Freshwater Biological Association

FBA Translation (New Series) No. 143

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Reference: Trudy Inst.Biol.vnutr.Vod. 22(25), 37-42. (1971)

Original language: Russian

Date of publication of original: 1971

Translator: I.M. Strachan

Date of publication of translation: 1980

Number of pages of translation: 7

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The role of infusoria and bacteria as food for Cyclopoida in Rybinsk Reservoir.

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Despite the fact that it is a long time since the methods of collection and quantitative estimation of protozoa were worked out (Gaevskaya, 1949) data on the abundance of these animals in freshwaters are not very numerous. Nevertheless, Infusoria and Rhizopoda at high densities are widespread in the water and sediments of lakes and reservoirs (Gourvich, 1961; Mordukhai-Boltovskaya, 1965; Shcherbakov, 1967; Chorik, 1969).

E.D.Mordukhai-Boltovskaya (1965) has shown that in Rybinsk reservoir the number of infusoria sometimes reaches a considerable value. Systematic observations on infusoria carried out by one of the authors in the Volga reach of Rybinsk reservoir have revealed two peaks in the number of these animals: in the 'dying off' period of diatoms (mid-June) and the 'dying off' period of blue-green algae (mid-August). Their biomass during this period reached 4-9 mg/l, and their numbers 500-1000 individuals per ml (Sorokin, 1970). Comparison of the seasonal dynamics of the populations of infusoria and their likely predators - cyclopoids - reveals a link between their numbers (fig.1). Maximum numbers of cyclopoids were observed at the end of June and the end of August, directly following the maximum numbers of infusoria. These data indicate that infusoria in the present instance may have been the food source of cyclopoids, as the number of daphnids and rotifers in the period indicated was relatively low.

In order to find out the importance of infusoria as a food source for cyclopoids we carried out experimental investigations using C^{14}.

For this we selected three species of cyclopoids, widely distributed in open regions of Rybinsk reservoir: Cyclops vicinus, Mesocyclops oithonoides and Mesocyclops leuckarti.

Cyclopoids were collected from the reservoir, transferred to the laboratory where they were identified to species, and placed in aquaria. The period of adaptation to experimental conditions was usually 24 hours, during which time the animals were fed with infusoria. The experimental animals were placed in small vessels containing 20-800ml depending on the particular experiment. Infusoria picked out from the reservoir water were cultured on bacterial food labelled with the carbon isotope C^{14}. In the cultures the predominant infusoria measured 15 x 30/um. This was close to the mean size of infusoria found in the reservoir. The density of cyclopoids usually corresponded with their density in natural conditions. Experiments lasted 3-8 hours, at room temperature. At the end of an experiment the animals were rinsed in filtered water and transferred for half an hour to a vessel containing unlabelled food (rotifers, infusoria).

In our work on the study of the nutrition of copepods we usually determined the radioactivity of animals in dried preparations. So, if a vessel contained 50 crustaceans, at the end of the experiment after fixation they were placed in five separate preparations (of ten individuals) in which their activity was determined with a correction for self-absorption. Then the arithmetic mean was calculated, and sometimes the mean square deviation for the five cases. In the present work, at the end of an experiment the cyclopoids were removed from the experimental vessel with a pipette and from them a homogenate was prepared, which was distributed in a thin layer on an object-glass, dried, and its radioactivity determined under a meter. Knowing the radioactivity of the homogenate and the number of animals picked out, we were able to obtain the actual mean activity per crustacean. Naturally, in these calculations there could be room for systematic error, for example due to loss during preparation of the homogenate or fluctuation in feeding of each individual. In order to discover the size of such error, we performed the following experiment. In a vessel holding 250ml of water, containing radioactive infusoria, there were placed 200 individuals of Cyclops vicinus. After three hours the animals were divided into four lots (of 50 individuals) then from each lot a homogenate was made up. The radioactivity of the prepared homogenates was found to be 78.0, 90.4, 91.3 and 96.8. For these samples the maximum deviation from the mean value was only 11%.

The quantity assimilated by cyclopoids from protozoa (C_y) without accounting for loss through respiration is calculated from the radioactivity of the animals (R) and the value of the specific activity of the food (C_p)

by the formula

$$C_y = \frac{R.C_r.24}{T} \quad /\mu g\ C/indiv./day$$

where T = length of experiment in hours (Sorokin, 1966).

We have shown that the intensity of feeding is indicated by the index of assimilation (C_y/C) which represents the percentage ratio of the size of C_y to the total carbon content (C) of the experimental crustacean.

Since C^{14} labelled infusoria, used as food, are difficult to separate from the labelled bacteria which serve as their food, there were often bacteria in the experimental vessels together with labelled infusoria. Is it not possible in such an instance for consumption of these bacteria by cyclopoids to affect the results of the experiment? We must answer this question in the negative as,firstly, in the experiments we used cultures of infusoria in which the numbers of bacteria were reduced by being consumed to below the margin of error. Secondly, it has been established previously that some species of cyclopoids, namely Mesocyclops leuckarti and Acanthocyclops viridis, are unable to utilise bacterioplankton (Monakov and Sorokin, 1960).

In order to obtain additional proof we set up the corresponding experiment with Cyclops vicinus. Into five vessels (volume 200ml) of natural water, prefiltered through a No.3 filter, there were placed up to 30 Cyclops individuals. To two of the vessels we added labelled bacteria so that their concentration in one case amounted to 4 million cells per ml, which was about twice as high as the number of bacteria in Rybinsk reservoir, and in another - 10 million cells per ml. Into the next two aquaria the same concentrations of bacteria were placed with the addition of a few protozoa. In the fifth vessel the cyclopoids were supplied with bacteria in the form of flocs.

The results obtained (fig.2) show that bacterioplankton, even if its concentration is high, cannot serve as a food supply for Cyclops vicinus. With the inclusion of an additional link, which in our case was infusoria, the radioactivity of the predatory cyclopoids was much higher. A similar high level was shown for the radioactivity of the animals when feeding on bacterial flocs.

The ability of C.vicinus to consume and assimilate bacteria in the form of flocs allows one to suppose that they can also feed on detritus, the

organic basis of which, as is known, is made up of bacteria and, probably, protozoa. This we have confirmed in an experiment, in which two species of cyclopoids were offered natural detritus with microflora labelled with C^{14}. Detritus was collected from the bottom of a pond with a pipette and heated to a temperature of 50° in order to kill the protozoa. Later, labelled hydrolysed-protein was added to some of this. The detritus was left to stand for 2-3 days, during which time the natural microflora acquired radioactive labelling by consuming radioactive hydrolysate.

In view of the impossibility of determining C_r for detritus, it was assumed that the ratio of the radioactivity of the animals, feeding on labelled detritus, to their biomass would show the intensity of feeding. the crustacean Cypridopsis vidua, known to be a detritus feeder, was taken as a control. The experimental results (table 1) show that the cyclopoids are evidently able to feed on the microflora of detritus, although their intensity of feeding in this instance was three times lower than that of Cypridopsis vidua.

Finally, cyclopoids were supplied with fresh infusorian plankton, the concentration of which approached that in nature. This shows that all the pelagic cyclopoids, and likewise the littoral form Eucyclops macruroides, are able to consume infusoria, dispersed in the water layer, at a concentration of approximately 50 individuals per ml. The index of assimilation for the cyclopoids was sufficiently high (table 2) and approaches the value obtained by us in an experiment investigating the diet of certain calanoids (Monakov and Sorokin, 1970).

Thus the data presented give evidence for this, that the species investigated are able as predators to consume infusorian plankton and bacteria in the form of flocs or small clumps of detritus. The first of these, as has been shown, has a high nutritive quality. The assimilability of this food, determined in a special equilibrium experiment on Cyclops vicinus, was shown to be a steady 80% (table 3).

The question arises: what concentration of planktonic protozoa is available to the cyclopoids? To answer this, the dependence of the feeding intensity of cyclopoids on infusorians, on the concentration of the latter, was determined. The experimental results are presented in table 4. From analysis it seems quite clear that stabilisation of the value of C_y/C is observed at certain concentrations of infusoria. For Cyclops vicinus and Mesocyclops oithonoides this ratio stopped increasing at concentrations of infusoria of 150-1000 indiv/ml, for Mesocyclops leuckarti - at even lower

concentrations of food. Probably at concentrations of infusoria lower than 150 individuals per ml cyclopoids experience a shortage of food.

In the open regions of Rybinsk reservoir the numbers of infusoria in the summer months fluctuate between 30 and 150 indiv/ml, and in the littoral-up to 400 indiv/ml (Mordukhai-Boltovskaya, 1965). In the peak period their numbers were even higher - up to 1000 indiv/ml. These concentrations reach and even exceed the optimal levels, determined in the experiments.

It is possible to surmise that in early spring, immediately after the freeing of the reservoir (from ice), when the pelagic plankton is composed almost entirely of cyclopoids (Mordukhai-Boltovskoi and Monakov, 1963; Luferova and Monakov, 1966), infusoria represent the main source of food for cyclopoids. According to the data of E.D.Mordukhai-Boltovskaya (1965), in this period the numbers of infusoria in the reservoir are usually very considerable.

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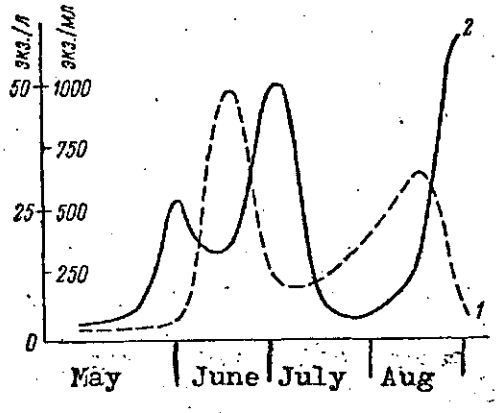

Fig.1. Seasonal dynamics of the populations of infusoria(1) and cyclopids (2) in the Volga reach water of Rybinsk reservoir in 1967.

Horiz.axis- months; vert.axis- left: density of cyclopids (indiv./l) -right: density of infusoria (indiv/ml).

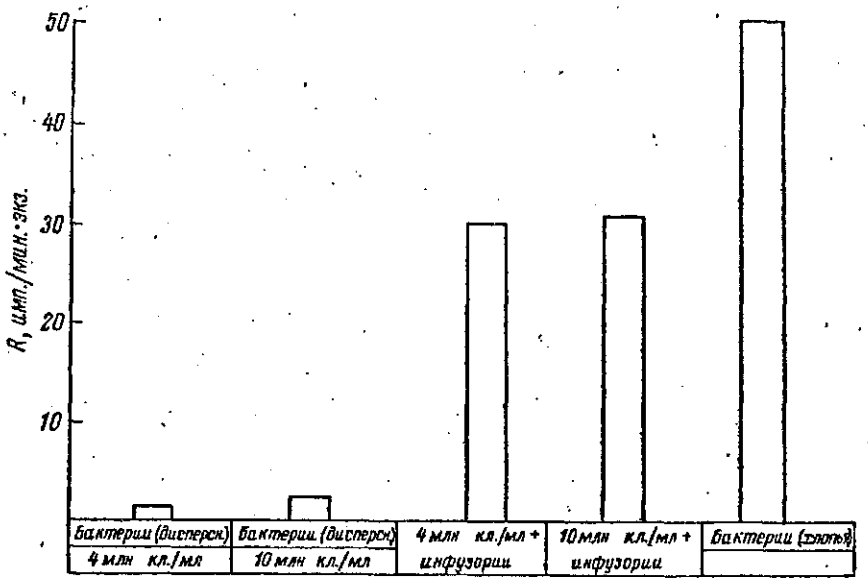

Fig.2. Consumption by cyclopids (Cyclops vicinus) of bacteria and infusoria.

Vert. axis - radioactivity of food(?) (counts/min/indiv.)
Horiz. axis (left to right) : bacteria (dispersed)- 4m cells/ml; sim.- 10 m cells/ml; 4 m cells/ml + infusoria; 10 m cells/ml + infusoria; bacteria (flocs).

Table 1. Comparison of the intensity of feeding of cyclopids and an ostracod on the labelled microflora of detritus.

species of crustacean	number of crustaceans	weight of 1 crustacean (B),mg	Radioactivity (R)of 1 indiv, counts/min.	$\frac{R}{B}$
Cyclops vicinus	32	100	4.5	0.04
Mesocyclops oithonoides	50	10	0.4	0.04
Cypridopsis vidua	50	30	3.7	0.12

Table 2. Assimilation of infusoria by cyclopids.

Species of cyclopid	Number of crustaceans	R, counts/ min/indiv.	C_y (μg C/ day/indiv)	C_y/C %
Cyclops vicinus	23	564.1	1.5	15
Mesocyclops leuckarti	25	184.2	0.5	17
M. oithonoides	43	157.8	0.4	40
Eucyclops macruroides	22	306.8	0.8	18

Footnote. Duration of experiment - 8 hrs; C_r for infusoria - $0.92.10^{-3}$ μg C.

Table 3. Assimilability of infusoria for Cyclops vicinus.

Radioactivity taken up & assimilated from food, counts/50 indiv							Assimilability $\frac{A.100}{A+F}$, %
Assimilated food			Excretion			Consumed food (A+F)	
Assimilated into body	Respiratory loss	Total (A)	Solid	Dispersed	Total (F)		
4050	610	4660	690	462	1152	5812	80.2

Footnote. Duration of experiment: consumption section - 20 min., assimilation section - 1 hr. Number of crustaceans - 50.

Table 4. Dependence of the intensity of feeding of cyclopids on infusoria on the concentration of food.

species	ind. per experiment	conc. of food, cells/ml	R, counts per min. per ind.	C_y, μg C per day per ind.	C_y/C, %
Cyclops vicinus	17	3600	403.7	2.6	26
	21	2000	582.8	3.7	37
	22	1000	513.0	3.2	32
	20	400	406.1	2.6	26
	20	150	174.1	1.1	11
	19	50	212.0	1.3	13
	19	20	86.8	0.5	5
	36	10	17.0	0.1	1
Mesocyclops oithonoides	48	2000	24.5	0.31	31
	51	1000	29.3	0.37	37
	38	400	28.8	0.36	36
	50	150	25.9	0.32	32
	44	50	10.9	0.13	13
	49	20	3.1	0.04	4
	63	10	0.5	0.006	0.6
Mesocyclops leuckarti	23	2000	187.2	2.4	53
	23	1000	170.0	2.1	46
	19	400	146.0	1.8	40
	23	150	164.6	2.0	44
	17	50	116.3	1.4	32
	27	20	55.0	0.7	15
	19	10	21.7	0.2	4

Footnote. C_r for infusoria - $1.62.10^{-3}$ μg C. Duration of experiment for C.vicinus - 1 hr., for M.oithonoides & M.leuckarti - 3hr.

Notice

Please note that these translations were produced to assist the scientific staff of the FBA (Freshwater Biological Association) in their research. These translations were done by scientific staff with relevant language skills and not by professional translators.