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ON THE CULTURE OF *PARACYCLOPS FIMBRIATUS* (CYCLOPOIDA) AND THE POTENTIAL OF THE SPECIES AS LIVE FOOD FOR JUVENILE FISH

MOŻLIWOŚCI HODOWANIA *PARACYCLOPS FIMBRIATUS* (CYCLOPOIDA) I WYKORZYSTANIA TEGO GATUNKU JAKO ŻYWEGO POKARMU DLA NARYBKU

Department of Invertebrate Zoology, University of Szczecin, Poland

Paracyclops fimbriatus can be easily cultured as a food source for juvenile fish. The crustacean can be fed protozoans living in sevage sludge and in hay infusions. When properly fed, the cyclopoid densities can be as high as 1 000 000 inds/dm^3. Methods of culture and harvest of the of the crustaceans are described. Data on length and biomass of all the 12 developmental stages are reported as well.

INTRODUCTION

Invertebrates usually cultured as food for larval fish include primarily rotifers, cladocerans, and *Artemia,* but not cyclopoids, otherwise known as a food preferred by larval carp (Szlauer and Szlauer 1980), coregonids (Szlauer 1974) and probably also other juvenile fish beginning to feed. The most likely reason why the cyclopoids have been neglected in this respect is the lack of knowledge which species could be appropriate for the purpose; such a species has to be both easy to culture and suitable to be offered as food. The present author found such species in 1987. During a laboratory experiment on the treatment of municipal sewage sludge, the author observed a mass occurrence of *Paracyclops fimbriatus* (Fisch.). The species' density in such an accidental culture reached 13 000 inds/dm^3. The observation prompted the author to commence studies aimed primarily at developing methods for culture of *P. fimbriatus* and at testing its potential as food for newly hatched fish larvae.

The present study involved a number of different methods which will be described in appropriate sections. The whole approach can be defined as based on laboratory experimentation.

RESULTS

Occurrence of *Paracyclops fimbriatus* and harvest of seeding material

To start a *P. fimbriatus* culture, it is necessary to locate and harvest the crustacean. *P. fimbriatus*, a cosmopolitan species, can be found on almost all continents. Its presence has been reported from Europe and Asia (Rylov 1948) as well as from South America (Reid 1987).

P. fimbriatus is common in Poland and Europe, but it is difficult to find as its life is associated with the benthic rather than the pelagic realm. It should be looked for in small streams, including strongly polluted ones. The present author's first finding was in a municipal sewage canal. According to Rylov (1948), *P. fimbriatus* occurs in different streams, lakes, ponds, in brackish water bodies, and in mountain lakes and subterranean waters. The species was reported both from inshore zone and from large depths (Rylov 1948).

To harvest *P. fimbriatus*, one should sample the bottom sediment, including the overlying mud layer. The sediment should then be sieved through a 1 mm mesh size sieve. The sieving residue, suspended in water, should be transferred to narrow necked bottles, the suspension filling each bottle almost to the top. The bottles are then kept undisturbed for 1–2 days after which time, due to deteriorating oxygen conditions, the cyclopoids and other small invertebrates will concentrate underneath the surface film in the bottle neck. They can be then siphoned off with a pipette or decanted and concentrated on a gauze. As found by Wichtowska (1994), a small amount of milk (about 1 cm^3/dm^3 water) added to the bottle accelerates the process of aggregation of the fauna underneath the surface film.

P. fimbriatus is frequently the only species occurring in samples. If this is the case, the specimens obtained can be used as a seeding material for the so-called pure culture.

All attempts should be made to eliminate other invertebrates, particularly ostracods and cyclopoids other than *P. fimbriatus*, from the initial sample. The culture medium should be free of other fauna as well.

Identification of *P. fimbriatus*; developmental stages; individual size

To identify the species, a sexually mature female, conspicuous due to egg sacs attached to the body, should be found. The following characters are indicative of the typical form of the species: 1) lst antenna 8-segmented; 2) a short row of spines on the upper surface of the terminal part of furca, almost perpendicular to its edge (Fig. 1); 3) furcal rami 5–6 times longer than wide. Apart from the typical one, the species includes also other forms with shorter furca (Rylov 1948). The body of *P. fimbriatus*, including the furca, is strongly flattened dorsoventrally, for which reason the species is easily identifiable when a female is

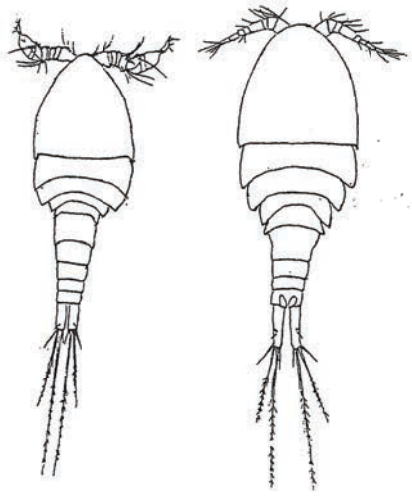

Fig. 1. *Paracyclops fimbriatus* male (left) and female (right)

viewed laterally. *P. fimbriatus* nauplii are strongly flattened, too; they are short, almost rubicund.

Length measurements carried out by B. Szlauer allow to conclude that the species has 6 naupliar and 5 copepodite stages. Table 1 summarises average body lengths of each stage, including the adult. The average length of nauplius, copepodite, male, and female is 0.179 mm; 0.454 mm; 0.640 mm; and 0.740 mm, respectively. The earliest nauplius measures 0.111 mm on the average, a body length similar to that of small rotifers.

Table 1

Approximate body length (mm) of different developmental stages of *Paracyclops fimbriatus* kept in a laboratory culture; March 1987

Group	Stage						Average
	I	II	III	Iv	V	VI	
Nauplii	0.111	0.138	0.160	0.190	0.223	0.253	0.179
Copepodites	0.317	0.372	0.462	0.521	0.596	–	0.454
Male	range: 0.588–0.678						0.640
Female	range: 0.693–0.782						0.740
Eggs							0.078

Envirnnmental preference

Apart from an adequate food supply, *P. fimbratus* seems to have no particular environmental preferences. It is highly tolerant of thermal conditions. Wichtowska (1994) encountered juveniles and females with egg sacs throughout the year, also at temperatures close to 0°C. In a laboratory culture, the species lived and reproduced at 33°C. Most probably, the species lacks the resting stage, typical of most cyclopoids.

P. fimbriatus shows behavioural traits which enable it to live, over prolonged periods of time, in anoxic water. Under anoxia, the individuals keep close to the surface film as if attached to it and seem to use atmospheric oxygen. Additionally, as observed by the present author and by Wichtowska (1994), the *P. fimbriatus* individuals may leave the water or, to be more exact, may migrate to the meniscus zone and stay there in a water layer thinner than their own thickness. This behaviour explains mass die-offs of the species in cultures as some individuals migrate too far away from the water edge and dry up.

Anoxia does not signify termination of the cultured stock; on the contrary, it enhances its feeding conditions as prey organisms, ciliates and rotifers, aggregate underneath the surface film along with *P. fimbriatus*. To sum up, *P. fimbriatus* can be kept in culture without fear that the culture will perish under anoxic conditions.

The crustacean in question is a fast swimmer and shows other adaptations to life in fast-flowing water: flattening of the body, ability to crawl on the substrate, clear rheotaxis and thigmotaxis. Those adaptations do not, however, rule out the species' ability to dwell in stagnant water, which is very convenient from the culturist's point of view.

Feeding

Numerous observations made by the author showed the ciliates, rotifers, and conspecific individuals to constitute the food of *P. fimbriatus*. Dense cultures frequently lacked the microinvertebrates mentioned, while their mass occurrence was recorded in control samples devoid of *P. fimbriatus*. However, there are some protozoans, e.g. small heterotrophic flagellates, that are either not fed upon or only marginally utilised by *P. fimbriatus*.

Cannibalism is evidenced by a typical complete, or almost complete lack of nauplii, and frequently copepodites as well, in dense cultures kept without feeding. The stock kept under such conditions did reproduce as ovigerous females were present. Thus the lack of early developmental stages can only be explained by cannibalism effected by adult individuals.

Observations made on abandoned cultures kept under extremely adverse feeding conditions seem to indicate that males prey upon females. Such cultures, as frequently observed by the author, consisted almost exclusively of males.

Planktonic and periphytic algae, filamentous cyanobacteria in particular, seem to be a potential food source probably untapped by *P. fimbriatus*. Fecal pellets of the crustacean contained no remains of those algae.

As opposed to some other cyclopoids, e.g., *Acanthocyclops robustus*, *P. fimbriatus* shows no predatory behaviour directed towards fish larvae.

Control of the culture; harvesting of *P. fimbriatus*

Due to its benthic mode of life, *P. fimbriatus* is difficult to find, even in small glass vessels, as it remains buried in the sediment under oxic conditions. For this reason it is difficult to assess the density of the culture or even make sure that the species is present. To find out if that is the case, a portion of sediment collected with a pipette can be observed. Alternatively, about 0.5 dm^3 of the suspension, after swirling the culture, can be transferred to a small vessel and the fluid slowly decanted before the suspended particulates settle. Owing to their rheotaxis, the *P. fimbriatus* individuals will stay in the remaining water on the bottom of the vessel. By repeating the procedure 3–5 times, almost all the cyclopoids can be extracted for, e.g., enumeration. This procedure, called concentration without sieving, can be

also used to harvest the crustaceans from the culture vessel once the culture is terminated. The procedure should be preceded by sieving through an about 1 mm mesh size sieve to remove fragments of plants, etc. Sieving should also precede another procedure used to harvest the cultured cyclopoids, namely screening through an 0.05 mm gauze. The culture should be placed in a bucket-shaped container and brought to anoxia. Its occurrence can be accelerated by adding milk: a dose of 1 cm^3 milk per dm^3 of culture medium will exhaust all the oxygen within 24 h, as a result of which all *P. fimbriatus* aggregate underneath the surface film. They can be then decanted onto a vessel, without transferring also the sediment from the bottom of the vessel. The procedure can be repeated 2–3 times to make sure that all the individuals have been harvested. In this way, live *P. fimbriatus* can be concentrated to be subsequently used as fish food. Decantation can be substituted by siphoning off the surface film with the cyclopoids attached.

P. fimbriatus cultures properly fed with mixed agregations of ciliates and rotifers

Such cultures have to be preceded by preparing cultures of food microorganims. The live food was kept in a tall glass vessel containing 8 dm^3 medium consisting of water, periodically fertilised with milk. The bottom of the vessel was soon covered with a sediment-like concentrate consisting mainly of live ciliates, rotifers, and *Scenedesmus*. The concentrate was siphoned off and offered as food to *P. fimbriatus* at 2-d intervals.

The cylopoids were kept in three types of cultures:

I. in a glass vessel 16.5 cm high and with 154 cm^2 surface water column, aerated, without additional substrate;
II. in a glass vessel as above, with aeration and substrate in the form of 1 m^2 of nylon gauze;
III. in a low 1540 cm^2 surface and 3.5 cm deep vessel, without aeration, with substrate as above.

Each treatment contained 5 dm^3 of culture medium (water fertilised periodically with milk). Identical portions of concentrated microfauna were added to each culture, making sure that the cyclopoids were fed ad lib. *P. fimbriatus* fed also on ciliates and rotifers living in the culture vessels.

The cultures were started by stocking the vessels with similar numbers of *P. fimbriatus* individuals. The cultures were kept from 2 March 1994 until 7 April 1994. During that time, composition of each stock was assessed 5 times. On termination of the culture, crustaceans from 0.1 culture volume were harvested 3 times to assess stock densities and to thin the stocks.

The results are presented in Tables 2 and 3. As shown by Table 2, the stock in each treatment was clearly dominated by early developmental stages (nauplii and copepodites). When the results of the three treatments are considered jointly, one observes that nauplii made up from 8 to 83% of the stock (mean of 46.6%). The mean contribution of copepo-

dites was 36.9% (10–80%). Females contributed 10.8% on the average (3–20%); about half of the females were ovigerous. Mature males were least abundant and contributed an average of 5.6% (1–13%).

Table 2

Composition (%) of *Paracyclops fimbriatus* stock kept under favourable feeding and oxygen condition

Date	Groups identified	Culture conditions		
		I aeration; no substrate	II aeration; substrate	III no aeration; substrate
March 13, 1994	females without eggs	2	3	1
	females with eggs	4	11	2
	males	4	4	3
	copepodites	50	37	41
	nauplii	40	45	53
March 21, 1994	females without eggs	2	4	5
	females with eggs	8	8	3
	males	10	1	3
	copepodites	39	72	80
	nauplii	41	15	9
March 24, 1994	females without eggs	10	1	3
	females with eggs	7	6	5
	males	6	5	11
	copepodites	24	34	25
	nauplii	53	54	56
March 28, 1994	females without eggs	12	3	13
	females with eggs	6	1	7
	males	13	5	5
	copepodites	15	35	11
	nauplii	54	56	64
April 7, 1994	females without eggs	10	14	3
	females with eggs	6	2	0
	males	5	6	3
	copepodites	10	79	11
	nauplii	69	8	83
Average	females without eggs	7.2	5.0	5.0
	females with eggs	6.2	5.6	3.4
	males	7.6	4.2	5.0
	copepodites	27.6	49.6	33.6
	nauplii	51.4	35.6	53.0

Considering the clear prevalence of early developmental stages in the stock, numerical domination of females over males, and a high percentage of ovigerous females, the stocks under culture can be considered as developing with a tendency to increase the abundance.

Composition of the stocks kept in the three culture types was very similar; thus no conclusion on the effect of experimental conditions used can be drawn.

Domination of early developmental stages is further evidenced by the data reported in Table 3 in which abundances attained in the three treatments are summarised.

Table 3

Stock densities of *Paracyclops fimbriatus* stock kept under favourable feeding and oxygen condition (ind./dm^3)

Harvest date	Groups	Culture conditions		
		I	II	III
		aeration; no substrate	aeration; substrate	no aeration; substrate
March 24, 1994	non-ovigerous females	2 300	170	670
	ovigerous females	1 600	1 330	1 170
	males	1 500	1 330	2 670
	copepodites	5 660	8 000	6 170
	nauplii	12 330	13 000	13 830
	total	23 390	23 830	24 510
March 28, 1994	non-ovigerous females	12 000	3 000	7 000
	ovigerous females	6 000	1 000	4 000
	males	13 000	5 000	3 000
	copepodites	15 000	35 000	6 000
	nauplii	55 000	55 000	35 000
	total	101 000	99 000	55 000
April 7, 1994	non-ovigerous females	6 040	3 000	4 010
	ovigerous females	4 030	500	0
	males	3 020	1 250	3 010
	copepodites	6 040	15 040	12 040
	nauplii	43 300	1 750	93 280
	total	62 430	21 540	112 340
Average of 3 harvests		62 273	48 123	63 950

The table allows to compare abundances and thus the culture success in each treatment. The highest abundance was attained in treatment III (in a shallow vessel). The stock density after about 1 month of culture was 112 340 ind./dm^3, including about 93 000 nauplii and 12 000 copepodites; the remaining stages constituted about 7 000 ind./dm^3. Similarly high density of *P. fimbriatus* 101 000 ind./dm^3 was found in treatment I. Here, too, the nauplii were dominant, but adult individuals were abundant (31 000 ind./dm^3). A very similar density (99 000 ind./dm^3) was found in treatment II.

Mean densities from 3 harvesting events (Tab. 3) illustrate the results obtained in the three treatments. The comparison shows that similar results were obtained when using a tall aerated jar (treatment I) and a shallow vessel with a nylon gauze insert (treatment III). Treatment II yielded a worse result.

Apart from the abundance of appropriate food, favourable oxygen conditions were typical of all the treatments. The proper oxygenation was attained by aeration and by enhancing contact with the atmosphere; the latter effect was obtained by keeping *P. fimbriatus* in a shallow (3.5 cm deep) water of a large surface area. To judge by the results, both ways of ensuring proper oxygen conditions worked equally well, aeration requiring additional energy supply. No effect of an insert on the culture results could be shown as the two treatments involving artificial substrate, II and III, produced the best and the worst result, respectively (Tab. 3).

Culture in municipal sewage sludge

The culture was started unintentionally, during an experimental treatment of the municipal sewage (the so-called raw sewage) in a glass vessel containing about 8 dm^3 of medium. The vessel contained an artificial substrate in the form of about 1 m^2 nylon gauze, used to enhance the treatment. The culture was aerated and additionally oxygenated due to photosynthetic activity of *Scenedesmus*, developing in the sludge.

Ciliates, rotifers, and oligochaetes (*Chaetogaster*) were the first organisms to grow in the medium, followed by a mass development of *P. fimbriatus*. Table 4 summarises the results of the culture. The stock was clearly dominated by nauplii, indicating the growing phase of the culture. The stock density reached 13 000 ind./dm^3. The table shows biomass data of each developmental stage. The most abundant nauplii contributed little to the total biomass (an effect of the small size), while copepodites contributed most of the biomass. The total biomass of 20.19 mg/dm^3 was similar to the biomass of zooplankton in hypertrophic water bodies.

Table 4

Abundance and biomass of a *Paracyclops fimbriatus* stock kept in municipal sewage sludge

Groups	Density (ind./dm^3)	Average length (mm)	Average weight (mg)	Biomass (mg/dm^3)
Females	220	0.740	0.0017	3.72
Males	195	0.640	0.0010	1.94
Copepodites	1 830	0.425	0.0050	9.15
Nauplii	10 770	0.179	0.0005	5.38
Eggs	3 870	–	–	–
Total (eggs excluded)	13 015	–	–	20.19

P. fimbriatus cultures in hay infusions

To culture the cyclopoid in this way calls for establishing a number of protozoan cultures in hay infusions. Shallow vessels in which adequate oxygen conditions can be maintained without aeration are suitable for the purpose. Once the hay culture has passed the stage of mass development of bacteria and protozoans, the water with the latter should be decanted to a different vessel and a medium thus obtained should be stocked with *P. fimbriatus*. It is necessary to monitor the amount of protozoans in the culture. When their numbers decline, the cyclopoids ought to be fed by adding protozoans-containing water from a parallel hay culture. By way of example, Table 5 summarises results of a hay infusion culture. Particularly worthy of attention is a steady increase in the stock density, from about 17 000 ind./dm^3 on day 15 to 30 000 ind./dm^3 on day 26 of the culture. Nauplii and copepodites were consistently the most abundant group in the samples. Moreover, ovigerous females were always present in the cultures. Those characteristics demonstrate that the stocks were in good condition and increased in abundance.

Table 5

Abundance and composition of a *Paracyclops fimbriatus* stock fed protozoans obtained from a hay infusion culture

Days of culture	15		22		26	
Stage	ind./dm^3	%	ind./dm^3	%	ind./dm^3	%
Non-ovigerous females	1 490	8.8	600	1.7	1 500	5.0
Ovigerous females	1 980	11.7	1 800	5.0	2 000	6.7
Males	990	5.9	7 800	21.8	1 500	5.0
Copepodites	5 950	35.3	9 000	25.2	16 500	54.9
Nauplii	6 450	38.2	16 300	45.6	8 500	28.3
Total	16 860	100.0	35 500	100.0	30 000	100.0

Another successful *P. fimbriatus* culture was carried out in a 4 cm deep cuvette containing about 6 dm^3 water. A hay infusion culture was set up by introducing a sediment portion taken from an aquarium containing individuals of *P. fimbriatus*. After 20 days, the stock was very numerous and consisted mainly of juveniles. Ovigerous females were present as well. Once moat of the stock had been harvested, the individuals remaining in the sediment were used to start a new hay infusion culture. The procedure was repeated several times; each time a *Paracyclops* harvest was obtained and the culture was "rejuvenated".

When running a hay infusion culture, care should be taken not to add too much hay in order to avoid oxygen deficiency. If, however, oxygen deficiency does occur, the culture medium should be diluted by, e.g., splitting the original culture into two, kept in separate vessels. To avoid oxygen deficiency, it is a good practice to add small hay portions throughout the culture period.

The procedure described involves joint rearing of microfauna and *P. fimbriatus* in the same medium. An additional advantage lies in an exchange of some of the medium after each culture cycle.

An attempt to use ready-made feeds to feed *P. fimbriatus*

As pointed out earlier, *P. fimbriatus* is a predator feeding on microfauna. Nevertheless, an attempt was made to feed the cyclopoids with ready-made feeds in the hope of substituting the natural food with a calorie-rich prepared one. The attempt was justified by a common practice of offering commercial feeds to cultured predators, e.g., salmonid fish.

The feeds used included cooked starches obtained from beans and potatoes, and cottage cheese. Generally, the results of such feeding were mediocre. At best, a density of 25 500 ind./dm^3 was obtained, 2 000 ind./dm^3 being the worst outcome. The cultures fed non-natural food suffered a deficiency of nauplii, their contribution ranging from 11.6 to 35%. The stocks were dominated by the oldest developmental stages (copepodites 4 and 5, males, and females) making up, on the average, from 30.6 to 69.8% of the stock density.

Table 6 summarises data on density and composition of a *P. fimbriatus* stock fed a starch mixture (beans + potatoes).

Table 6

Results of *Paracyclops fimbriatus* culture fed mixed starches (beans + potatoes)

Date	Nov. 20, 1993		Dec. 2, 1993		Dec. 12, 1993		Average	
Groups	ind./dm^3	%	ind./dm^3	%	ind./dm^3	%	ind./dm^3	%
Females, males, copepodites 4 and 5	1 453	70	5 000	20	4 950	51	3 802.0	30.64
Copepodites 1 - 3	622	30	1 300	51	1 350	14	4 990.7	40.24
Nauplii	0	0	7 500	29	3 330	35	3 610.0	29.10
Total	2 075	100	25 500	100	9 630	100	12 401.7	100.00

The results obtained when offering ready-made feeds cannot be regarded as caused exclusively by the non-natural food as the feeds constituted a medium for flagellates and ciliates to develop on; those organisms were most probably preyed upon by *P. fimbriatus*.

Fate of abandoned cultures

Once the feeding of *P. fimbriatus* is terminated, the stock density rapidly decreases and its composition changes so that the stock consists exclusively of mature individuals which stop breeding. However, even after prolonged periods of abandonment, not all the cyclopoids perish. A starved stock is a source of seeding material to start a new culture with.

Table 7 shows composition of a starved stock which was used to start a new culture. The stock contained non-ovigerous females without eggs in the oviducts; such females made up 35% of the stock density. The stock was dominated by males (65%), while completely lacking nauplii and copepodites. After 25 days of intensive feeding with protozoans, a thriving culture, dominated by nauplii (80.4%) and containing females (9%), mostly ovigerous, was obtained.

Table 7

Composition of a *Paracyclops fimbriatus* stock after a prolonged starvation (A) and after a period of intensive feeding (B)

Stage	A	B	
	Beginning of culture	Termination of culture	
	%	ind./dm^3	%
Non-ovigerous females	35.0	1 000	3.9
Ovigerous females	0.0	1 500	5.9
Males	65.0	1 000	3.9
Copepodites	0.0	1 500	5.9
Nauplii	0.0	20 500	80.4
Total	100.0	25 500	100.0

Attempts to test *P. fimbriatus*'s utility as food for juvenile fish

The tests involved mainly offering a mixture of all developmental stages of *P. fimbriatus* to juvenile *Lebistes reticulatus*. The cyclopoids had been obtained from laboratory cultures. The fish body length ranged within 6.5 to 11 mm. A total of 5 tests was carried out at 25°C. Additionally, juvenile *Rutilus rutilus* measuring 10 mm and mature *L. reticulatus* were, too, offered *P. fimbriatus* as food. In all cases, the fish, including the smallest ones measuring 6.5 mm, immediately rushed to the *Paracyclops* individuals and eate them. The fast swimming cyclopoids were soon captured by the fish. In vessels containing no mud or other substrate, all the *P. fimbriatus* were consumed in a short time.

No aggressive behaviour on the part of *P. fimbriatus* towards fish was observed. On the other hand, the cyclopoids, while swimming away from the attacking fish, frequently tried to escape by crawling onto the vessel wall above the water level.

Fish faeces were found to contain carapaces of the cyclopoids consumed, the soft body parts having been completely digested. The carapaces were complete, undamaged.

The observations reported show *P. fimbriatus* to be eagerly consumed and well digested by juvenile and adult small fish. Thus *P. fimbriatus* is potentially a good source of nutrition in fish cultures.

DISCUSSION

The work described above was aimed at developing methods of culture of *P. fimbriatus*. The best cultre method proved the one whereby the highest stock density, i.e., about 100 000 ind./dm^3 was attained. The method involved intensive feeding of the cylopoids with the microfauna (ciliates and rotifers), kept in separate vessels.

Worth recommending is also a method involving a joint culture of protozoans and *P. fimbriatus*, hay infusion being used as a medium-enriching factor.

While pointing out to the best culture results, it should be borne in mind that in no case did *P. fimbriatus* perish. This is an evidence of the fact that the cyclopoid species in question is particularly amenable to culture procedures.

Moreover, *P. fimbriatus* was also shown to be an excellent food for newly hatched fish larvae. As demonstrated by direct observations, fish individuals 6.5 mm long fed on adult *P. fimbriatus*. Even smaller larvae can most likely feed on the cyclopoids as the earliest *P. fimbriatus* nauplii reach 0.1 mm in length, the smallest copepodites being only 0.3 mm long.

One should not fear that *P. fimbriatus*, as a live food, will infect the fish with parasites. Cyclopoids in general are known to be intermediate hosts for fish nematode and plathelminth parasites. *P. fimbriatus* was used in experimental infestation of eel with para-

sitic nematodes (Haenen et al. 1991). The threat of an infection, while of concern under natural conditions, can be ruled out in the case of cultures as the cyclopoids are reared without a contact with fish.

The present study yielded also a number of observations and conclusions which can serve as practical tips and hints for those willing to undertake such cultures. Recommendations concerning culture conditions involve stock density and stock composition. Domination of nauplii evidences optimal or excessive feeding. On the other hand, adverse feeding conditions produce changes involving disappearance of nauplii and copepodites, the stock consisting of adult individuals only. The two extremes are separated by intermediate situations which reflect different feeding conditions.

Obviously, changes in stock density reflect changes in culture conditions, particularly those involving available food supply.

The above remarks are of a great practical importance. By determining the composition of the stock, which is a simple task, one can get information on the availability of food supply and improve the situation, if necessary.

In *P. fimbriatus* cultures exposed to light, a mass occurrence of algae, usually *Scenedesmus obliquus* will develop in masses. The presence of algae is very advantageous. Their photosynthesising activity supplies oxygen and no anoxia occurs even in cultures kept in tall vessel without aeration. The algae are grazed by rotifers and utilise metabolites, thereby removing them from the water.

As opposed to *Scenedesmus* and other Chlorococcales, the presence of filamentous cyanobacteria developing on the culture vessel walls is not desirable. The vessels should be periodically cleaned of the cyanobacteria.

Undoubtedly, aeration enhances the culture. However, favourable oxygen conditions can be provided by using shallow (4–5 cm deep) vessels of large surface area. Shallow vessels are also recommended in culturing of other aquatic animals, including fish larvae.

Care should be taken to avoid excessive accumulation of sediment and hay remains in the culture vessel as oxygen conditions will deteriorate and harvesting of the cyclopoids will be difficult. This is one of the reasons why old cultures should be terminated and replaced by the newly set up ones.

Thinning of the stock is very advantageous, even when there is no need to feed fish fry.

Although *P. fimbriatus* is capable of living under critical oxygen concentrations, development of such conditions should be prevented because, among other things, cyclopoids crawl onto the vessel walls in an attempt to avoid suffocation and dry up.

The culture should be kept ostracod-free. The omnivorous ostracods consume the food of the cyclopoids and prey on the *Paracyclops* individuals themselves. When ostracods appear in a culture, they should be immediately eliminated. *Acanthocyclops robustus* is

a predator capable, as shown by Wichtowska (1994), of wiping out the whole stock of *P. fimbriatus*. The cultures frequently house cladocerans such as *Chydorus sphaericus* and *Daphnia magna* whose presence can be tolerated. *Ch. sphaericus* can even be harvested and used as food for juvenile fish.

While not denying the utility of *Artemia salina* nauplii in feeding juvenile fish, *P. fimbriatus* cultures are an equally good way to rapidly obtain live food. Abandoned cultures of the crustacean, provided they contain enough plant remains, can be kept for months and serve as a source of individuals to start a culture a new. The seeding material can be easily obtained all the time, in winter and during the summer, from natural water bodies, small streams in particular.

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Translated by Teresa Radziejewska PhD

Lech *SZLAUER*

MOŻLIWOŚCI HODOWANIA *PARACYCLOPS FIMBRIATUS* (CYCLOPOIDA) I WYKORZYSTANIA TEGO GATUNKU JAKO ŻYWEGO POKARMU DLA NARYBKU

STRESZCZENIE

W wyniku przeprowadzonych badań stwierdzono, *że Paracyclops fimbriatus* jest gatunkiem dającym się łatwo hodować, między innymi dzięki zdolności przeżywania kryzysów tlenowych. Odżywia się *Ciliata* i *Rotatoria*. Daje się hodować w ściekach komunalnych. Może być karmiony pierwotniakami z hodowli sianowych. Hodowany w bardzo dobrych warunkach pokarmowych może osiągać liczebność przekraczającą 100 000 osobników/dm^3. Cechuje go kanibalizm uprawiany przez osobniki starsze w stosunku do osobników młodocianych. Zjawisko to nasila się w złych warunkach pokarmowych i doprowadza do tego, że w stadzie pozostają osobniki dorosłe, a w krańcowych sytuacjach — tylko samce. Dobrze hoduje się w płytkich naczyniach o dużej powierzchni, bez potrzeby mechanicznego napowietrzania. Jest chętnie zjadany i dobrze trawiony przez narybek o długości 6,5 mm oraz większe ryby. Nie atakuje wylęgu ryb.

W pracy przedstawiono metody hodowania *P. fimbriatus*, sposoby oceny warunków pokarmowych w hodowli, metody odławiania oczlików i praktyczne wskazówki dotyczące ich hodowli. Przedstawiono również wyniki pomiarów długości i biomasy wszystkich (dwunastu) stadiów rozwojowych *P. fimbriatus*.

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Author's address:

Lech Szlauer PhD DSc Prof Tit
Department of Invertebrate Zoology
University of Szczecin
Wielkopolska 15, 70-451 Szczecin, Poland