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THE PRESSURE OF PELAGIC PREDATORS OF THE GENUS *MESOCYCLOPS* (COPEPODA, CRUSTACEA) ON SMALL ZOOPLANKTON*

ABSTRACT: In a laboratory experiment the food selectivity and the daily food ration of two species of Cyclopidae: *Mesocyclops leuckartii* (Claus) and *M. oithonoides* (Sars) were estimated in relation to small zooplankton (rotifers, protozoans, nauplii). Also the possibilities of feeding on plant food (*Ceratium*) by these predators were investigated. The data allowed to determine the pressure of *Mesocyclops* on small zooplankton of some Masurian lakes.

KEY WORDS: Lakes, laboratory experiments, *Mesocyclops leuckartii*, *M. oithonoides*, feeding behaviour, pressure of predators, zooplankton.

Contents

1. INTRODUCTION

Copepods of the family Cyclopidae play a dominant role in the community of invertebrate pelagic predators. Because of their great abundance, long period of occurrence in the pelagial

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the Cyclopidae should be considered as another factor, beside the fish, which actively determines the abundance of zooplankton.

In the pelagial of lakes of northern Poland there are species of the following genera: *Cyclops*, *Eucyclops*, *Acanthocyclops* and *Mesocyclops*, representatives of the latter, namely *Mesocyclops leuckartii* (Claus) and *M. oithonoides* (Sars) reach high numbers (Patalas 1954, 1963, Gliwicz 1969).

Mesocyclops leuckartii is a cosmopolitan species. In the USSR it occurs far in the north and in lakes of Samarkanda region (Ulomskij 1953). This species has been also found in brackish water of the Botnicka Bay (Rylov 1948). Patalas (1954) has observed that *M. leuckartii* was the only species occurring in all 28 lakes of Western Pomerania, both in α-mesotrophic lakes and in strongly eutrophicated shallow water bodies. It occurred quite abundantly in all places, and in an extreme case it was over 50% of all crustaceans.

Also frequent occurrence was noted in the case of *M. oithonoides* which was found in 24 lakes (Patalas 1954), and most frequently in extremely eutrophic lakes. Often these two species occur together, but *M. oithonoides* is found in deeper water layers. Similar character of occurrence has been also observed by Gliwicz (1969) in the lakes of the Masurian Lakeland, where both species were abundant both in the oligotrophic-α-mesotrophic Lake Wukśniki and in the eutrophic Mikołajskie Lake. In the latter, the average number of both *Mesocyclops* species (without the nauplii) is 20 ind./l in the summer, although it may also exceed 100 ind./l.

The kind and size of food on which Cyclopidae may feed ranges considerably: from typical animal food as rotifers, all development stages of Copepoda and Cladocera, from protozoans to plant food and detritus. This depends on the availability of a given kind of food in the environment (abundance, size, concentration). The way the adult Cyclopidae catch food determines the size of available food particles – food items. Thus, small food (bacteria, detritus) can be consumed only in the form of aggregates, whereas in the case of algae the filamentous species, colonial species or other large net algae are available.

Furthermore, species frequently close from the point of systematics have entirely different food requirements. Fryer (1957) has stated that within the genus of *Acanthocyclops* two species are typical carnivorous ones, whereas the other two feed on plant food.

Thus the Cyclopidae are not specialized predators, they feed almost on all kinds of food that are available if occurring in sufficient quantities. Ostracoda, larvae of Diptera (Fryer 1957) and also young development stages of another plankton predator – *Leptodora kindtii* (Focke) (Morduchaj-Boltovskaja 1958) can be also consumed. Considering such a wide food spectrum the Cyclopidae can be of great significance as a factor controlling the development of the entire community of pelagic zooplankton. The Cyclopidae may be of special significance in reducing small non-predatory zooplankton – rotifers, nauplii, protozoans, as because of their size they are practically unavailable for fish and also for *L. kindtii* (Karabin 1974).

Still, there are very few data on the quantitative and qualitative effect of predators on these organisms, and especially on rotifers. Mc Queen (1969), on the ground of laboratory experiments, has found that rotifers (*Keratella cochlearis* Gosse) are preferred to other bigger plankton organisms. At the same time Varbapetjan (1972) has observed that *K. cochlearis* in comparison to other rotifer species is practically not consumed. These data are already sufficient to draw a conclusion that the rotifers may be really a significant element of the food of Cyclopidae.

Representatives of the genus *Mesocyclops* are the dominant element in the community of pelagic predators. Thus the researsh conducted in the years 1970–1974 was concerned with quantitative and qualitative feeding of *Mesocyclops* sp. on small non-predatory zooplankton, and an estimate of the food ration of a single predator and the entire predatory population – and thus the determination of the pressure of *Mesocyclops* on small zooplankton in the lake pelagial.

2. MATERIAL AND METHODS

Predatory forms of *Mesocyclops* sp. were exposed for a time in bottles containing "natural" food from the water body, and then the quantitative and qualitative feeding of this predator was estimated by comparing the abundance of food in bottles with the predator with control bottles without the predator.

The experiments were carried out in several series, at different seasons of the year, but according to the above-mentioned pattern. Bottles of a capacity of 100 ml were filled with lake water filtrated through a net, then using the pipette a determined amount of food taken from the lake was added. In all bottles of a given series there was the same amount of food. Both concentrated food and food of a natural density were applied. In thus prepared bottles the predators were placed (copepodites of IV–VI stage and adult ones), their numbers in a series ranged from 0 (control) to 16 individuals. For each density of *Mesocyclops* sp. 2–3 repeats were made. The temperature was 18–19°C, the exposure lasted 24 hours. Such period is the best, because a shorter exposure does not cover the entire daily cycle of an animal, and it has to be presumed that there are periods when the predator is not grazing. Furthermore, at longer exposure the adaptation effect of individuals examined to the conditions of the experiment decreases. Over the initial period of investigations, amongst other things, when determining the proper duration of experiment, it has been observed that at 6 hours of exposure and to a smaller extent at 12 hours of exposure there is no relation between the density of predator and of food and the amount of consumed food. At an exposure longer than 24 hours the results may be distorted due to smaller availability of food caused by high consumption.

After 24 hours the contents of the bottles were fixed in Utermöhl solution, then with 4% formalin, and all specimens in bottles were counted.

Because the natural zooplankton from a lake or pond was used the method required several restrictions due to plankton composition. Over the period examined in Mikołajskie Lake small zooplankton (plenty of algae) was not abundant and zooplankton had to be concentrated which resulted in excessive amount of algae in the food. Fast decay of algae in bottles worsened the oxygen conditions and the animals died quickly. Attention had to be called also to the presence of *Asplanchna* sp. and colonial rotifers in the food as they distorted the results: *Asplanchna* sp. because of its predatory character of feeding and consumption of rotifers (E j s m o n t - K a r a b i n 1974), whereas the colonial rotifers because of their uneven quantitative distribution in particular bottles. Therefore, one experiment was with not concentrated lake zooplankton (Mikołajskie Lake), other series of experiments were based on concentrated food from a small natural pond with an appropriate plankton composition – minimal amounts of phytoplankton.

An experiment on the possibilities of feeding on plant food by *Mesocyclops*, and especially on *Ceratium hirundinella* (O. F. M.) Bergh was according to the pattern of experiment with animal food.

3. RESULTS AND DISCUSSION

3.1. CONSUMPTION OF SMALL ZOOPLANKTON AND FOOD SELECTIVITY OF *MESOCYCLOPS* SP.

Six series of the experiment were conducted. In series I the food consisted of not concentrated zooplankton from the epilimnion of Mikołajskie Lake, in other series (II–VI) the food consisted of zooplankton from the pond. Thus the food composition in series I considerably differed from that of the remaining five, where the species composition was similar but the percentage contribution differed. The total abundance of food was only different in all series, it ranged from 83 to 773 ind./100 ml. Species composition and the abundance of food are given in Table I.

Table I. Abundance of the food of *Mesocyclops* sp. and its species composition in series I–VI of the experiment

Food composition	Number of ind./100 ml					
	I	II	III	IV	V	VI
Polyarthra dolichoptera Idelson	12	21	62	339	140	318
Synchaeta oblonga Ehrenberg	–	30	73	19	136	193
S. kitina Rousselet	–	23	26	–	78	59
Trichocerca sp.	24	–	–	–	–	–
Pompholyx sulcata Hudson	11	–	–	–	–	–
Keratella cochlearis Gosse	23	–	–	–	–	24
Other	6	6	6	12	7	5
Rotatoria – total	76 (92%)	80 (70%)	167 (57%)	370 (77%)	361 (58%)	599 (80%)
Nauplii	7 (8%)	59 (30%)	126 (43%)	38 (8%)	258 (42%)	144 (20%)
Larvae of *Dreissena polymorpha* Pall.	–	–	–	76 (15%)	–	–
Total	83	139	293	484	619	743

In all series, the rotifers were the dominant group, although in series III and V the nauplii were a considerable percentage of the total food – 43 and 42. The nauplii, Cyclopidae and Calanoidae, were not distinguished as the latter were not numerous (single individuals). In series IV the food consisted of very young larvae of *Dreissena polymorpha* which hatched during the experiment. Protozoans were not taken into account when analysing the food composition, because many forms were destroyed when fixing with formalin. The feeding intensity of the predator (Fig. 1) and the composition of consumed food (Fig. 2) were estimated by comparing the numbers and food composition after 24 hours of feeding by *Mesocyclops* with the food composition in the control. *Mesocyclops* displayed a selective character of feeding. Rotifers were mainly consumed. The numbers of nauplii in bottles with predator stock slightly differed from those in control bottles and this was not really due to the number of predators. These changes were not related also to the total amount of food, nor to the numbers of nauplii. Changes in the numbers of rotifers had a directional character in all series of the experiment –

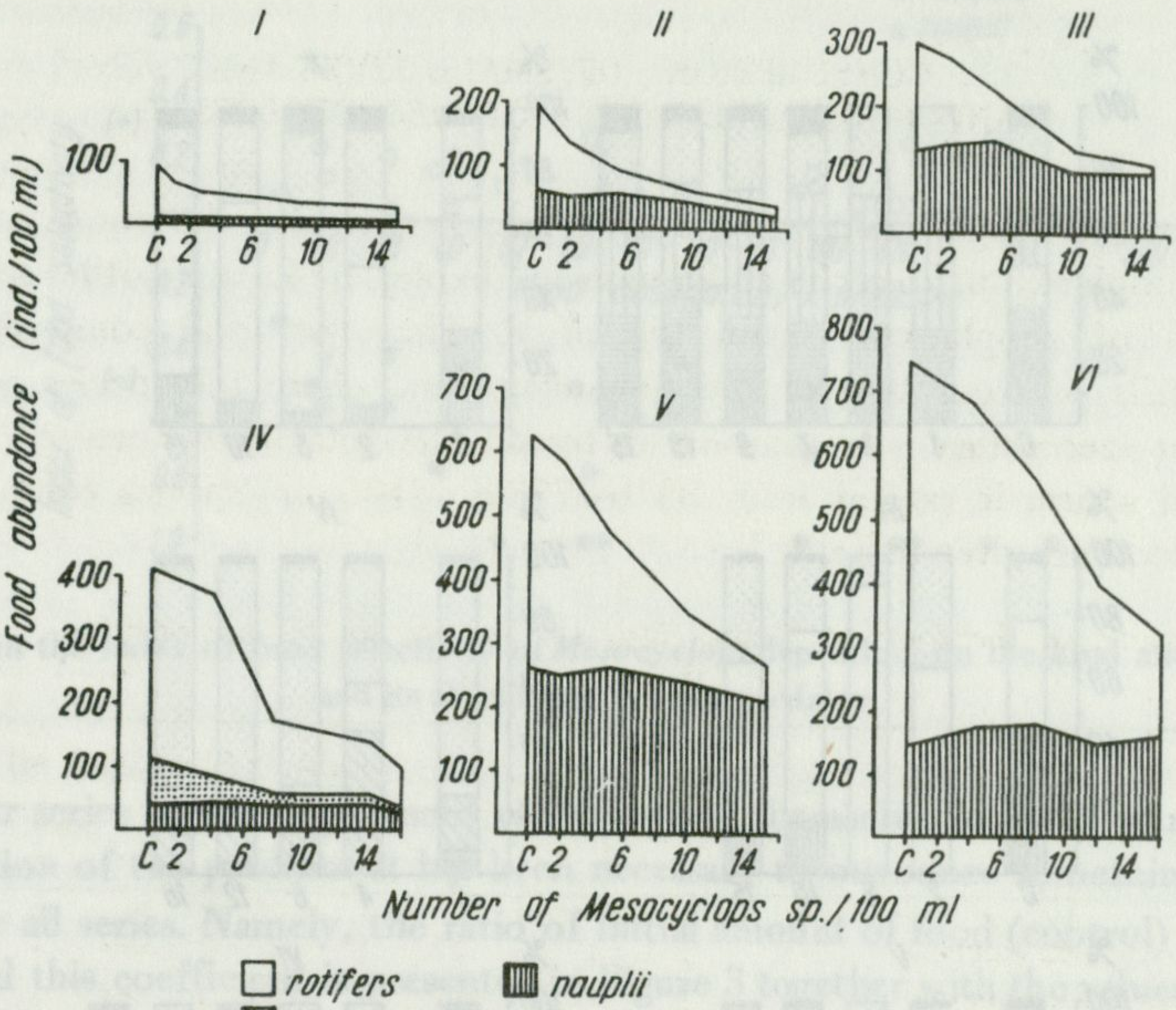

Fig. 1. Changes in food abundance after a 24-hour exposure depending on the density of *Mesocyclops* I–VI particular series of the experiment, C – control

with the increasing number of predators the numbers of rotifers in bottles decreased – sometimes there were only few individuals (series I, II, III). In particular series the curve showing the intensity of consuming rotifers (and thus of the whole food consumed) changed. At small and mean amount of food the feeding intensity visibly decreased at high concentrations of predators, but in series with a large amount of food the feeding intensity was rather constant. The decrease of feeding intensity was caused first of all by the elimination of almost all rotifers from the food, secondly by consumption of nauplii, even when their numbers were high (series II, III).

The selective character of feeding by *Mesocyclops* is reflected by the composition of food it consumes (Fig. 2). Rotifers are sometimes 100% (series III, VI). Even in series III and V, where the nauplii are over 40% of small zooplankton, their contribution to food consumed does not exceed 20%. The number of consumed nauplii frequently increases when the concentration of predators increases; at low numbers of *Mesocyclops*, where despite their feeding the numbers and thus the availability of preferred food (rotifers) has remained high over the period of exposure – the nauplii were only a slight percentage of food consumed. At high densities, when the availability of preferred food rapidly decreases, the number of consumed nauplii increases. Only in series VI, where because of a high number of rotifers (over 600 individuals) their availability has remained high, even at large concentrations of predators, the nauplii are not consumed at all. In series IV, where the food consisted also of larvae of *Dreissena polymorpha*, they were a considerable percentage of food consumed, especially at low numbers of predators. The great difference in the contribution of particular species of rotifers between the food supply and the food consumed is quite striking. This concerns mainly the two species of

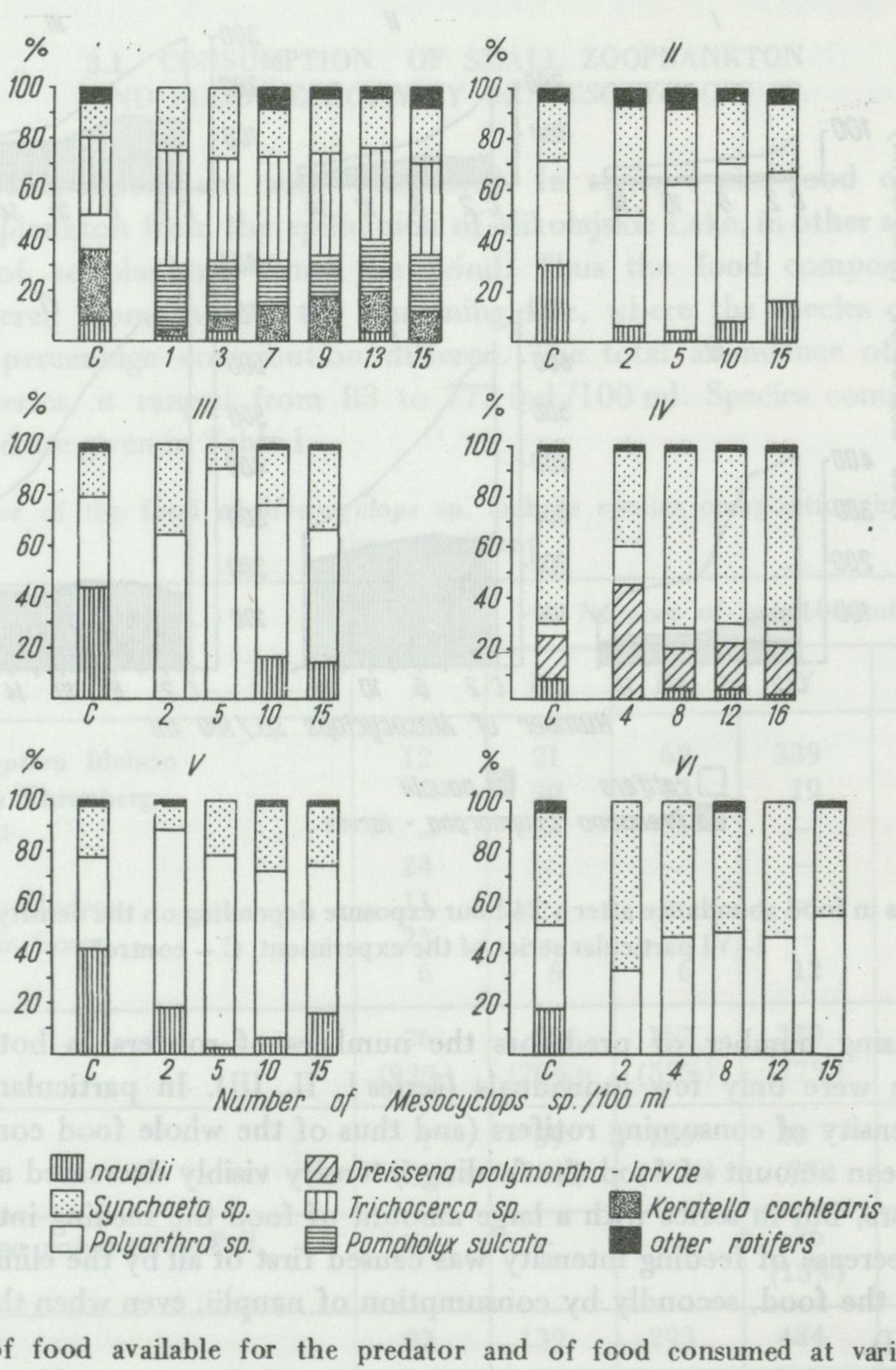

Fig. 2. Percentage of food available for the predator and of food consumed at various densities of *Mesocyclops* in I–VI series of the experiment (C – control)

Synchaeta (jointly presented in Figure 2), their percentage in the food consumed exceeded considerably, sometimes several times, their contribution to the control.

In order to determine food selectivity in terms of quantity and for purposes of comparison I v l e v ' s (1955) index of food selectivity was used:

$$S = \frac{k - q}{k + q}$$

where: k – percentage of a given food component in food consumed, q – percentage of a given component in the food complex. Results are presented in Figure 3.

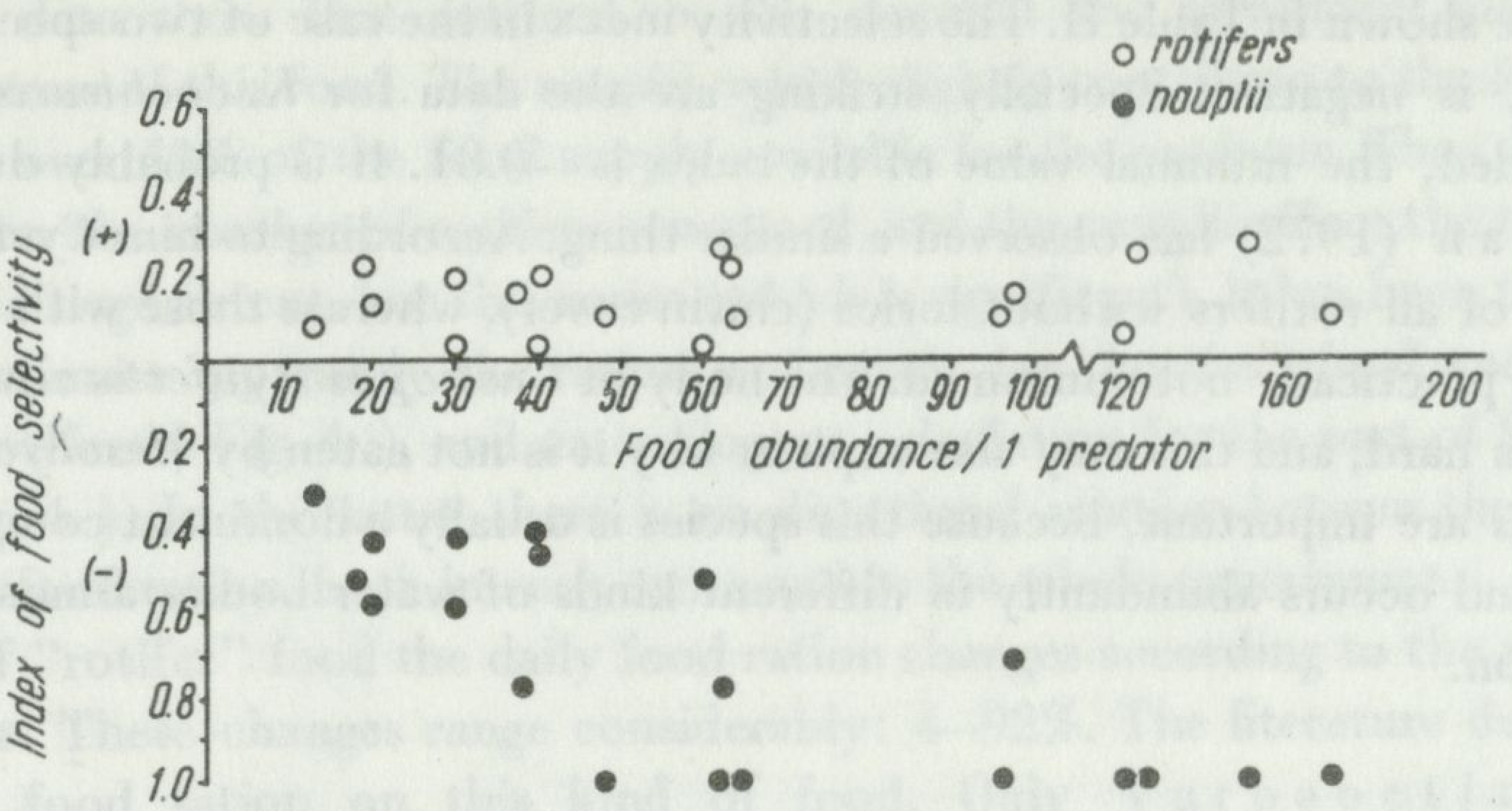

Fig. 3. Changes in the index of food selectivity of *Mesocyclops* depending on the kind and density of food and its abundance per one predator

As particular series of the experiment varied among themselves in the total amount of food and concentration of the predator it has been necessary to introduce something common and comparable for all series. Namely, the ratio of initial amount of food (control) to the numbers of predator and this coefficient is presented in Figure 3 together with the values of Ivlev's (1955) index. They quantitatively confirm the selective character of feeding by *Mesocyclops*. Thus, for the nauplii this index is always negative and ranges from –1.0 to –0.32. These changes are reversely proportional to the availability of all food; as the coefficient of the amount of food to the numbers of predator decreases, the values of Ivlev's (1955) index, as regards the nauplii, become positive – below 50 ind./l of *Mesocyclops* there are no extreme negative values. These results confirm an earlier conclusion that the nauplii are avoided when other food is available. The selectivity index for rotifers is always positive and ranges from +0.02 to +0.28. These values are not related to the amount of food per one predator.

Ivlev's (1955) index for particular species of rotifers was also calculated. As the food composition was limited (two or three species dominated, other occurred in small numbers) an additional experiment was made to observe food selectivity at greater specific differentiation. Zooplankton was sampled from Lake Flosek and consisted of: *Pompholyx sulcata*, *Gastropus stylifer* Imhof and *Keratella cochlearis*, also other species but less abundantly. Results of all

Table II. Ivlev's (1955) index of food selectivity for particular species, components of the food examined

Species	Min.	Max.	Mean
Synchaeta sp.	+0.03	+0.67	+0.24
Pompholyx sp.	+0.10	+0.32	+0.21
Polyarthra sp.	–0.41	+0.32	+0.06
Gastropus sp.	–0.37	–0.16	–0.29
K. cochlearis	–0.81	+0.06	–0.43
Rotatoria – total	+0.03	+0.27	+0.13
Nauplii	–1.00	–0.32	–0.72

experiments are shown in Table II. The selectivity index in the case of two species, *K. cochlearis* and *G. stylifer*, is negative. Specially striking are the data for *K. cochlearis*. This species is obviously avoided, the minimal value of the index is -0.81. It is probably due to the lorica. V a r b a p e t j a n (1972) has observed a similar thing. According to him *Cyclops scutifer* Sars consumes first of all rotifers without lorica (chitin cover), whereas those with lorica (*Keratella*, *Kellicottia*) are practically not consumed. The body of *Gastropus stylifer* is covered with chitin, thinner and less hard, and this may also explain why it is not eaten by *Mesocyclops*. The results on *K. cochlearis* are important, because this species is usually a dominant component of rotifer zooplankton, and occurs abundantly in different kinds of water bodies almost over the entire vegetation season.

3.2. DAILY FOOD RATION OF *MESOCYCLOPS* SP.

The results allowed to estimate the daily food ration of *Mesocyclops* as a percentage of the body weight of one *Mesocyclops*. The weight of particular species of rotifers was determined on the basis of nomograms of Č i s l e n k o (1968), and the weight of nauplii and the predator acc. to the equation:

$$W = 55 \cdot 1^{2.73}$$

(K l e k o w s k i and Š u š k i n a 1966). The results are given in Figure 4.

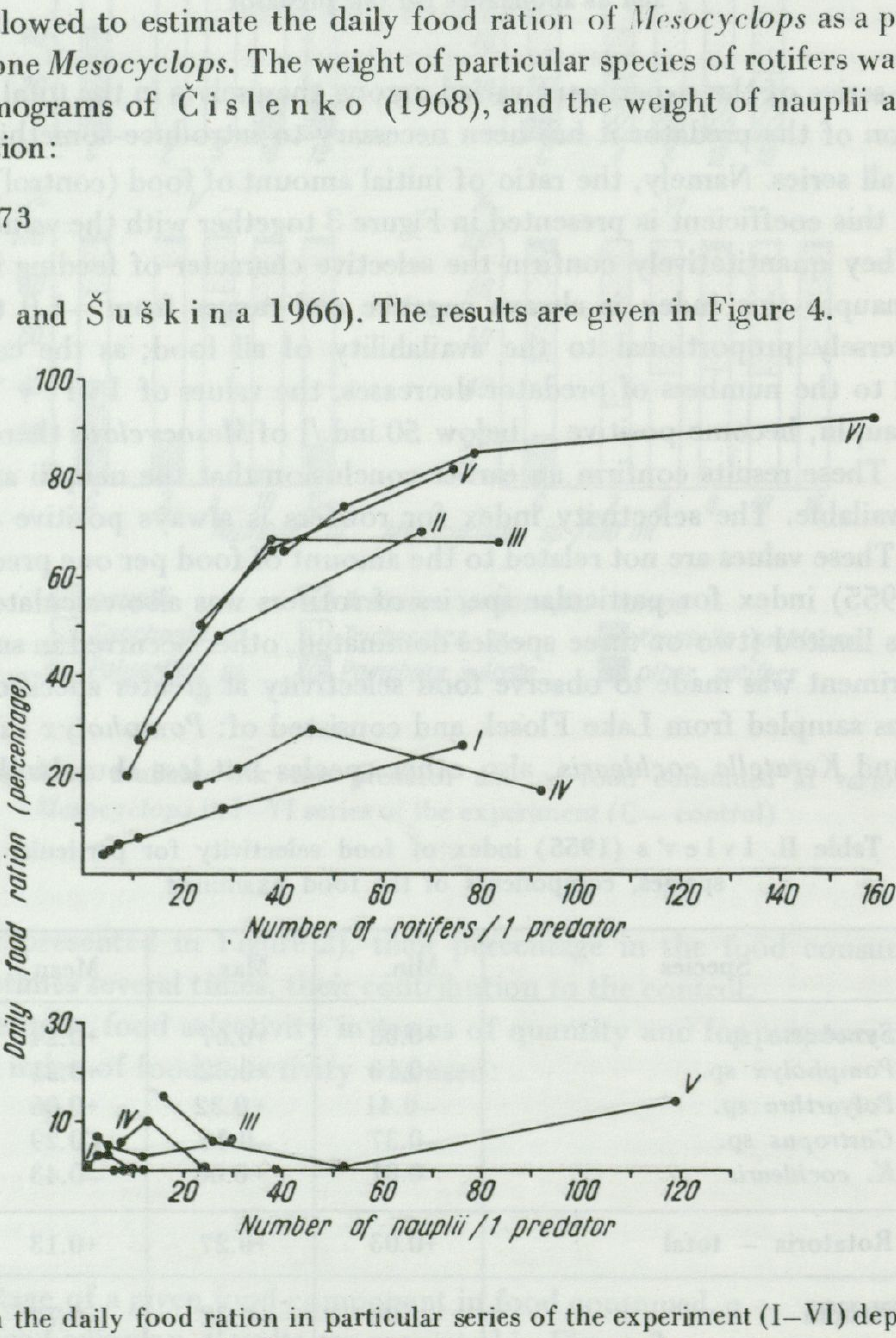

Fig. 4. Changes in the daily food ration in particular series of the experiment (I–VI) depending on the kind of food and its abundance per one predator

The previous data show that rotifers are the essential and significant element of food, 80–100% of biomass of this food. The nauplii, which slightly contribute to the food consumed, cover sometimes over 40% of the food supply available for the predator. Thus, the food ration depends largely on the number of rotifers consumed, and the nauplii affect the total number of available food to a large extent, but this varies (which is significant). It has been thus considered worthwhile to estimate separately the ration exclusively for "rotifer" food and in relation to the number of rotifers (Fig. 4), and an analogous calculation for the part of food formed by the nauplii (Fig. 4). In the latter there is no directional relation betwen the food available (nauplii) and the food ration, both in each series and in the whole experiment.

But in case of "rotifer" food the daily food ration changes according to the amount of food per one predator. These changes range considerably: 4–92%. The literature does not provide data about the food ration on this kind of food. Only V a r b a p e t j a n (1972) has mentioned that in case when the food of the predator consists of two kinds of rotifers: *Conochilus* and *Polyarthra*, the daily ration, according to the density of rotifers, was 6.7–21.5%. But these data are for another, much larger copepod – *Cyclops scutifer*.

It is also striking that the daily food rations from various series of the experiment, but at the same index of food availability, are usually similar, although the absolute amount of food in particular series and the number of the predator varies. For example, food rations of 65–67% were obtained in different series at following numbers of rotifers: 162, 369 and 629 ind./100 ml, and at the density of the predator: 10, 5 and 2 individuals.

Only in the case of series I and IV the daily food rations differ considerably from those in other series. This is caused by different food composition (Fig. 2). In series I small rotifers dominate: *Polyarthra* sp. sp., *Pompholyx sulcata*, *K. cochlearis* and others; the case is similar in series IV where *Polyarthra* covers 40–75% of food consumed, whereas in other series dominates rather the big species – *Synchaeta oblonga*. Thus, the conclusion is that the biomass of this food is another factor, besides the abundance, which limits the daily food rations. Figure 5 confirms this showing the relation between the daily ration and the biomass of available food (biomass of rotifers/1 predator).

And so, the lowest food rations (4–16%) obtained in series I correspond to the lowest

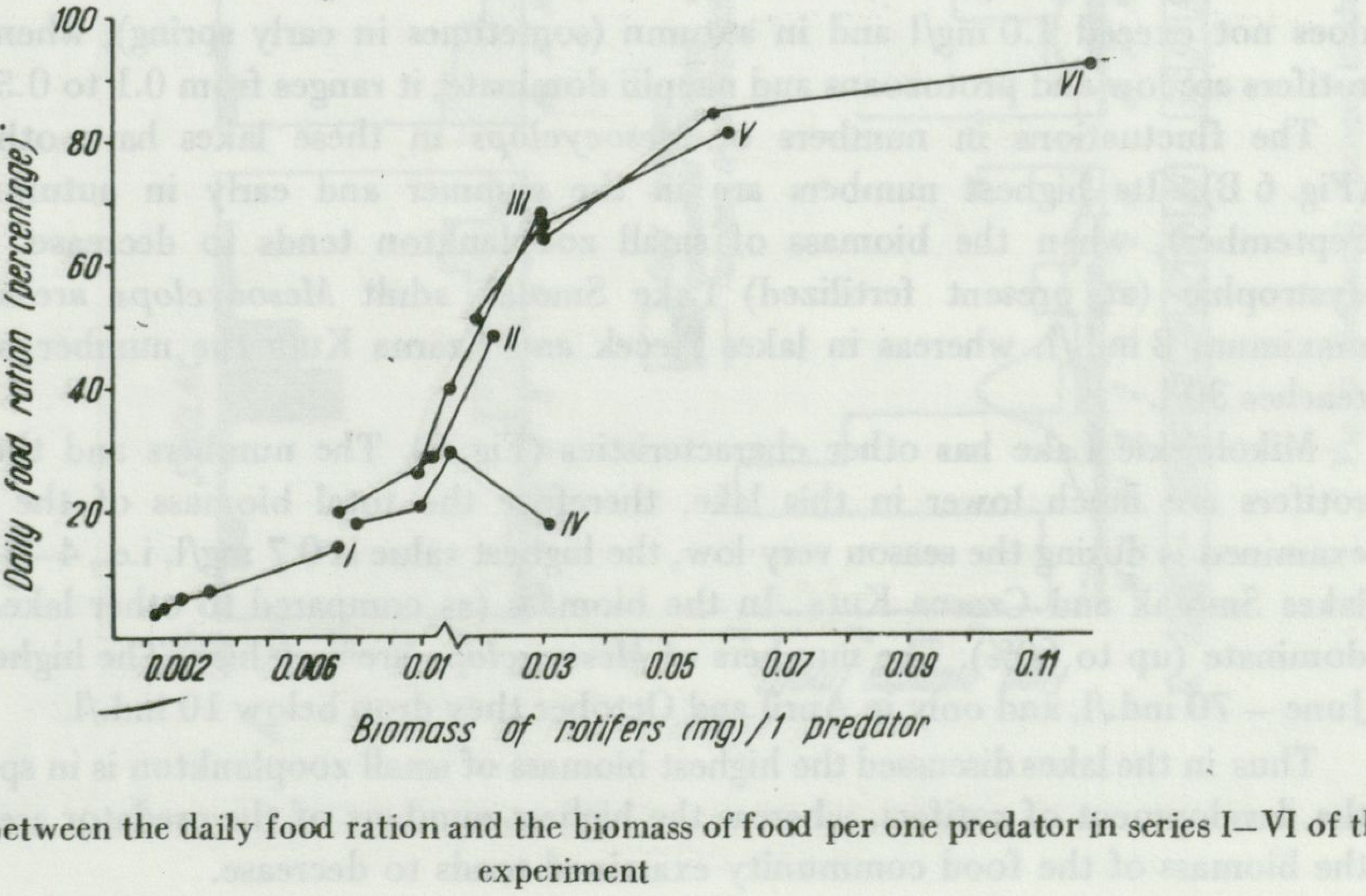

Fig. 5. Relation between the daily food ration and the biomass of food per one predator in series I–VI of the experiment

biomass of available food, and the values in series IV approximate the daily food rations in other series obtained at the same biomass of food per one predator.

Predatory Cyclopidae usually do not hunt their food, but catch it when they come across it. The food abundance limits the possibilities of contact between predator and prey, i.e., limits the availability of food for the predator. But at the same abundance of food its biomass decides about the value of food ration.

The food demands of the predator are satisfied if despite the increase in biomass (or in abundance) of food the food ration does not increase or increases slightly. In this experiment when the biomass of food per one predator increases from 0 to 0.03 mg the daily food ration increases about 67%, at an increase 0.03–0.60 mg the food ration increases only 17%. It can be, therefore, assumed that over 0.03 mg/1 predator, which corresponds to the food ration = 70%, the food demands of *Mesocyclops* are more or less satisfied.

3.3. ESTIMATION OF BIOMASS AND CONSUMPTION OF SMALL ZOOPLANKTON BY *MESOCYCLOPS* SP. IN SOME LAKES

Assuming that the relation: rotifers-food ration is a general one: small zooplankton-food ration it is possible to estimate whether the small zooplankton in the lake may be a sufficient food supply for *Mesocyclops*, and if so, what is the pressure of predator on the total biomass of food examined. These relations have been examined in four lakes: Mikołajskie Lake (1966) (Hillbricht-Ilkowska et al. 1970) and in lakes: Smolak, Piecek and Czarna Kuta (a characteristics of these lakes by Węgleńska et al. 1975) on the basis of data from 1974 on the numbers and biomass of protozoans (L. Bownik-Dylińska – unpublished data), rotifers – without *Asplanchna* (J. Ejsmont-Karabin – unpublished data), nauplii, and also on the basis of the total number of adult *Mesocyclops leuckartii* and *M. oithonoides*.

The rotifers distinctly dominate in the small zooplankton of lakes Smolak, Piecek and Czarna Kuta (Fig. 6 A). In the spring and summer they are 50–99% of biomass of zooplankton examined, only in the late autumn their contribution decreases to 15–20%. They decide mainly about the value of biomass of food for *Mesocyclops*. Maximal biomass values, up to 3.0–4.0 mg/l in spring, are due to the peak of occurrence of rotifers. In other months this value does not exceed 1.0 mg/l and in autumn (sometimes in early spring), when the numbers of rotifers are low and protozoans and nauplii dominate, it ranges from 0.1 to 0.5 mg/l.

The fluctuations in numbers of *Mesocyclops* in these lakes have other characteristics (Fig. 6 B). Its highest numbers are in the summer and early in autumn (July, August, September), when the biomass of small zooplankton tends to decrease. In the originally dystrophic (at present fertilized) Lake Smolak adult *Mesocyclops* are not numerous – maximum 8 ind./l, whereas in lakes Piecek and Czarna Kuta the number of adult predators reaches 30/l.

Mikołajskie Lake has other characteristics (Fig. 6). The numbers and thus the biomass of rotifers are much lower in this lake, therefore the total biomass of the food community examined is during the season very low, the highest value is 0.7 mg/l, i.e., 4–6 times less than in lakes Smolak and Czarna Kuta. In the biomass (as compared to other lakes) the protozoans dominate (up to 60%). The numbers of *Mesocyclops* are very high. The highest numbers are in June – 70 ind./l, and only in April and October they drop below 10 ind./l.

Thus in the lakes discussed the highest biomass of small zooplankton is in spring and is due to the development of rotifers, whereas the highest numbers of the predator are in summer when the biomass of the food community examined tends to decrease.

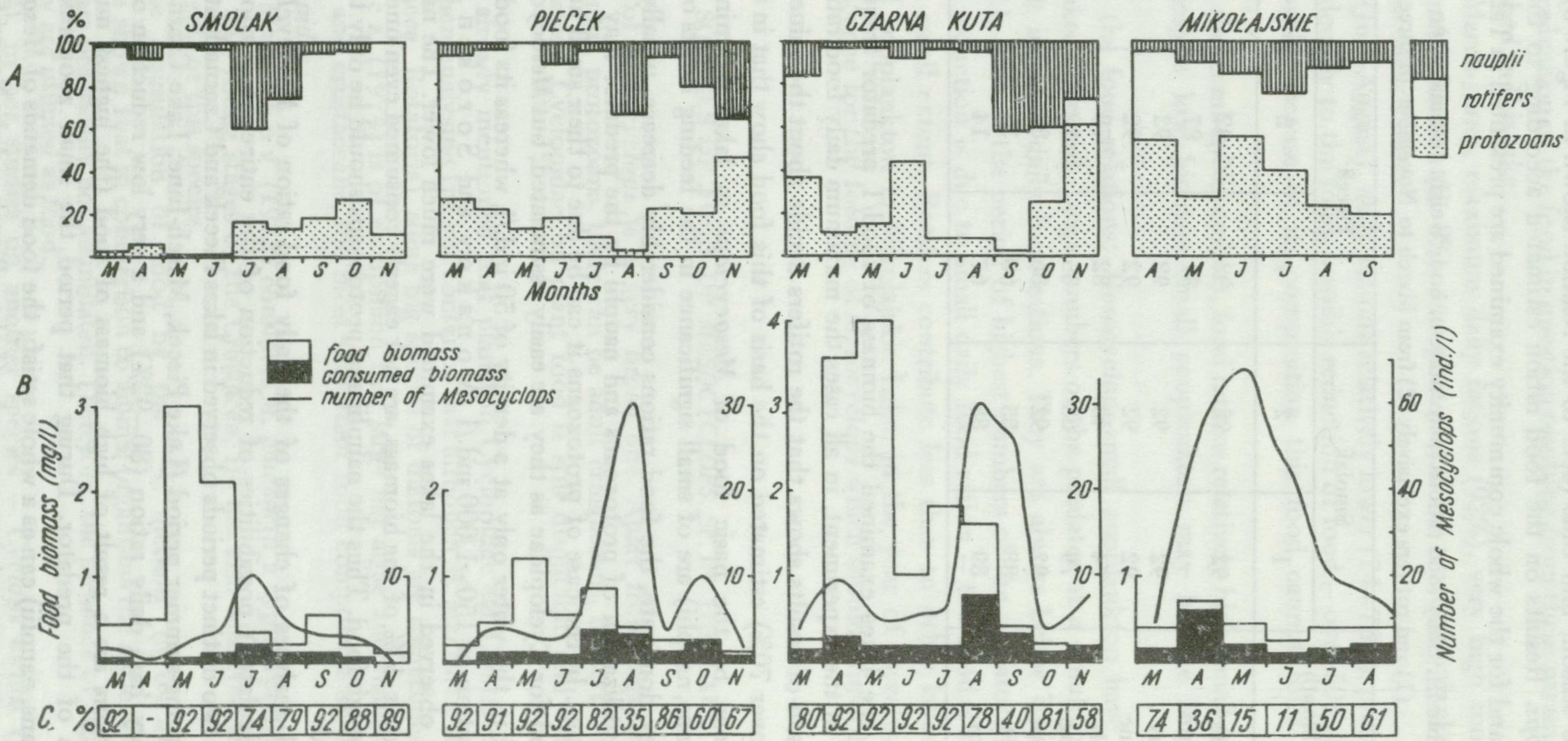

Fig. 6. Seasonal changes in the percentage of small zooplankton (A), its biomass, numbers of *Mesocyclops* and its possibilities of pressure upon food (B) and the daily food ration (C) in four Masurian lakes

The above data allowed to calculate the biomass of food per one predator in particular lakes during the season, and thus (acc. to the relation shown in Figure 5) the daily food ration of *Mesocyclops*. Results on the food ration estimated according to the dominant kind of food (rotifers) and for the whole community examined are presented in Table III.

Table III. Daily food rations (percentage of body weight)estimated on total small zooplankton (1) and rotifers exclusively (2) from March to November in three lakes examined

Month	Smolak		Piecek		Czarna Kuta	
	1	2	1	2	1	2
March	92	92	92	92	80	60
April	–	–	91	87	92	92
May	92	92	92	92	92	92
June	92	92	92	92	92	88
July	74	48	82	78	92	92
Aug.	79	68	35	22	78	74
Sept.	92	92	86	80	40	22
Oct.	88	85	60	38	81	48
Nov.	89	88	67	14	58	7

As in the lakes examined the biomass of food/1 predator frequently exceeds the values obtained in the experiment, in all cases the maximum daily food ration was accepted as = 92%. Comparison of results shows that the rotifers decide about the value of food ration. High food rations (over 70%) estimated on the basis of this food show that in some periods (March-July) rotifers can be the basic food of *Mesocyclops* in lakes examined. Other kinds of food (protozoans, nauplii) are of small significance in the feeding habits of this predator. In autumn, when they dominate, the food rations considerably decrease, usually below 70%. Furthemore the real utilization of protozoans and nauplii by the predator may be even lower than in the calculations. In the case of protozoans it can be due to their small numbers. Protozoans can be good food for Cyclopidae as they are easily assimilated, but *Mesocyclops* can catch protozoans scattered in the water only at a density of 50 ind./l, whereas its food demands are satisfied at a concentration of 150–1,000 ind./l (M o n a k o v and S o r o k i n 1971). Still, the maximum numbers observed in the lakes examined were much lower. The nauplii, which sometimes in autum cover 40% of the biomass, are not eagerly consumed even under conditions when there is not enough food. Thus the nauplii and protozoans should be only the additional food in lakes examined.

Detail analyses of changes of the daily food ration of *Mesocyclops* during the season and (thus calculated) possibilities of reduction of the entire small zooplankton by the predator point to two distinct periods observed in lakes Piecek and Czarna Kuta:

I – spring-summer period (Lake Piecek, March-June; Lake Czarna Kuta, March-July) which has a very high daily ration (80–92%) and a very low reduction of small zooplankton. High food rations are a result of high biomass of food (the highest number of rotifers) at small numbers of the predator. During that period the small zooplankton community (rotifers, protozoans, nauplii) can as a whole satisfy the food demands of *Mesocyclops*.

II – summer-autumn period (Lake Piecek, July-November; Lake Czarna Kuta, August-November). The estimated food rations are much lower (35–86%), but the reduction of small zooplankton is very high (35–85%).

These relations differ slightly in Lake Smolak, where the numbers were low over the season. Considering the numbers of the predator, the composition and biomass of food, the food ration and the possibilities of reduction of the food in question resulting from these parameters, three periods can be distinguished in this lake:

I – spring period (March-June), maximum daily rations (92%), very high food biomass, rotifers dominate, minimal reduction (2–8%), over that period the small zooplankton may be an essential element of predator's food.

II – summer period (July-August), daily rations relatively lower (74–78%), protozoans and nauplii contribute considerably to the food, possible reduction of food – over 50%. Despite the high food ration, probably because of its composition this food cannot fully satisfy the demands of the predator.

III – autumn period (September-November), food rations relatively high, small reduction of this food (3–30%), despite low biomass small zooplankton may be the basic food of *Mesocyclops* again.

In Mikołajskie Lake the food relations: *Mesocyclops*-small zooplankton have a different character than in the lakes discussed. Large numbers of the predator at a simultaneously low food biomass also result in small daily food rations. They are always below 70%, except in April, and decrease to 11–15% in the period of highest numbers of the predator (June, July). The relatively low food reduction is due to small daily food ration – this food is available for the predator only to a small extent. Rotifers contribute less than to other lakes. All these results show that small zooplankton in Mikołajskie Lake, in the year of investigations, was probably of little significance for the feeding of *Mesocyclops* which should primarily use other kinds of food.

3.4. OTHER SOURCES OF FOOD OF *MESOCYCLOPS* SP. IN THE LAKE

The food spectrum of *Mesocyclops* is a very broad one. Apart from organisms already mentioned: rotifers, nauplii, protozoans, there can be adult crustaceans, bacteria, detritus and algae. Feeding of predatory Cyclopidae on plant food is still disputable and unsufficiently explained.

Birge (1897) has already mentioned that plankton Cyclopidae eat *Ceratium*. Fryer (1957) has observed, when analysing the gut contents, that although *M. leuckartii* feeds mainly on animal food (Crustacea, Rotatoria), some big species of diatoms are sometimes caught by this predator. Gliwicz (1974) is of an opinion that large net algae and filamentous algae are, besides the rotifers and crustaceans, the most important food component of *Mesocyclops leuckartii* and *M. oithonoides*.

On the other hand, Monakov (1972) considers *M. leuckartii* a typical predator feeding on protozoans, rotifers and young stages of the Crustacea. He has also observed the constant presence of algae in the guts of this species.

Still, studies on the assimilation of food by the ^{14}C method (Monakov and Sorokin 1972) have shown that in comparison to animal organisms the algae *Scenedesmus*, *Microcystis*, *Anabaena* are practically not assimilated. Therefore, the presence of algae in guts is not yet a proof that they are utilized as food.

Bogatova (1954), in her studies on another species – *Cyclops viridis* (Juriné) has observed that when it was reared on plant food (*Scenedesmus*) the adult individuals survived for some time but did not reproduce, whereas the young ones died very quickly.

The algae in the guts of *Mesocyclops* may have been brought in with the animal food (in the guts of filtrators consumed). A simple experiment, based on the experiment with small zooplankton, was made in order to find whether *Mesocyclops* may catch actively large cells of algae. Bottles of a capacity 100 ml were filled with filtrated water, then some phytoplankton was added, in which *Ceratium hirundinella* was about 90%. This species produces in Mikołajskie Lake long lasting water blooms (Hillbricht-Ilkowska and Spodniewska 1969). In 1966, the maximum biomass was 10.02 mg/l, and the maximum numbers – 216 cells/ml. Then various amounts of predatory forms of *Mesocyclops* (5–23 individuals) were placed in bottles. Apart from the initial control, fixed immediately after filling the bottle, the bottles with phytoplankton but without the predator were also exposed. The exposure lasted 25 hours. Afterwards the phytoplankton was fixed and all *Ceratium* cells were counted.

Results are presented in Figure 7. The numbers of *Ceratium* decrease together with the increasing density of predator – from about 4,500 cells in the control to 2,400 cells at 23 individuals of *Mesocyclops* – and thus the decrease is almost double.

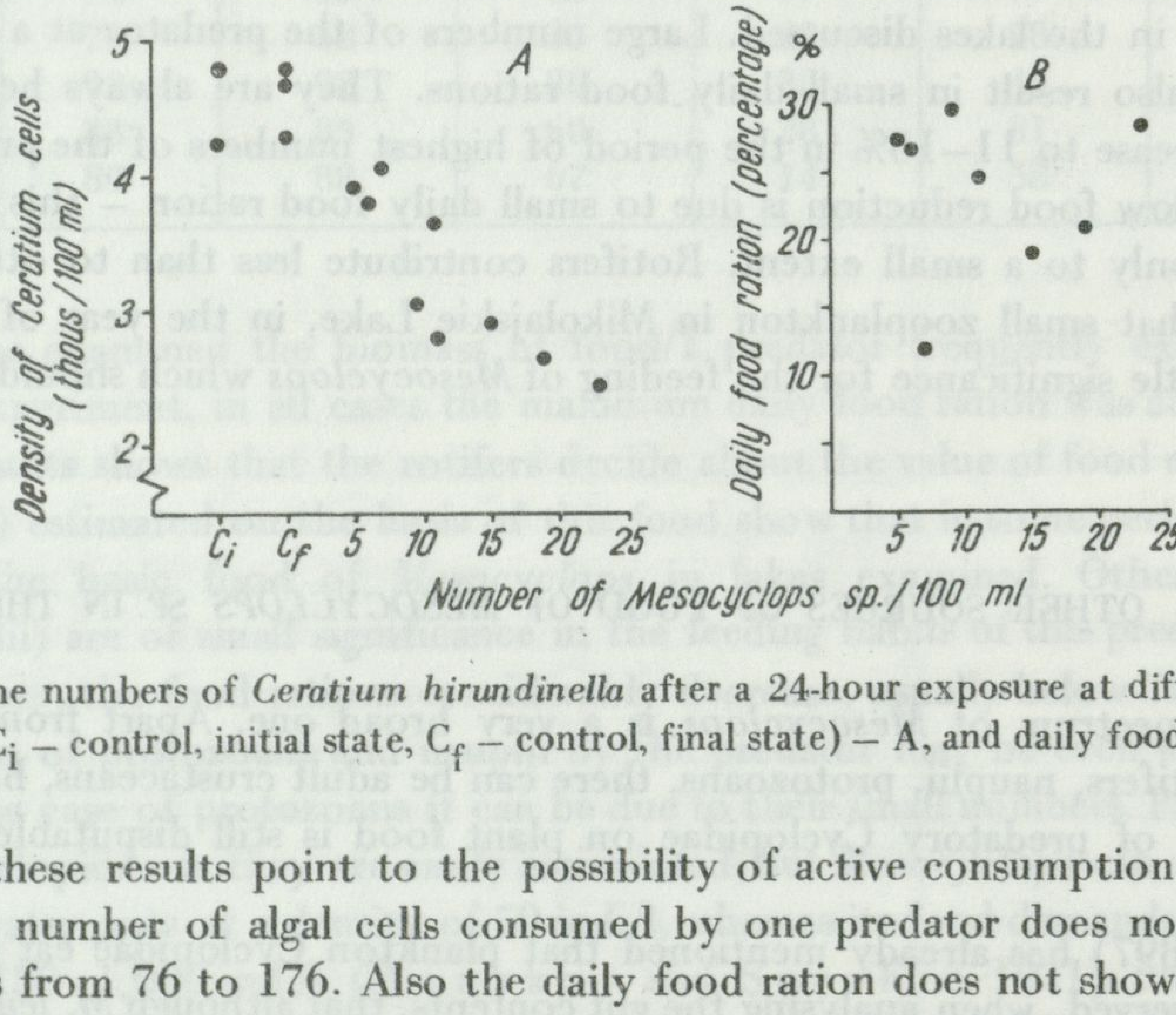

Fig. 7. Decrease in the numbers of *Ceratium hirundinella* after a 24-hour exposure at different densities of *Mesocyclops* (C_i – control, initial state, C_f – control, final state) – A, and daily food ration – B

Undoubtedly, these results point to the possibility of active consumption of *Ceratium* by *Mesocyclops*. The number of algal cells consumed by one predator does not depend on its density and ranges from 76 to 176. Also the daily food ration does not show any correlation with the density of predator and ranges considerably 12.0–29.1%. These are relatively low values considering that other food is not available. These data allow to assume that *Mesocyclops* can eat algal cells, especially big species such as dinoflagellates. But there are no data on the assimilation of this food. Probably other demands of the predator are thus satisfied (enzymes, hormones, vitamins), also *Ceratium* may be used as food in periods of deficiency of animal food; in August 1966 the mean biomass of this species was 6.71 mg/l.

Anyway, Gliwicz's (1974) opinion that net and filamentous algae are an equally valuable food of this predator, besides rotifers and crustaceans, cannot be accepted.

Therefore, when there is a deficiency of small zooplankton, usually in late summer and autumn in the three lakes examined and in Mikołajskie Lake all the year round, the crustaceans should be the other basic food source. Varbapetjan (1972) has observed that in the mixed food of *Cyclops scutifer:* rotifers + crustaceans (*Bosmina*, *Daphnia*, *Ceriodaphnia*) the latter were not eaten at all; this shows rather preference for rotifer food which dominated in these experiments. Monakov and Sorokin (1959) state that *Mesocyclops leuckartii* consumes Crustacea and the daily ration depending on the species consumed is: *Eudiaptomus* *graciloides* (Lilljeborg) – 28%, *Ceriodaphnia quadrangula* (O. F. Müller) – 38%, *Daphnia longispina* O. F. Müller – 80%, *Diaphanosoma brachyurum* (Liévin) – 92%. Thus the values are high. In Mikołajskie Lake (1966) in the period of maximum numbers of *Mesocyclops* the mean monthly biomass of crustaceans was: May – 1.72 mg/l, June – 4.03 mg/l, July – 1.99 mg/l, which corresponds to daily food rations of 67, 83 and 75%. Thus over the period examined the crustaceans may be the basic food element for *Mesocyclops* in this lake.

Bacteria can be another source of food for copepods and adult *Mesocyclops*. Monakov and Sorokin (1960) have observed that *M. leuckartii* cannot feed on dispersed bacterioplankton, because of the way this species catches food. But the nauplii of *Mesocyclops* which are filtrators can assimilate the dispersed bacterioplankton with an intensity protecting their growth and development. For adult individuals the bacteria are available only with bigger detritus particles (Monakov and Sorokin 1971). The intensity with which this food is consumed in the case of *M. oithonoides* is three times smaller than for a typical detritus-feeder (*Cypridopsis vidua* (O. F. Müller)). However, it seems that when the detritus content in open water is high, in the late summer in Mikołajskie Lake (Gliwicz and Hillbricht-Ilkowska 1975), it can be a component of the food supply of *Mesocyclops*.

Thus the nauplii, detritus together with bacterial flora growing on it and big algae (e.g., *Ceratium*) are only additional food of *Mesocyclops* sp. used when the basic food is insufficient. The basic food consists of rotifers (used in investigated lakes in the spring), crustaceans (especially the young stages) and protozoans, but the latter because of their small numbers in the lakes examined are available for the predator to a small extent and thus can be also regarded as additional food.

4. SUMMARY

Food selectivity and daily food rations of two species of Cyclopidae: *Mesocyclops leuckartii* and *M. oithonoides* as regards small zooplankton (rotifers, nauplii) were examined under laboratory conditions. The experiment was conducted in six series differing as to the amount and composition of food.

According to the food consumed (Fig. 2) it can be said that *Mesocyclops* feeds selectively. Mainly the rotifers were consumed, the nauplii were avoided – Ivlev's (1955) index of food selectivity ranged from –1.0 to –0.32 (Table II, Fig. 3). Selectivity took also place as regards the rotifers only; species with lorica – *Keratella cochlearis* and *Gastropus stylifer* were consumed reluctantly (Table II).

The daily food ration depended on the food biomass per one predator and was 4–92% (Fig. 5). These data allowed to estimate the pressure of *Mesocyclops* sp. on small zooplankton of several lakes. These lakes varied both in the composition and biomass of small zooplankton (0.75–4.0 mg/l) and the numbers of *Mesocyclops* (1–70 ind./l) (Fig. 6).

In three lakes: Smolak, Piecek and Czarna Kuta the community of small zooplankton examined could be the basic food of the predator in spring and early in summer, whereas in Mikołajskie Lake it had no special significance.

The possibilities of *Mesocyclops* feeding on other kinds of food, such as: crustaceans, protozoans, bacterioplankton, detritus and algae, were also analysed.

An experiment was carried out in order to find out whether *Mesocyclops* can catch and eat big algae – *Ceratium hirundinella*. The results were positive; the daily food ration ranged from 12 to 30% of the body weight of *Mesocyclops* (Fig. 7).

5. POLISH SUMMARY

Oceniono (w warunkach eksperymentu laboratoryjnego) wybiórczość pokarmową oraz dobową rację pokarmową dwu gatunków *Cyclopidae*: *Mesocyclops leuckartii* i *M. oithonoides* w stosunku do drobnego zooplanktonu (wrotki, naupliusy). Eksperyment przeprowadzono w sześciu seriach różniących się liczebnością i składem pokarmu.

Na podstawie zjedzonego pokarmu (rys. 2) stwierdzono, że *Mesocyclops* żerował w sposób wybiórczy. Zjadane były głównie wrotki, natomiast naupliusy były wyraźnie unikane – wskaźnik wybiórczości Ivleva (1955) waha się w granicach od –1,0 do –0,32 (tab. II, rys. 3). Wybiórczość istniała również w obrębie pokarmu wrotkowego; niechętnie były zjadane gatunki pancerzykowe – *Keratella cochlearis* i *Gastropus stylifer* (tab. II).

Wielkość dobowej racji pokarmowej była uzależniona od wielkości biomasy pokarmu przypadającej na jednego drapieżnika i wynosiła 4–92% (rys. 5). Na podstawie tych danych określono presję *Mesocyclops* sp. na drobny zooplankton kilku jezior. Jeziora te różniły się zarówno składem i biomasą drobnego zooplanktonu (0.75–40 mg/l), jak też liczebnością *Mesocyclops* (1–70 osob./l) (rys. 6).

W trzech jeziorach: Smolak, Piecek i Czarna Kuta rozpatrywany zespół drobnego zooplanktonu mógł być podstawowym pokarmem drapieżnika w okresie wiosny i wczesnego lata, natomiast w Jeziorze Mikołajskim pokarm ten odgrywał niewielką rolę.

Dokonano także analizy możliwości odżywiania się *Mesocyclops* innymi rodzajami pokarmu, jak: skorupiaki, pierwotniaki, bakterioplankton, detrytus oraz glony.

Przeprowadzono eksperyment mający odpowiedzieć na pytanie czy *Mesocyclops* może chwytać i zjadać duże glony – *Ceratium hirundinella*? Wynik eksperymentu był pozytywny; dobowa racja pokarmowa wahała się w granicach 12–30% ciężaru ciała *Mesocyclops* (rys. 7).

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