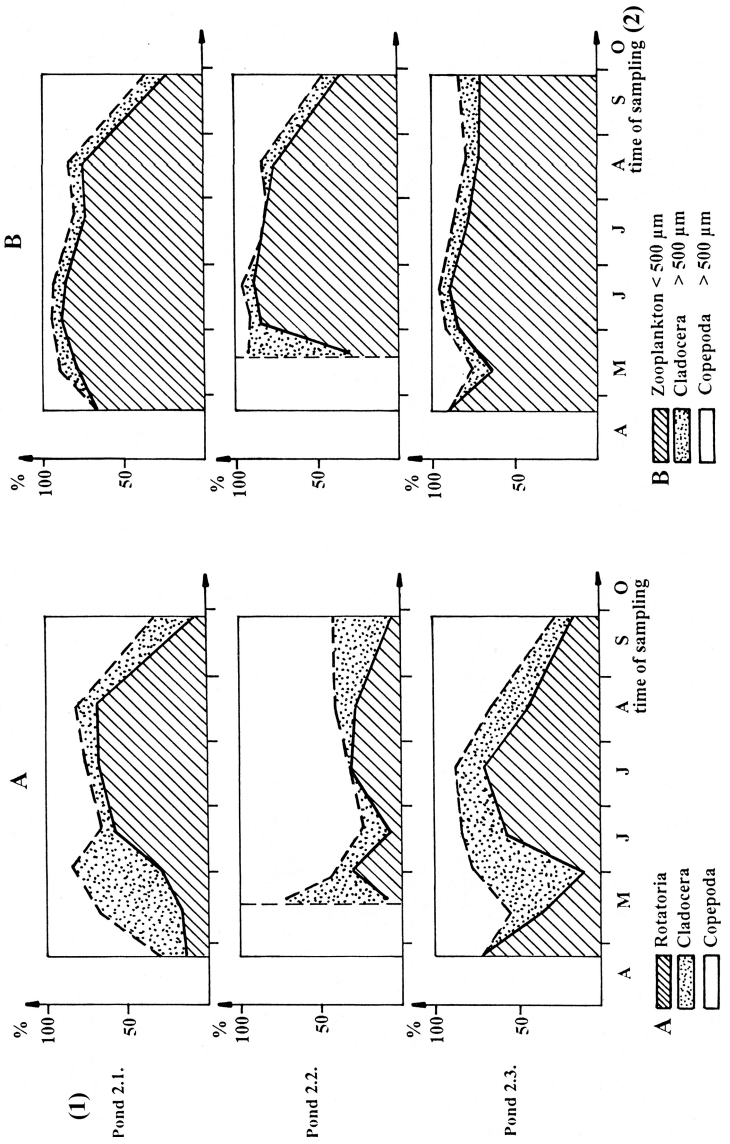


2. ábra: A rendszertani kategóriák (A) és a méret szerint vizsgált (B) zooplankton biomassza alakulása az 1. tórendszerben

Kísérleti tavak(1), Mintavételi idő(2)

Figure 3

Changes of zooplankton abundance investigated by taxon (A) and by size (B) in pond system 2

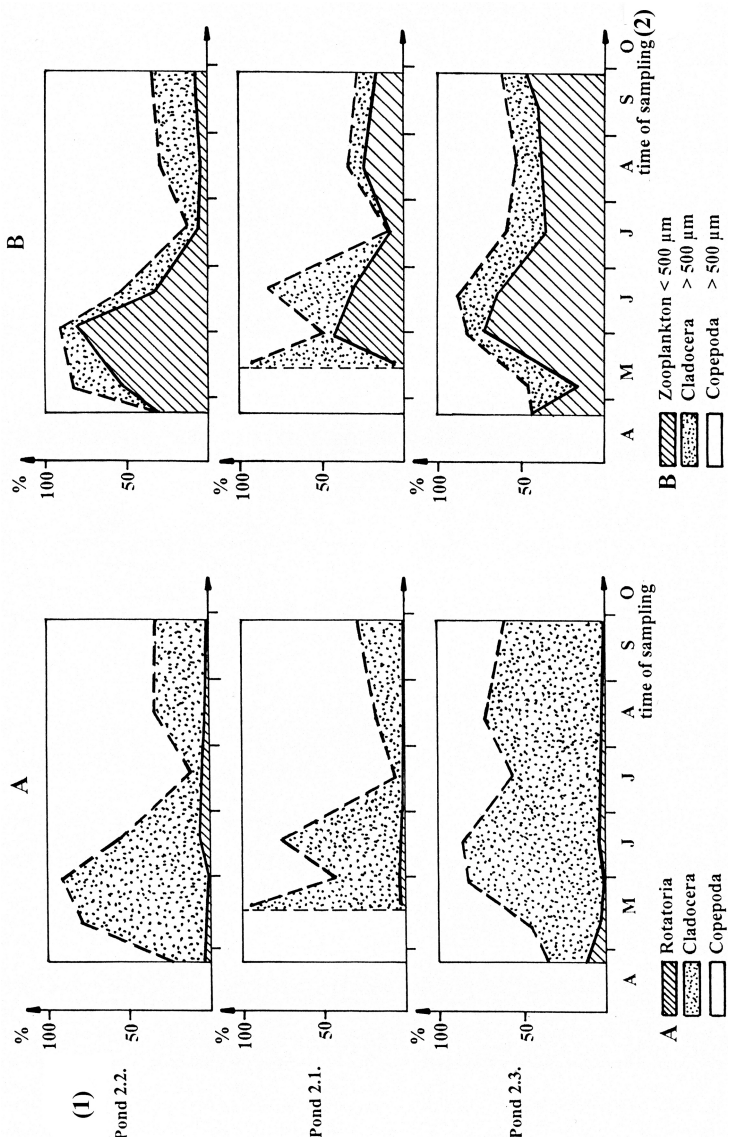


3. ábra: A rendszertani kategóriák (A) és a méret szerint vizsgált (B) zooplankton egyedszám alakulása a 2. tórendszerben

Kísérleti tavak(1), Mintavételi idő(2)

Figure 4

Changes of zooplankton biomass investigated by taxon (A) and by size (B) in pond system 2



4. ábra: A rendszertani kategóriák (A) és a méret szerint vizsgált (B) zooplankton biomassza alakulása a 2. tórendszerben

Kísérleti tavak(1), Mintavételi idő(2)

In the group larger than 500 microns Cladocera and Copepoda, biomass had a ratio of 23 and 42% on average, with extreme values of 0-85 and 2-91% respectively. It is important to know the ratio of these two taxa, as they have different characteristics with respect to feeding, population dynamics and nutrition. Copepoda species have less fibre (chitin) and greater feeding value for fish (*Tasnádi*, 1983; *Körmendi*, 1989).

The abundance and the biomass of zooplankton groups change in time: these proportions can be followed in *Figures 1-4*. The main influencing factors in these changes are population dynamic relations, but fish stocking also exerts strong effects.

Copepoda can also be judged to be the steadiest zooplankton group in terms of biomass. The ratios of Copepoda (%) and Cladocera (%) of consumable size are shown in *Table 5*.

Table 5

Copepoda:Cladocera ratio in zooplankton of consumable size

Pond (1)	Copepoda (%) Cladocera (%)
1.1.	1.6
1.2.	4.3
1.3.	0.7
2.1.	3.5
2.2.	1.4
2.3.	2.2

5. táblázat: A felvehető méretű Copepoda fajok százalékos aránya a Cladocera fajokhoz

Halastó(1)

The data given in Table 5 suggest that the Copepoda:Cladocera ratio is determined by the stocking structure of the pond. Copepoda is more significant when bighead and silver carp are stocked in a polyculture dominated by common carp, even in the case of fingerling rearing. Cladocera dominance can be observed in ponds of common carp – grass carp biculture. The Copepoda:Cladocera ratio is also probably influenced by stocking density. Mass production of Cladocera species (eg.. *Daphnia sp.*, *Moina sp*.) can be expected at low stocking densities.

The I/B ratio calculated from total abundance and biomass per pond and per sampling can be characterised by the following values: mean=93.7, S.D.=80.9, min.=9.0, max.=368.9. This ratio had a skewed distribution due to the values of 110-368 in June and July. This shows that in summer the smaller zooplankton dominated, but it does not automatically follow that there was not enough larger-sized zooplankton which was consumable for the common carp.

CONCLUSIONS

The almost constant dominance observed for the zooplankton group smaller than 500 microns in the fish ponds investigated indicates without doubt that with carp

monoculture, or where carp represents 90% of the stock, a significant part of the 'natural food' is unutilised in fish production.

The grouping of zooplankton according to size seems to be a much more informative method for evaluating available carp feed than taxonomic classification. The latter also has to be maintained as an important source of information on the biological water quality and production biology status of fish ponds.

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