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Fish culture

UTILIZATION OF AUTUMN ZOOPLANKTON IN CARP FRY REARING

WYKORZYSTANIE JESIENNEGO ZOOPLANKTONU DO WYCHOWU NARYBKU KARPIA

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The carp hatched in mid-November were reared for a month in aquaria at 20–27°C and fed with zooplankton caught in littoral of a lake. During the winter the fry was kept at 10–16°C and fed with dry feeds. By late April, the fish treated in this way were found to attain a mean individual weight of 1.29 g (the weight ranging within 0.29–4.84 g). When kept in sparsely stocked pond without any further feeding, the fry reached a mean individual weight of 318 g (the range of 149–520 g) in October, i.e., at the end of their first year of life.

INTRODUCTION

In traditional pond carp cultures the carp fry of 1–3 g individual weight for the further rearing is obtained as late as in the summer. The fry, however, is needed in

April-May as ponds should be stocked at that time, whereby the culture cycle can be shortened by a year. It is for this reason tha attempts are made to accelerate the carp fry rearing under controlled conditions (Seidlitz and Seidlitz, 1972; Anwand, 1978; Uffermann and Seidlitz, 1978; Woźniewski and Littak, 1979; Littak and Woźniewski, 1979). At present, artificial spawning and carp egg incubation are well under control so that the newly hatched fry can be obtained at practically any time during the year. However, difficulties arise when it comes to rearing the carp from hatch to fry owing to the fact that massive amounts of live zooplankton have to be supplied to feed the juvenile fish. Lakes are a rich source of such food (Szlauer, 1976, 1977). The Germans have made use of these resources by utilising lacustrine zooplankton to rear commercially the fry of carp and plant-feeding fish (Seidlitz and Seidlitz, 1972; Wolf et al., 1978; Schlumpberger and Liebemann, 1978; Uffermann and Seidlitz, 1978; Anwand, 1978). The technologies proposed by the authors mentioned assume the spring zooplankton reaching its annual peak density is used. The solution is satisfactory, but it cannot be regarded as the only one possible. Apart from its main peak in spring, zooplankton density reaches another, lesser peak – the autumn maximum occurring in October, November, and on occasions in December. It was decided to utilise this autumn peak to rear the fry from hatch obtained during an autumn artificial spawning. The attempt was justified by the general deficiency of carp fry in winter cultures carried out in heated cooling water. Such an early fry can yield commercial-size fish at the end of the first year of their life. There is till another promising way of handling the early fry, namely to stock the culture ponds with it in April. Such an attempt was adopted as the other objective of the present project. In April the maximum density of fauna consisting the fish food begins and lasts over and June. With the traditional stocking in July, the richest spring portion of the natural food is lost for the culture and so is the warmth of these two spring months.

METHODS

Carp larvae hatched on 18 Nov. 1979 were obtained from the Inland Fisheries Institute's Experimental Station at Żabieniec. The rearing, feeding included, began on 22 Nov. 1979; two groups of 320 individuals each were placed in 100-l aquaria (3.2 ind l^{-1}), initially at 20°C. After 6 days the water was heated in one aquarium and after 13 days in the other, the water temperature of 26–27°C being maintained until 21 Dec. The two groups were treated as parallel replicates. The aquaria water was aerated, 1/3 of the water volume being changed daily by supplying warm water directly from the tap. Various waste materials accumulated on the bottom were removed each day as well.

The first 29-d stage of the experiment (22 Nov. – 21 Dec.) can be described as an intensive rearing at a temperature close to the optimal one, the fry being fed daily with live zooplankton harvested from the Lake Brodowskie littoral by means of a 0.2 mm mesh size net. On the 21st day of such rearing the food was supplemented by a dry feed (finely granulated EWOS feed).

The second stage of the experiment, described as a cool water culture, began on 22 Dec. 1979 and lasted until April 1980, i.e., until stocking of a culture pond with the fry was performed. During that time the fishes were given a scanty food consisting of various granulates offered daily in amounts sufficient for survival. The water temperature in two 190–1 aquaria ranged within 10–16°C. The water was aerated; 1/3 of its volume was changed almost daily.

Four times during the period of rearing the fry was weighed. The fish feeding behaviour was under observation. Intestinal content was being examined, particularly at the initial stage of rearing.

Concurrently with the rearing the littoral zooplankton resources in the lake mentioned were being assessed, for which purpose quantitative zooplankton samples were taken by a 5-l Patalas sampler (89 cm^2 mouth area) in such a way that the bottom of the sampler was reaching the lake bottom, the upper part protruding above the surface. The samples were collected several times at each of the 20 sites close to the shore down to the dept of 70 cm. The sampler mouth area being known, the number of animals caught was converted to the density over 1 m^2 of the bottom; subsequently the biomass was calculated by means of the generally accepted methods and tables given by Starmach (1955) and Kosowa (1961).

The next stage of the experiment was to transfer the fry reared (259 individuals) to a 2500 m^2 pond for 170 days (29 April – 15 October 1980). The pond was filled with preliminarily neutralised and decanted effluents from the "Police" Chemical Plant. The medium corresponded to some extent to ponds fertilised with mineral fertilizers.

RESULTS

The results of the carp fry rearing commenced on 22 Nov. 1979 for the 4-d-old larvae are presented in Table 1. The first stage of rearing, lasting for 29 days at the temperature of up to 27°C and accompanied by the liberal fedding with live zooplankton resulted in obtaining the fry of 0.157 g mean individual weight. Fairly high losses were incurred during this period, 72% of the initial number of individuals surviving the first stage of the experiment.

The second stage lasting for 130 days (21 Dec. 1979 – 29 April 1980), i.e., the cool (10–16°C) water culture, was also a success. In spite of scant food consisting of feeds only, the fishes reached a mean individual weight of 1.29 g (0.29–4.84 g) by the end of April, the losses amounting to 7–8% only.

The mean survival rate after the two stages was 64%, the rates being similar in both replicates. The overwintered fry fed voraciously; they fed even at 10°C, readily consuming each feed offered.

A number of observations were made during the period of rearing. On their 4th day of life the larvae were observed to feed. The feeding proceeded exclusively in the water column until the 6th day, the bottom food organisms being additionally sought for

Table 1

Individual weight and survival rate of carp fry reared in autumn – winter

Date of weighing culture stage	Mean individual weight (g): survival rate (%)					
	Replicate I		Replicate II		Mean	
	g	%	g	%	g	%
22 Nov. 1979 beginning of rearing	0.0051	–	0.0051	–	0.0051	–
7 Dec. 1979	0.04	–	0.024	–	0.032	–
20 Dec. 1979 end of rearing at 26–27°C	0.164	73	0.151	71	0.157	72
29 Feb. 1980	0.77	71	0.93	68	0.85	69
29 April 1980 end of rearing at 10–16°C	1.24 range 0.29 – 4.84	66	1.34 range 0.54– 3.18	62	1.29 range 0.29 – 4.84	64

subsequently. The first food organisms were the *Arcella sp.* protozoans, rotifers, ostracods, and – most of all – the smallest cladoceran species *Chydorus sphaericus.* A *Chydorus*-oriented feeding selectivity can be ascribed to the fry beginning to feed. The cladoceran was consumed althought the zooplankton offered consisted of many other organisms, rotifers included. The *Chydorus* domination in the fry food lasted 2–3 days after which mainly the *Cyclopoida* were taken up. The 20-d-old fry of 0.04 g mean individual weight were found to ingest even 7 mm long mayfly larvae. Of the littoral fauna offered, *Simocephalus sp.*, a semi-sessile cladoceran was consumed as the last resort. The fact that the littoral fauna was supplied as food resulted in some predators (zygopteran dragonfly larvae and *Hydra*) appearing in the aquaria. The dragonfly larvae were found to consume the fry, the *Hydra* showing no such activity; they were, however, food competitors for the fry by virtue of their feeding on zooplankton. The fry was never attacked by the *Cyclops* species represented in the littoral fauna.

In spite of its being rapidly transferred from a 3–5°C to that of 27°C, the zooplankton offered to the fish did not die off; on the contrary, it remained alive after 2–3 days in the aerated water.

In spite of its small size (about 1.5 ha), the water body the zooplankton was collected from showed some features typical of a lake; the littoral constituted a belt several m wide and overgrown by a diverse submerged and emerged flora.

At the end of November 1979, when the zooplankton harvesting began in order to

Table 2

Density (ind. m^{-2} bottom) and biomas (mg m^{-2} bottom) of littoral animals in the Lake Brodowskie

Taxon	Density (ind. m^{-2})					Wet weight (mg m^{-2})				
	1979			1980		1979			1980	
	27 Nov.	11 Dec.	27 Dec.	18 Jan.	31 March	27 Nov.	11 Dec.	27 Dec.	18 Jan.	31 March
Chydorus	33 708	24 944	27 416	23 174	213 573	256.5	308.4	336.5	268.0	2 613.7
Pleuroxus	674	0	0	0	0	12.1	0	0	0	0
Simocephalus	2 247	4 944	4 045	702	0	198.6	805.8	665.1	73.0	0
Total *Cladocera*	36 629	29 888	31 461	23 876	213 573	467.2	1 114.2	1.001.6	341.0	2 613.7
Megacyclops	0	1 573	0	0	2 966	0	70.8	0	0	103.8
Macrocyclops	0	899	1 348	2 668	0	0	75.3	130.3	228.9	0
Eucyclops	5 006	5 843	3 595	12 079	23 730	89.7	130.1	136.2	258.1	608.5
Diacyclops	674	1 573	449	4 775	0	16.8	33.0	6.0	128.4	0
Cyclops	14 831	12 135	17 303	11 657	15 573	476.4	472.8	732.2	470.2	1 088.9
Eudiaptomus	1 348	2 921	6 517	6 039	2 966	123.3	248.5	579.5	594.7	326.3
Total *Copepoda*	21 860	24 944	24 213	37 219	45 236	706.2	1 030.5	1 584.2	1.680.3	2 127.5
Nauplii	10 112	7 416	8 539	28 511	324 719	40.4	29.7	34.1	114.0	1 298.9
Mytilina	1 573	2 022	0	0	0	1.6	1.1	0	0	0
Notholca	9 213	6 292	8 090	21 348	51 685	6.4	5.0	6.5	17.0	41.3
Trichocerca	2 247	225	0	0	0	5.6	0.4	0	0	0
Keratella quadrata	0	0	225	0	741	0	0	0.3	0	0.4
Illoricate Rotatoria	4 045	2 247	3 595	1 966	6 674	5.7	2.2	3.6	2.0	6.7
Total *Rotatoria*	17 079	10 786	11 910	23 315	59 101	19.3	8.8	10.4	19.0	48.4
Nematoda	1 348	225	899	140	0	134.8	33.7	62.9	9.8	0
Oligochaeta	0	0	0	0	2 966	0	0	0	0	637.7
Ostracoda	4 494	898	225	2 107	2 225	107.9	22.5	5.6	52.7	55.6
Chironomid larvae	449	449	225	702	741	120.9	96.6	48.3	151.0	159.4
Grand total	92 421	75 281	82 697	116 011	64 903	1 911.4	2 808.0	2 904.8	2 466.3	7 460.5

feed the fry, the water temperature was 5°C. The lake froze on 1 Jan. 1980 and thawed on 31 March.

The zooplankton or – to be exact – the small invertebrate fauna of the lake littoral was highly diversified in terms of both its species composition and its ecological features (Table 2). Apart from typical, substrate-bound littoral organisms (*Simocephalus vetulus, Rhynchotalona rostrata, Eucyclops serrulatus, E. speratus, E. macruroides, Macrocyclops fucus, M. albidus, Megacyclops viridis),* the ubiquitous *Chydorus sphaericus* occurred along with such typically planktonic species as *Cyclops vicinus, Diacyclops bicuspidatus, Eudiaptomus graciloides;* a species typical of small reservoirs – *Cyclops strenuus strenuus,* benthic forms (oligochaetes, chironomid larvae) as well as small representatives of nekton (mayfly larvae) were present too. Typical of the fauna was also the size variability. Very small animals (rotifers, nauplii, copepodites, *Chydorus sp.*), medium-sized crustaceans, and animals longer than than 2 mm (*Megacyclops viridis, Macrocyclops fuscus,* oligochaetes, Chironomid and *Cloeon* larvae) were co-occurring.

The major role in terms of biomass was played by the *Cyclopoida, Eudiaptomus graciloides, Chydorus sphaericus, Simocephalus vetulus,* and *Cloeon* mayfly larvae.

Over the period of study (November – March) the wet weight of the fauna was found to range from 1911 to 7460 mg m^{-2}. An increase in the biomass observed towards the end of the winter (late March) is worth stressing. A more than 3-fold biomass increase was brought about by increassing abundance of *Chydorus sphaericus, Cyclops strenuus,* oligochaetes, and *Cloeon* larvae.

The third stage of the experiment, namely the pond culture, began (29 April) when the water temperature 10.5°C and zooplankton appeared. Until its final capture (15 Oct. 1980) after 170 days in the pond culture, the fry increased their individual weight, on the average, from an initial 1.29 g to 318 g. The length and weight of the fish on capture ranged within 185–200 mm and 149–529 g, respectively. The fishes were in a good condition. Of the 258 individuals stocked, however, only 46 were retrieved (17.8% survival rate). One of the causes of such losses was predation by herons during an emergency. water level low-down to about 20 cm depth, this depth remaining for more than 2 weeks in August. During the period of the pond culture, the mean water temperature was 15.3°C (9–22°C range). Owing to a low stocking density, an abundant food fauna (i.a., *Daphnia magna* and chironomid larvae) was found to occur in the pond throughout the culture duration.

DISCUSSION

The rearing of carp fry up to the 1–3 g juvenile stage creates ample possibilities of improving the final effects of the culture. Small size of the fry allows to rear it in small volumes of water, whereby control can be exercised over water temperature, oxygen and food supply, etc. at a low cost. As a result, juveniles for a further rearing are obtained, the fishes being already through the most critical developmental stages and remaining highly resistant to adverse environmental conditions. Moreover, the juveniles may be kept on an artifical food and – owing to their small size – no considerable technical problems are encountered when using various culture installations. A possibility of obtaining such fish at a desired period and, consequently, of their further rearing at an appropriate time creates an additional chance of increasing the fish stock supplied to the market. The above remarks apply fully to the fry rearing in autumn-winter months as suggested. The feasibility of the proposal presented has been already explained in the Introduction. What remains is to consider the proposal in terms of providing sufficiently large amounts of zooplankton to feed the fish. It has been already mentioned that in the autumn months a secondary (following the major spring one) peak is observed in the lacustrine zooplankton abundance. When studying the zooplankton removed from the fertile Lake Płoń, Szaluer (1977) found a density of 351 ind. l^{-1} in October, i.e., about half the spring (April) peak of 802 ind. l^{-1}. At the same time, the autumn peak was more than 100% higher than the winter and summer minima (115 and 150 ind. l^{-1}, respectively). The Lake Płoń autumn zooplankton included, compared to the spring composition, more crustaceans relative to rotifers. Similar was the pattern found by Szaluer and Widuto (1966) in the eutrophic Lake Sukiel. During the autumn maximum (October – November) the density was about 140 crustacean ind. l^{-1}. During the minima (February, July) the respective crustacean densities were 77 and 101 ind. l^{-1}. The autumn zooplankton peak in the eutrophic Lake Chełmżyńskie featured 145 ind. l^{-1} compared to 229, 60, and 30 ind. l^{-1} in spring, summer, and winter, respectively. In this lake, too, the crustacen contribution to the autumn zooplankton was higher than to the spring one richer in rotifers (Szlauer, 1958). These examples and a number of others reported from various lakes over the world demonstrate high abundances of zooplankton in autumn. It can be approximately assessed that the autumn densities are only half the spring ones. Owing to the high reproduction rate and fast growth of zooplankters, production rather than biomasss should be taken into account when assessing the zooplanktonic resources of a lake; production exceeding biomass by the factor of 2.2–3.5 as early as after one month. A mean annual zooplankton biomass ranges – depending on the lake trophic status – from 1.3 to 4.7 g m^{-3} (Petrović, 1971).

A circumstance most favourable for zooplankton harvesting in late autumn is a low phytoplankton density, which greatly facilitates net operations. Another positive aspect of utilising the autumn zooplankton as a juvenile carp food is a minimised probability of infesting the fish with trematodes, cestodes, and other parasites.

The zooplankton to be used in the autumn-winter carp rearing can be caught either directly in lakes or in their outflows (B. Szlauer, 1977). Lacustrine littoral can be taken into account, too. Although the literature data on autumn peaks concern the mid-lake zooplankton, the peaks are recorded also in the littoral. The mid-lake species occur in masses in the littoral as well. A good illustration is provided by the small lake described, where typically planktonic species of *Eudiaptomus* and *Cyclops* contributed significantly to the biomass. So far, the lacustrine littoral zooplankton has not been taken into account as a food to be used when rearing the carp fry, although it forms communities the composition of which is similar to a natural food of the pond-reared carp fry. The qualitative richness and size diversity among the species making up the community present a possibility for the fry to select a food most appropriate in different developmental stages. When discussing the utilisation of littoral zooplankton as fish food, difficulties encountered in harvesting cannot be disregarded. Moreover, the already caught material is always contaminated; the contaminants, however, creating no large problems. They can be gotten rid of by using sieves and decantation. Finally, the fry is capable of selecting food animals even from a "littered" zooplankton.

The technology proposed calls for an initial stage of intensive rearing at 27–30°C for about 30 days, liberal feeding with live zooplankton being indispensable. This stage should proceed in November and early December, i.e., when the water bodies are still free of ice and zooplankton can be harvested fairly easily. Past this stage artificial feedstuffs are suggested. During the winter months the fry should be kept in warm colling water supplied, for instance, by a power station. This water's temperature is on the average by 10°C higher than that in natural water bodies and reaches 10–16°C in winter. It was this temperature range that the next stage of the experiment was carried out at. In spite of a scarce food consisting exclusively of feeds, the fry continued to grow at 10–16°C and showed a very high survival rate. It can be concluded that the proposed winter rearing of carp fry in cooling water, at an abundant food supply, should yield fish of more than 4 g mean individual weight as early as in April. Some of the fish, when kept further in heated water, are expected to attain commercial size by the end of their first year of life.

Another suggestion put forward by the authors as to the procedures involved in overwintering the fry is to keep the fish at 10–16°C until ponds are ready to be stocked. In this case, too, heated power station cooling water is recommended. In this case the fishes should be offered at least the minimum food doses, intensive feeding being strongly recommended. This stage of rearing should be terminated at the mass occurrence of zooplankton in the ponds to be stocked, which usually happens as early as in late April at a several °C water temperature. The advantages of this suggestion are as follows:

1) elimination of a winter hold-up period in the 1-yr old carp feeding and growth,
2) stocking the ponds with feeding fish in a good condition and with a voracious appetite,
3) stocking being effected at the most appropriate moment,
4) "summer" fry weighing a few g being stocked in April, that is 2 months earlier than required by the traditional method. It is this earlier start of the culture that makes it possible to utilise the warmth of May, June, and early July in the carp rearing; first of all, it facilitates the full utilisation of the spring density peaks of pond zooplankton and other food fauna. These circumstances should suffice to let the fry grow to the C_2 size at the end of their first year of life.

The expectations presented above have been fully justified by the results of further rearing and autumn spawning of the fry transferred to a pond in April. In October, i.e., close to the end of their first year of life, fishes weighing, on the average, 318 g were obtained the maximum weight exceeding 500 g. This is the C_2 size attained by the traditional method as late as after the second season. Another feature should be added to those listed as causing such high increments, namely very favourable feeding conditions in the pond, which has resulted from a reduced stocking density. The fishes enjoyed an ample supply of natural food, no additional feeding being necessary. They were observed to continue feeding at 10°C, which was evidenced by the contens of their intestines examined on 15 October, the content being dominated by chironomid larvae, *Simocephalus sp.*, and *Daphnia magna* cladocerans.

The objective of both a pond and cage culture of carp is to conclude the culture, i.e., to obtain marketable fish, within one year. It can be contended that the solution presented here does create such a possibility, provided the weight of about 300 g is accepted as a commercial size. In our opinion, the carp of this size are even more valuable than the traditionally consumed large individuals: their weight (300 g) is equal to a single portion; they do not contain excessive fat; their gonads are still underdeveloped, the viscera therefore making up 12.4% of the total weight only. Additionally, the bones are so delicate as to pass unnoticed when eaten.

There is still an additional aspect in favour of the autumn-winter rearing of carp fry, an organisational one: should the autumn rearing fail for some reason, the procedure can be repeated in early spring, juveniles being still obtained within a shortened period of time.

SOME MORE IMPORTANT CONCLUSIONS AND STATEMENTS

1. The zooplankton occurring in Polish lakes and showing an autumn density peak from October through December can be utilised as a live food in carp fry rearing.
2. Autumn lacustrine littoral zooplankton is quantitatively very rich. Its applicability for newly hatched carp and fry feeding has been confirmed. The biomass of this zooplankton in the lake studied ranged from 1911 to 7460 mg m^{-2} littoral within November-March.
3. The newly hatched carp beginning to feed exhibited initially a feeding selectivity with regard to the cladoceran *Chydorus sphaericus*, cyclopoid copepodites being preferred latter on.
4. The 29-d long (22 Nov. – 21 Dec.) carp rearing at about 27°C and intensive feeding with live littoral zooplankton resulted in a 0.157 g individual weight fry of 72% survival rate being obtained.
5. The carp fry reared in autumn were overwintered (22 Dec. – 19 April, i.e., 130 days) at 10–16°C and fed scarcely with feeds. The mean increment over this time was from 0.157 g to 1.29 g, 7–8% losses being incurred.
6. The autumn-spawning carp fry transferred to a pond on 29 April and kept without feeding was found to reach a mean weight of 318 g (weight ranging within 149–529 g), a marketable size, by 15 October, i.e., before terminating its first year of life.

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WYKORZYSTANIE JESIENNEGO ZOOPLANKTONU DO WYCHOWU NARYBKU KARPIA

Streszczenie

W okresie późnej jesieni i na początku zimy występują w naszych jeziorach duże ilości zooplanktonu pelagicznego i litoralowego. Ten ostatni był wykorzystywany do karmienia wylęgu karpia z przyspieszonego tarła, przeprowadzonego w połowie listopada. Przez pierwsze 30 dni życia wylęg był chowany w temperaturze 27°C i karmiony żywymi zwierzętami. Od połowy grudnia ryby przetrzymywano w temperaturze 10–16°C, karmiąc je wyłącznie paszami sztucznymi. Tak chowane karpie uzyskały na początku kwietnia średni ciężar 1,89 g (0,29–4,84). Chowane dalej w stawie, w rzadkiej obsadzie, bez karmienia, uzyskały w październiku następnego roku, tj. pod koniec pierwszego roku życia, śr. ciężar 318 g (149–520 g).

Przedstawiony sposób, pozwalający uzyskiwać kilkugramowy narybek karpia już na początku wiosny, stwarza możliwość skrócenia cyklu hodowlanego tej ryby do jednego roku w wodach podgrzanych i o jeden rok w stawach o normalnej temperaturze.

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ИСПОЛЬЗОВАНИЕ ОСЕННЕГО ЗООПЛАНКТОНА ДЛЯ ВЫРАЩИВАНИЯ МАЛЬКОВ КАРПА

Резюме

Поздней осенью и в начале зимы в наших озерах имеется большое количество пелагического и литорального зоопланктона. Последний использовали для подращивания личинок карпа из ускоренного нерестa произведенного в половине ноября. Личинок выращивали в течение 30 дней при температуре 27°C и кормили живым кормом. С половины декабря рыб выдерживали при температуре 10 - 16°C, питая их только искусственным кормом. В начале апреля следующего года карпы весили в ср. 1,89г (0,29-4,84). Потом их выращивали в прудах при небольшой плотности посадки, без подкармливания. В октябре, т.е. в конце первого года жизни, они весили в ср. 318 г. (149-520г). Предлагаемый способ позволяющий получить мальков карпа весом в несколько граммов уже в начале весны, дает возможность сокращения цикла выращивания этого вида до 1 года в подогретых водах и сокращения цикла на 1 год в прудах с нормальной температурой.

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