The state of zooplankton in the feeding pond when growing commercial underyearlings of carp using a one-year combined technology

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Abstract. The paper presents the characteristics of the zooplankton of a feeding pond when it is stocked with carp larvae grown in recycling aquaculture systems (RAS). Larvae were received in the RAS by the factory method of reproduction on April 26, 2020, which is at least 1 month earlier than the terms of natural spawning of carp in ponds. Increasing the growing season allows you to get commercial carp in one season instead of 2 years. The mass of larvae during stocking was 50.1 ± 2.5 mg. 210,000 pieces of carp larvae were released into a feeding pond with an area of 20 hectares on 05/15/2020. The research took place on a reservoir located in the Ordynsky district of the Novosibirsk region from 15.05.2018 to 30.09.2018 and from 15.05.2020 to 30.09.2020. In 2018, the cultivation of commercial two-year-olds from carp yearlings weighing 70.2 = 10.3 g from 29.05.2018. The total volume of stocking is 700 kg. The aim of the research was to study the species composition of zooplankton in a feeding pond during its early stocking by an undergrown carp larva and compare it with the traditional technology of the introduction of carp yearlings. The tasks included: to establish the thermal regime of the reservoir, abundance and biomass of zooplankton, to identify the dynamics of the mass of carp fingerlings and to establish feed coefficients. **Keywords:** temperature regime, feeding pond, commercial carp fingerlings, number and biomass of zooplankton, weight of fingerlings and two-year-olds.

1 Introduction

Currently, carp is one of the most accessible and popular species among the aquaculture objects grown not only in Russia, but also abroad [1, 5]. The population of our country prefers to eat carp weighing from 0.4 kg to 1.5-2.0 kg, depending on the region. Due to the climatic conditions of Western Siberia, where the ice period of fish keeping lasts up to 180 days, it is economically feasible to obtain marketable products in the shortest possible time. With the traditional technology of growing commercial carp, it takes a year and a half. In the first year, larvae are obtained by natural spawning or factory method, then fingerlings are grown in growing ponds. Then they are transferred to wintering and two - year - old carp weighing from 500 g to 1500 g are grown for the second summer .

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In our experience, we carried out factory spawning of carp in closed water supply installations 1-1.5 months earlier than natural deadlines, carried out the rearing of larvae and planted them immediately in a feeding pond. Depending on the initial mass and planting density of larvae, it is possible to grow carp fingerlings weighing from 0.3 to 0.8 kg. The combined technology of growing commercial carp fingerlings has a number of advantages: the costs of transporting yearlings with the use of life-saving transport are reduced, because larvae can be transported in small-sized plastic bags; the efficiency of using the reservoir's feed base increases, which reduces feed costs.

A prerequisite for rapid growth rates is not only an increase in the duration of the feeding period from 3 months to 4.5-5 months, but also a high availability of natural fodder. One of the most important starting feeds is zooplankton [2]. Experiments of some scientists have shown that when feeding zooplankton at the rate of 0.8 g per carp larva (weighing from 0.52 g), followed by the addition of a mealworm to the diet for 7 weeks of cultivation, you can get a juvenile weighing 37.62-38.94 g [4]. Growing larvae on starter feeds using both artemia and starter compound feeds for 8 weeks from the moment of switching to external nutrition, at best, gives a result of 3,490 ± 0.015 g [3].

The work is devoted to the study of the zooplankton community as an important feed base of the pond during the annual cultivation of commercial carp fingerlings from larvae grown in a closed water supply system. The early stocking of the reservoir by an undergrown carp larva makes it possible to maximize the use of the natural food of the reservoir, including zooplankton, while significantly reducing the cost of artificial feed. The role of zooplankton in the diet of carp persists for a long time, for example, in the works of scientists [6,7] two-year-old carp weighing from 460.8 g to 752.5 g, actively ate zooplankton, with a share in the diet from 14.2 to 51.8%.

2 Material and methods of research

The research took place in May-September 2018 and 2020 on a feeding pond with an area of 20 hectares located in the Ordynsky district of the Novosibirsk region. The feeding pond of the channel type near the dam had a maximum depth of 5.5 m, the average depth was 1.6 m. The total area of the pond is 20 hectares.

The stocking of the reservoir with carp larvae weighing 50.1 ± 2.5 mg grown in closed water supply installations was carried out on May 15 in the amount of 210,000 pieces .

The temperature regime of the reservoir was studied by daily temperature measurements in the morning and evening using a mercury thermometer from 15.05. to 30.09.

Zooplankton samples were taken at three permanent points of the pond corresponding to different biotopes: among thickets of soft vegetation, in an open shallow area and in an open deep-water area of the pond.

At each point, 50 liters of water were filtered through the Apstein network (mill gas No. 70). Zooplankton sampling was carried out once every ten days. The selected samples were immediately fixed with a 5% formalin solution.

The species composition of zooplankton was identified by conventional methods using an Altami CM-0745T microscope. Each individual was determined to the species and calculated in the Bogorov chamber for 3 repetitions from each sample. The biomass of copepods and branchiform crustaceans was determined based on the individual mass of each zooplankter species according to the formula W= g×lb [10]:

where l is the length of the animal's body, mm

g – mass with a length equal to 1 mm,

b is the power factor.

Carp fingerlings were weighed during control catches once every 10 days.

In order to determine the effectiveness of the feed used , the feed coefficient was calculated according to the formula:

KK= P/M, where

KK – feed ratio

P – feed consumption for the period

M – fish weight gain over the period

3 Research results and discussion

The Novosibirsk region is one of the northern areas of pond fish farming in Russia, in which the temperature regime is of particular importance for the successful cultivation of fish. Under the conditions of our experiment, the temperature regime did not go beyond the average values for this zone (Table 1). Among the features of temperature dynamics, we can note a good warming of the water in the second and third decade of May, because usually at this time of the year, recurrent cold can be observed with a decrease in temperature to 11-12 degrees. This was exactly the decline in 2018. In general, 2020 by the sum of the degree days, it was warmer by 15.1% compared to 2018 (Table 2).

Table 1. Temperature regime of the pond in 2020, ^{0}C.

Decade	May	June	July	August	September
1		19.65±0.4	24.35±0.41	24.38±0.2	18.15±0.65
2	20.0±0.58	21.47±0.22	25.69±0.32	23.11±0.43	15.82±0.08
3	19.64±0.36	21.85±0.28	23.61±0.4	20.68±0.25	13.95±0.52
Average temperature	19.76±0.3	21.02±0.24	24.52±0.26	22.66±0.33	15.97±0.42
Sum of degreedays	336	651.5	760.1	702.4	479.2

Table 2. Temperature regime of the pond in 2018, ^{0}C.

Decade	May	June	July	August	September
1		17.05±0.84	23.8±0.36	20.1±0.1	15.5±0.49
2	8.75±0.63	21.6±0.16	24.2±0.2	20.1±0.18	12.95±0.3
3	10.64±0.34	23.18±0.18	21.27±0.41	19.18±0.38	11.73±0.14
Average temperature	9.97±0.37	20.58±0.37	23.03±0.31	19.77±0.13	13.38±0.35
Sum of degreedays	169.5	617.5	714	613	401.5

During the studied growing season in 2020, 6 species of the order Rotifera, 7 species of the order Cladocera and 2 species of Copepoda were identified (Table 2). The composition of zooplankton was not stable and out of 15 species only 2 (*Mesocyclops leuckarti, Eudiaptomus graciloides*) were noted in each hydrobiological sample. Zooplankton species such as *Keratella quadrata, Daphnia longispina* and *Ceriodaphnia reticulata* have not been detected only 1 time. *Polyphemus pediculus* and *Brachionus quadridentatus* have been registered in the community only once.

Table 3. Phenological composition of the feeding pond zooplankton community in 2020.

№	Taxon	Date								
		15-May	1-Jun	12-Jun	21-Jun	2-Jul	14-Jul	30-Jul	15-Aug	25-Aug
Rotifera										
1.	Brachyonus quadridentatus	-	-	-	-	-	-	+	-	-
2.	Euchlanis dilatata	-	+	-	+	-	+	-	-	-

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3.	Filinia longiseta	-	-	-	-	-	-	+	-	+
4.	Keratella cochlearis	-	-	-	-	-	+	+	-	-
5.	Keratella quadrata	+	+	-	+	+	+	+	+	+
6.	Platyias quadricornis	-	-	-	-	-	+	+	-	-
Cladocera										
1.	Bosmina longirostris	+	+	+	-	+	-	-	+	+
2.	Ceriodaphnia reticulata	+	+	+	+	+	+	-	+	+
3.	Chydorus sphaericus	-	+	+	+	+	+	-	+	+
4.	Daphnia longispina	+	+	+	+	+	+	-	+	+
5.	Diaphanosoma brachyurum	+	-	+	+	+	+	-	+	+
6.	Polyphemus pediculus	-	-	+	-	-	-	-	-	-
7.	Scapholeberis mucronata	+	-	-	-	-	-	-	-	+
Copepoda										
1.	Mesocyclops leuckarti	+	+	+	+	+	+	+	+	+
2.	Eudiaptomus graciloides	+	+	+	+	+	+	+	+	+

Table 4. Phenological composition of the feeding pond zooplankton community in 2018.

№	**Taxon**	**Date**		
		14.07	20.07	18.08
Rotifera				
1.	Keratella quadrata	+	+	+
2.	Brachyonus quadridentatus	-	+	-
3.	Keratella cochlearis	-	+	+
Cladocera				
1.	Bosmina longirostris	+	+	+
2.	Chydorus sphaericus	+	+	+
3.	Ceriodaphnia reticulata	+	+	+
4.	Daphnia longispina	+	+	+
Copepoda				
1.	Mesocyclops leuckarti	+	+	+
2.	Eudiaptomus graciloides	+	+	+

In the composition of zooplankton in 2018 for the same period in 2020, 3 species fewer representatives of Rotifera were identified, 3 species fewer representatives of Cladocera, and the composition of Copepoda was identical.

The number of zooplankton is subject to significant fluctuations during the season and is determined by such main factors as temperature, abundance of predators, food availability [8]. The predominant predators with the largest biomass in the conditions of the studied reservoir were fingerlings of carp and weed fish (rotan, minnow).

In the studied reservoir, on June 1, there was a sharp decrease in the number among all zooplankton groups after stocking with carp larvae on 05/15/2020. The largest decrease in the number was observed in the species *Bosmina longirostris* by 321.8 times (Table.5). As noted by a number of scientists, carp prefers representatives of the order Cladocera, and in the early stages of development eats species of taxon Rotifera and Copepoda [11, 12, 13].

The high number of zooplankton up to and including June 21 can be explained by the relatively low ichthyomass in the feeding pond compared to the volume of water masses, and hence the biomass of zooplankton. The cultivation of carp fingerlings in growing ponds with traditional technology does not give such advantages due to the small area and depth of the reservoir. Thanks to such a reserve and favorable conditions, first of all, an increase in water temperature (Table.1), most likely there was a sharp increase in the number of plankton 02.07.2020.

Table 5. Dynamics of zooplankton abundance in 2020, ind.*1000/m^3.

Taxon	**15-May**	**1-Jun**	**12-Jun**	**21-Jun**	**2-Jul**	**14-Jul**	**30-Jul**	**15-Aug**	**25-Aug**
Rotifera									
Brachyonus quadridentatus	-	-	-	-	-	-	0.50	-	-
Euchlanis dilatata	-	0.25	-	0.22	-	1.33	-	-	-
Filinia longiseta	-	-	-	-	-	-	4.67	-	5.56
Keratella quadrata	14.89	4.58	0.0	1.56	95.22	14.94	19.0	14.0	18.22
Platyias quadricornis	-	-	-	-	-	0.44	0.67	-	-
Keratella cochlearis	-	-		-	-	0.22	0.67	0.33	-
Total	14.88	4.83	0.0	1.78	95.22	16.94	25.5	14.33	23.78
Cladocera									
Bosmina longirostris	241.39	0.75	1.42	-	0.22	-	-	1.0	12.83
Chydorus sphaericus	0.0	5.33	1.30	6. 33	0.44	5.28	-	73.67	20.22
Ceriodapnia reticulata	4.96	0.0	6.71	12.11	35.06	4.17	-	978.33	538.56
Daphnia longispina	14.88	3.92	54.67	5.11	233.3 9	9.28	-	34.0	19.33
Diaphanosoma brachyurum	1.65	0.0	2.38	0.83	0.89	11.96	-	6.11	6.39
Polyphemus pediculus	-	-	0.21	-	-	-	-	-	-
Scapholeberis mucronata	4.96	-	-	-	-	-	-	-	5.56

Total	267.84	10.0	66.67	24.39	270.0	30.69	0.0	1093.11	602.89
Copepoda									
Mesocyclops leuckarti	18.19	30.25	49.58	83.56	67.5	47.61	7.0	177.22	225.06
Eudiaptomus graciloides	72.75	53.83	10.96	17.44	53.67	23.72	-	2.56	1.11
Total	90.93	84.08	60.54	101.0	121.17	71.33	7.0	179.78	226.17
Total zooplankton	373.65	98.92	127.75	127.17	486.39	118.96	32.50	1 287.22	852.83

In mid-July 2018 (Table. 6) the number of zooplankton was higher than in the same period of 2020, which indicates a smaller press of two-year-olds of carp compared to carp fingerlings. This is also confirmed by the work of researchers [6,7]. Since mid-August, there has been a general trend towards an increase in the number of zooplankton, which in 2020 amounted to 39.6 times, and in 2018 4 times (Table 6). This pattern is most likely caused by the active feeding of fish with artificial feeds, their consumption in August increased by 461.4% compared to July (2020) and by 315.3% (2018). A similar opinion is shared by a team of European researchers [8].

The dominant species in 2020 in terms of the average frequency of occurrence was *Ceriodaphnia reticulata* with an indicator of 45.1%, in 2018 *Bosmina longirostris* dominated with an average frequency of 33.3%.

Table 6. Dynamics of zooplankton abundance in 2018,ind.*1000/m^3.

Taxon	Date		
	14.07	20.07	18.08
Rotifera			
Keratella quadrata	62.9	118.1	15.9
Brachyonus quadridentatus		0.1	
Keratella cochlearis		0.1	0.8
Total	62.9	118.3	16.7
Cladocera			
Bosmina longirostris	0.3	0.6	358.7
Chydorus sphaericus	3.9	1.5	0.8
Ceriodaphnia reticulata	18.01	9.6	169.9
Daphnia longispina	43.9	29.7	5.4
Total	66.11	41.4	534.8
Copepoda			
Mesocyclops leuckarti	33.6	10.3	124.7
Eudiaptomus graciloides	12.8	12.6	45.1
Total	46.4	22.9	169.8
Total zooplankton	175.41	182.6	721.3

Biomass is a direct consequence of changes in the number of zooplankton, but depends on the type of dominant zooplankton, because their mass in the reservoir varied from 0.004 mg to 0.11 mg. The

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largest representatives of zooplankton *Daphnia longispina* dominated the community on June 12 and July 14 (Table 7). In 2018, *Daphnia longispina* were dominant in 66.6% of samples (Table 8). In general, representatives of Cladocera in 2020 had a lower specific abundance and biomass compared to 2018, which indicates more strong pressure from youngsters in comparison with two-year-olds. Fish primarily eliminate sedentary and larger branched crustaceans, and then oar-footed crustaceans [9]. In addition, the authors testify to the absence of the influence of carp weighing from 920 ±83 g on the zooplankton of ponds [2], which is close to the values of the mass of two-year-olds in our experiment, which reached 1050 ±67 g by 15.09.

A significant increase in zooplankton biomass on August 15-25 is caused by the previously described fact of a decrease in fish pressure due to an increase in the level of feeding and, in this regard, an increase in the organic load on the reservoir, which is also a stimulant for the growth of zooplankton abundance and biomass [14].

Table 7. Dynamics of zooplankton biomass in 2020, mg/m^3.

Taxon	**15-May**	**1-Jun**	**12-Jun**	**21-Jun**	**2-Jul**	**14-Jul**	**30-Jul**	**15-Aug**	**25-Aug**
	Rotifera								
Brachyonus quadridentatus	-	-	-	-	-	-	0.29	-	-
Euchlanis dilatata	-	0.4	-	1.1	-	4.35	-	-	-
Filinia longiseta	-	-	-	-	-	-	-	-	1.55
Keratella quadrata	5.4	3.2	-	0.6	43.7	6.86	5.29	3.89	8.37
Platyias quadricornis	-	-	-	-	-	1.45	1.70	-	-
Keratella cochlearis	-	-	-	-	-	0.08	0.14	0.07	-
Total	5.4	3.6	0.00	1.7	43.7	12.75	7.41	3.96	9.91
	Cladocera								
Bosmina longirostris	1819.2	3.7	16.37	-	1.8	-	-	8.77	120.99
Chydorus sphaericus	0.0	34.1	8.27	34.0	2.6	25.80	-	599.75	118.77
Ceriodapnia reticulata	30.3	-	36.22	57.4	256.3	40.13	-	2373.55	2074.83
Daphnia longispina	1700.0	64.0	2515.01	242.6	8847.3	285.95	-	1664.03	685.11
Diaphanosoma brachyurum	100.1	-	54.34	20.7	24.97	137.22	-	139.82	116.78

Polyphemus pediculus	-	-	59.22	-	-	-	-	-	-
Scapholeberis mucronata	38.4	-	-	-	-	-	-	-	117.96
Total	3688.0	101.9	2689.4	354.7	9133.04	489.10	0.00	4785.91	3234.45
	Copepoda								
Mesocyclops leuckarti	106.2	64.7	185.9	255.5	98.0	86.5	9.7	930.7	970.3
Eudiaptomus graciloides	4255.8	2753.0	968.3	618.4	1 803.0	1351.8	0.0	19.8	49.5
Total	4361.9	2817.7	1 154.1	873.9	1901.01	1438.26	9.70	950.50	1019.84
Total zooplankton	8055.3	2923.2	3858.15	1230.3	11077.8	1940.11	17.1	5740.4	4264.20

Noteworthy is the fact that the biomass of *Eudiaptomus graciloides* decreased in August 2020 (Table. 7), whereas in 2018 (Table. 8) on the contrary, it has increased. Probably, this trend is due to the selectivity of fish to this type of zooplankton due to their sizes reaching 1.5 mm.

Table 8. Dynamics of zooplankton biomass in 2018, mg/m^3.

Taxon	**Date**		
	14.07	**20.07**	**18.08**
Rotifera			
Keratella quadrata	75.5	110.3	13.3
Brachyonus quadridentatus	0	0.1	0
Keratella cochlearis	0	7.9	0.2
Total	75.5	118.3	13.5
Cladocera			
Bosmina longirostris	0.9	4	1434.3
Chydorus sphaericus	13.3	4.2	3.3
Ceriodaphnia reticulata	125.4	98.6	588.8
Daphnia longispina	1131.2	726.8	38.9
Total	1270.8	833.6	2065.3
Copepoda			
Mesocyclops leuckarti	116.35	11.8	124.1
Eudiaptomus graciloides	315.2	247.4	454.4
Total	431.55	259.2	578.5
Total zooplankton	1777.85	1211.1	2657.3

Zooplankton is a good starter food, but is also actively used by carp fingerlings throughout the season. During July and August, we constantly recorded flocks of carp feeding in the upper layers of the water. Of the feed resources presented in the reservoir, only zooplankton can accumulate in the surface layers, attracting fingerlings, but an analysis of the fish diet will be required to confirm this in the future.

Carp fingerlings were not fed until the third decade of July, but their mass by July 15 reached 57.83 ± 2.78 g (Fig. 1). When fishing the pond, 17676 kg was obtained with an average weight of carp fingerlings 280.71 ± 10.71, it follows that the number on July 15 was at least 62968.9 pcs. Thus, the natural fish productivity at that time already amounted to 3641.4 kg or 182 kg/ha. In accordance with the existing regulations for the first fish farming zone, the natural fish productivity is 70 kg/ha. Consequently, already in the middle of the growing season, we have a higher fish productivity index, which indicates a more efficient use of the natural food supply by undergrown carp larvae than by two-year-olds.

An important indicator of the use of the introduced feed and the natural feed base is the feed coefficient. In 2020, the total fish productivity was 17676 kg with feed costs (wheat grain waste) 19507 kg, respectively, the feed coefficient was:

$$КК = 19507 \text{ kg}/17676 \text{ kg} = 1{,}1.$$

In 2018, the fish productivity for two-year-olds of carp was 6960 kg . Stocking was carried out by yearlings of carp weighing 700 kg . Accordingly, the increase in ichthyomass was 6260 kg, with feed costs (wheat grain waste) 15595 kg, therefore the feed coefficient was:

$$КК = 15595 \text{ kg} /6260 \text{ kg} = 2.49.$$

Thus, with the same annual natural fish productivity of the reservoir, it can be stated that the efficiency of using the natural feed base when growing fingerlings is more than 2.4 times higher compared to growing two-year-olds.

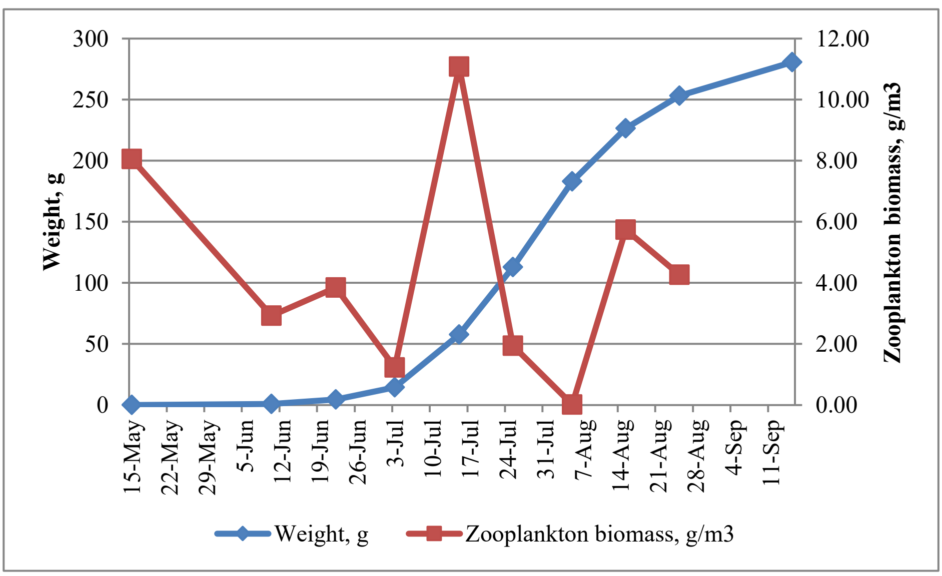

Fig. 1. Dynamics of the mass of carp fingerlings and zooplankton biomass, 2020.

4 Conclusion

The role of zooplankton as an integral part of the natural food supply is of great importance for the growth of carp fingerlings grown up in the USV in the early stages. We have revealed the active effect of fish on the qualitative and quantitative composition of zooplankton of the feeding pond during the entire summer period.

A comparison of the efficiency of using the feed base by fingerlings and two-year-olds of carp in a feeding pond showed a two-fold advantage of using the former. In order to highlight the role of zooplankton in the formation of natural fish productivity, additional studies of the nutrition of carp fingerlings grown using combined technology (RAS + feeding ponds) are required.

In order for carp fingerlings to reach a mass of 600-800 g, it is necessary to choose the optimal weight and planting density of the undergrown larvae.

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