Arch. Ryb. Pol.	Archives of Polish Fisheries	Vol. 7	Fasc. 1	103 - 112	1999

TANK-CAGE METHOD OF REARING COREGONID (*Coregonidae*) FISH. II. EUTROPHIC LAKE

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ABSTRACT. The aim of the studies was to determine the possibility of using a combined rearing system of tanks and illuminated cages for coregonid larvae in eutrophic lake. Studies were carried out in 1990. Tank rearing took place in Dgal Hatchery, cage rearing was performed in eutrophic Lake Leginskie. Increasing the egg incubation temperature, larvae hatching was accelerated about 3 weeks earlier. The larvae were reared on artificial feeds, at 16 ±1 °C, for a period of 19 days. Then they were transferred to illuminated cages, in which they fed on the zooplankton only. The control group consisted of the larvae hatched in the usual period in cold hatcheries, and reared identically as the experimental fish. Cage rearing lasted for 63 days. Growth rate , mortality, LDS and fish biomass were determined throughout of the experiment. The larvae attained the weight of 41 mg at the end of tank rearing. Fry obtained at the end of the cage rearing weighed from 1732 to 2023 mg (experimental fish) and from 475 to 648 mg (control fish). Stock mortalities amounted from 65 to 80 %. Experimental fish finished their larval development after 42 days, whereas a certain part of control group did not finished their larval development till the end of cage rearing. There were high values of fish biomass in cages in tank-and-cage rearing (from 2.39 to 3.24 kg/m^3). The results of the experiment have showed that tank-and-cage rearing of producing coregonid stocking material may be applicable in eutrophic lakes.

Key words: COREGONID LARVAE, REARING, TANKS, CAGES

INTRODUCTION

According to Colby et al. (1972), changes in the aquatic ecosystems lead to a disappearance of economically valuable fish, in this of whitefish. Species characteristic of clean waters frequently give way to cyprinids (roach, bream, white bream, bleak), which often develop in excessive numbers, leading to the inhibition of their growth rate. This phenomenon is very unsatisfactory from the point of view of fisheries management, and according to Prejs et al. (1997) may result in deteriorating water quality. Sometimes the only method to maintain populations of lake whitefish is to release stocking material of possibly high body weight (Łuczyński 1987, Viljanen 1988, Mamcarz 1990). Production of heavy stocking material is possible, among others, also thanks to tank-cage rearing method (Champigneulle and Rojas-Beltran 1990, Mamcarz and Kozłowski 1991, Kozłowski et al. 1996). Effectiveness of this method of fry production depends, however, on trophic state of the lake used for cage fish rearing (Kozłowski 1993).

MATERIAL AND METHODS

Eyed whitefish eggs originated from the Fishery Enterprise in Ełk (fish hatchery in Olecko). Hatching of the larvae was accelerated by about 3 weeks compared to typical fish hatcheries in Mazuria Lake District, this being achieved increasing the incubation temperature.

Larvae were stocked into tanks on March 20, 1990. Two days later, when majority of the larvae have already resorbed yolk sacs, artificial feeding was initiated. This day (22 March) was taken as the beginning of tank rearing which lasted until April 9. Then the fish were transferred to lake cages, where they were reared until June 11. Tank rearing was carried out in the Hatchery Station „Dgał" of the Inland Fisheries Institute in Olsztyn. Procedure at this stage of fish rearing was described in detail by Kozłowski et al. (1996).

Fish in tanks were given artificial feeds (Poczyczyński et al. 1990), while in lake cages they fed on the zooplankton. End of the cage rearing stage corresponded to larvae hatching in other hatcheries of the region. The control group consisted of the larvae which had hatched in the „usual" period and were stocked into lake cages with no pre-rearing. Cages were stocked at the same time with the experimental fish (group B) and the control ones (group W), each in two replications. All fish were counted at stocking as well as at the end of the experiment.

Rearing of the newly hatched larvae (W) was performed in cages of 1.86 m^3. For group B, cages of 4.7 m^3 were used. These cages were also used for group W between the third and the sixth week of rearing (Mamcarz and Nowak 1987). Beginning from the seventh week, cages 2 x 2 x 2.5 m were used, made of a net with mesh size 4 mm. Cages were illuminated with electric 60 W/24 V bulbs suspended 10 cm above the water surface. Number of dead fish was registered daily. Initial stock of the fish in cages was 17000 fish in the experimental group, and 16250 fish in the control. Initial mean body weight and length in the experimental and the control group: 40.8 and 5.0 mg, and 20.5 and 11.0 mm.

Cage rearing was performed in Lake Legiñskie (area 228.3 ha, epilimnion depth 9 m, maximal lake depth 37.2 m), which is classified as vendace type (Mamcarz 1982).

Water temperature was measured daily at the depth of 0.1, 1.5 and 3.0 m. The mean value for these three measurements was treated as the average temperature of the epilimnion.

To determine the growth rate, fish samples were collected every week. They consisted of 50 fish. The collected larvae were preserved in 4 % formalin solution, then measured (up to 0.1 mm) and weighed (up to 1 mg). Stage of larval development was also determined according to a 14-degree scale LDS (Łuczyński et al. 1988). The dependence between weight and length of the fish was determined according to the equation:

$$W = aL^{b}, \quad \text{where:}$$

W - mean individual weight (mg),

L - mean individual length (l.t. mm),

a and b - regression coefficients.

The calculated functions were transformed to the logarithmic form:

$$\log W = a \log L - b$$

F Snedecor's statistics were used to verify the hypothesis on parallelity of the obtained regression lines and equality of the free coefficients of the equations, assuming the level of significance at 0.05.

SGR (standard growth rates) were calculated for particular stages of fish rearing using the equation:

$$SGR = 100\left(\frac{\ln W_2 - \ln W_1}{t}\right)$$

where:

W_1 - mean individual weight (mg) at the beginning of the analysed period,

W_2 - mean individual weight (mg) at the end of the analysed period,

t - period duration (days).

Fish biomass in the cages was determined per 1 m^3 of water. Total fish weight was calculated multiplying the mean individual weight by the number of alive fish.

RESULTS

Mean weights and lengths of the fish during cage rearing are presented in Figs. 1 and 2. After 63 days of rearing the mean weight of experimental fish was 2023.9 and 1732.5 mg in particular cages, and of the control fish: 648.0 and 475.0 mg. Average

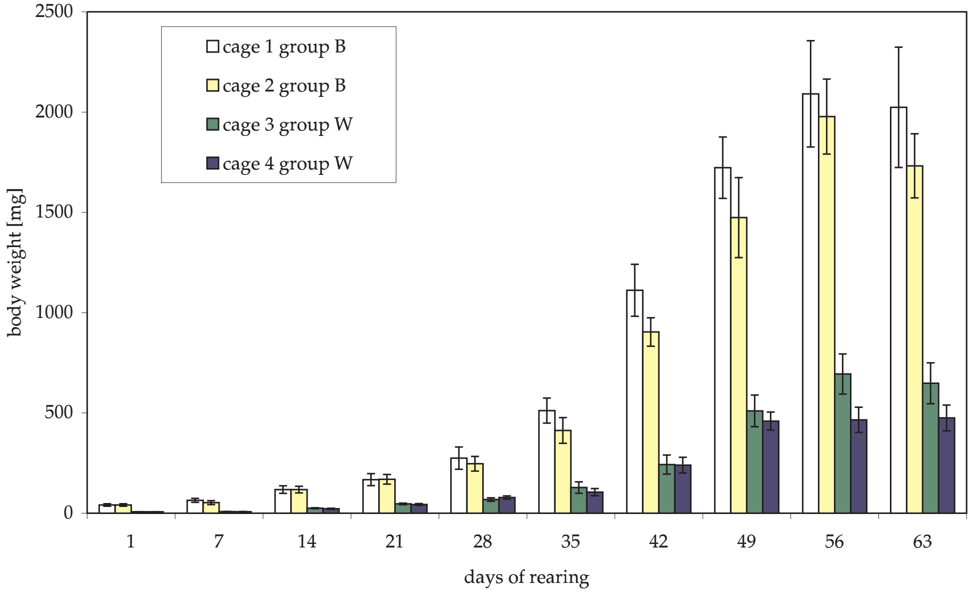

Fig. 1. Increments of individual mean body weight of the larvae during cage rearing

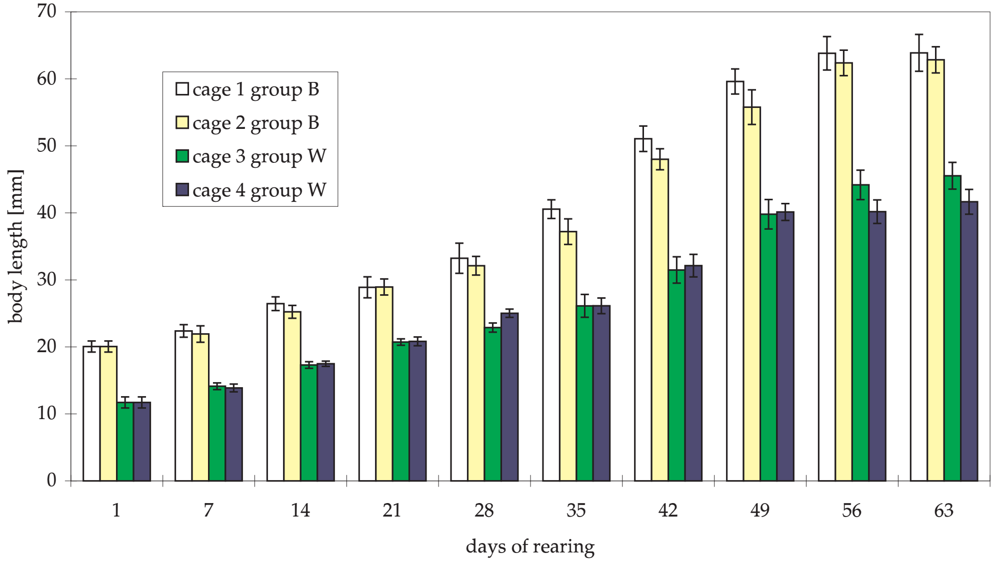

Fig. 2. Increments of individual mean body length (l.t.) of the larvae during cage rearing

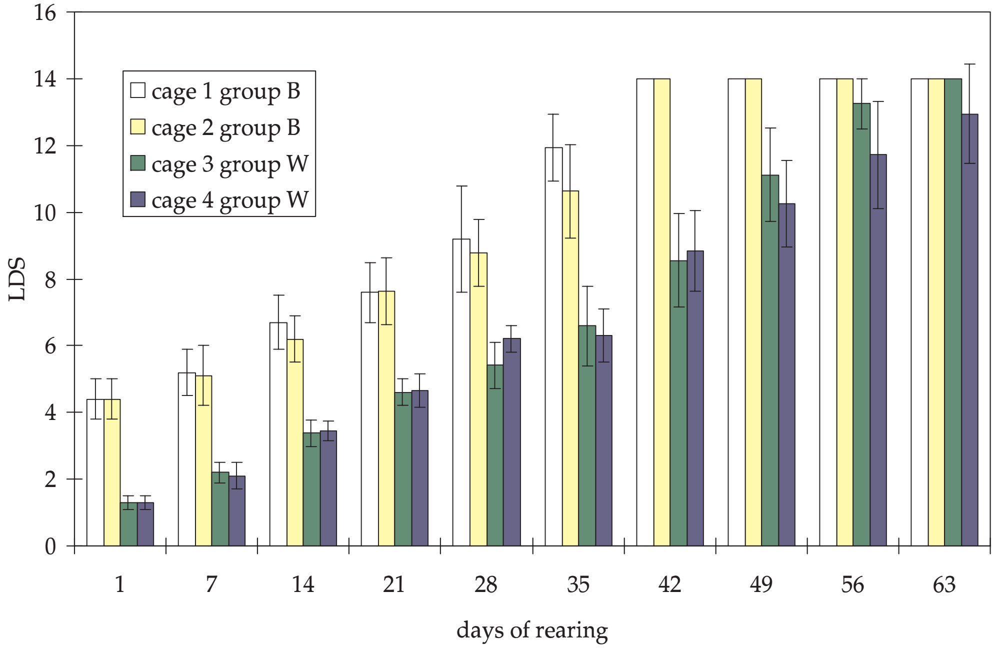

Fig. 3. Increase of the mean LDS of the larvae during cage rearing

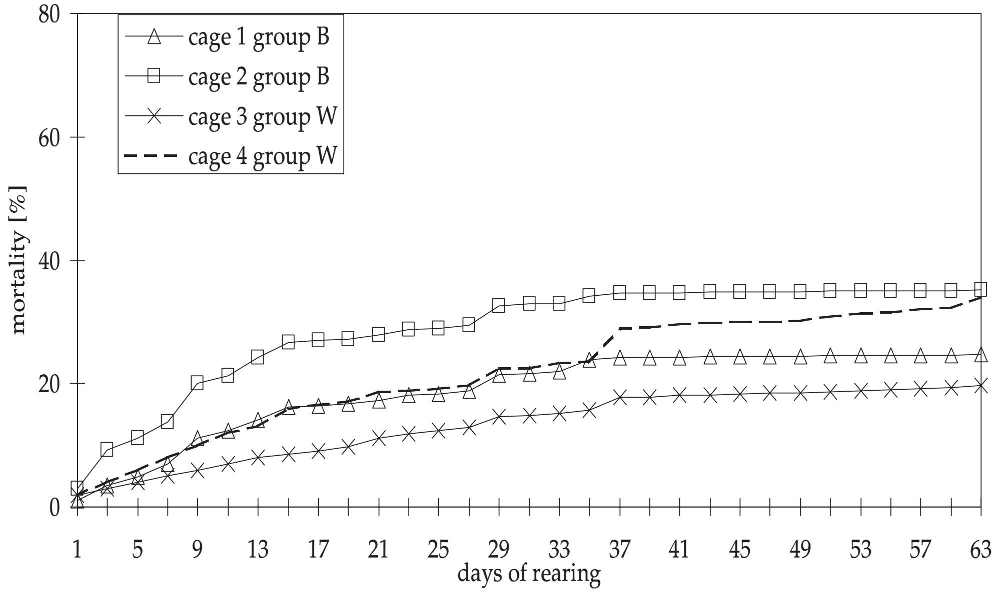

Fig. 4. Mortality of the larvae and fry during cage rearing

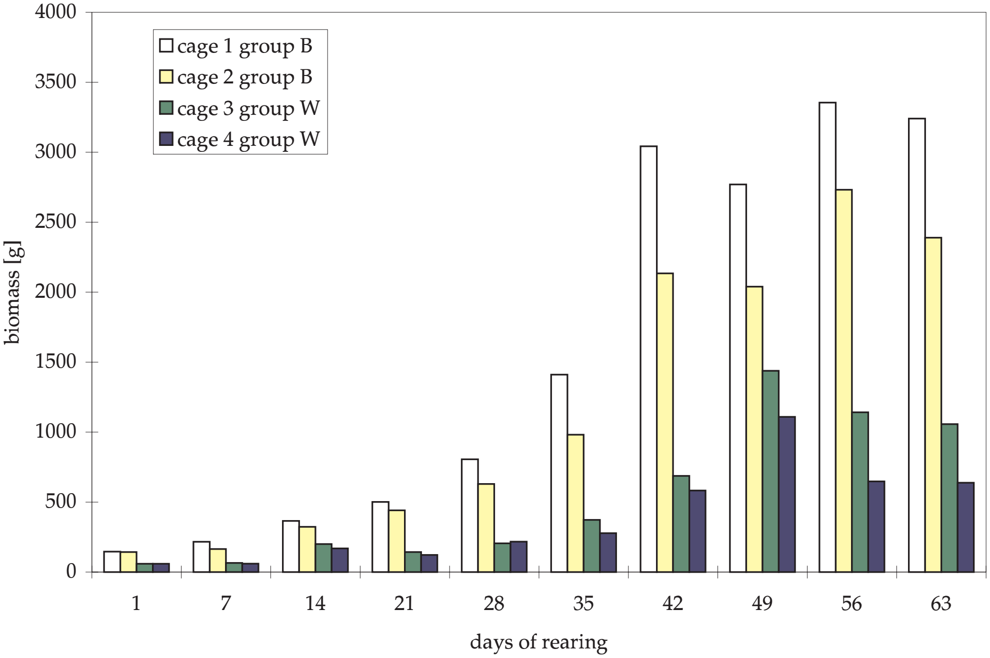

Fig. 5. Increments of fish biomass during cage rearing

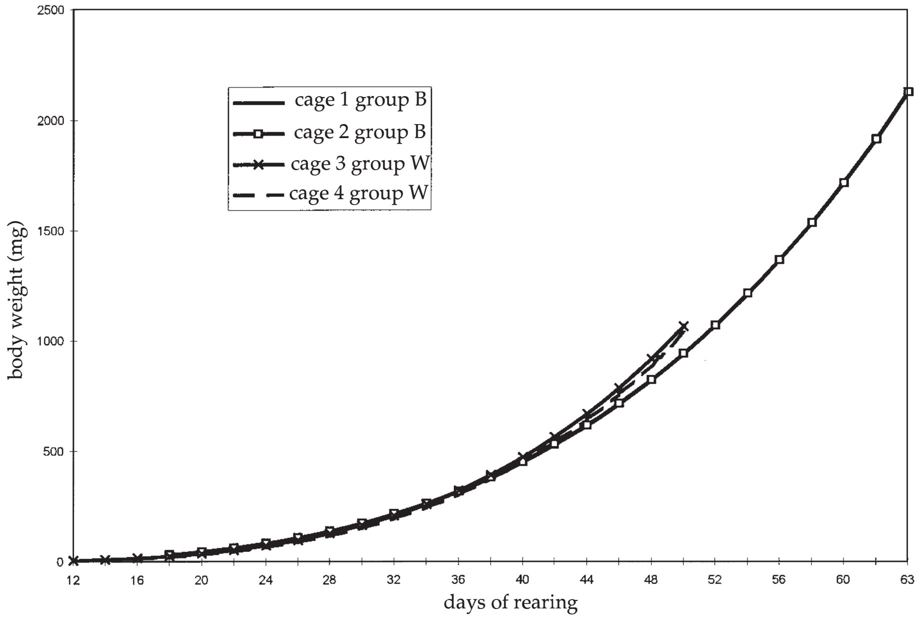

Fig. 6. Dependence between fish length and weight during cage rearing

length of the first was 65.3 and 63.2 mm, and of the latter - 45.6 and 41.7 mm. SGR values in groups B and W amounted on the average to 6.20 and 5.95 $\%d^{-1}$, and 7.72 and 7.23 $\%d^{-1}$ respectively.

Fish which had first been reared in the tanks completed their larval development reaching the fry stage (LDS=14) after 42 days, while part of the fish in group W did not attain this stage even after 63 days of rearing (Fig. 3).

The highest mortalities were observed during the first two weeks of rearing. Mortality in this period ranged from 90 to 500 fish.cage.d^{-1}. Until 15th day of rearing, fish losses ranged from 8.3 to 27.0 % per cage, decreasing in the subsequent period. After 9 weeks of rearing fish survival ranged from 75.4 and 65.0 % (groups B) to 80.7 and 67.7% (groups W) (Fig. 4).

In all variants of the experiment the fish gradually increased their weight. At the end of the experiment, fish biomass in particular cages amounted to: 3.24 and 2.39 kg m^{-3} (experimental groups), and 1.06 and 0.64 kg m^{-3} (groups W) (Fig. 5). The highest biomass increments of 3.09 and 2.25 kg.m^{-3} were observed in the cages stocked with the fish which had been first reared in tanks. Lower mass increments of 1.00 and 0.58 kg.m^{-3} were recorded in the control groups.

Statistical analyses (test F - Snedecor's, $p<0.05$) of the weight-length relationship presented in form of regression lines revealed statistically significant differences in growth rates between groups B and W. More rapid growth was observed for the fish in groups W (Fig. 6).

Average water temperature during cage rearing amounted to 13.9^{o}C, ranging from 7.6 (at the beginning) to 17.4^{o}C (at the end of the experiment).

DISCUSSION

Cage rearing of coregonids can be carried out in different types of water (Bryliñski et al. 1979, Mamcarz 1990), using the stocking material of different age and size (Champigneulle and Rojas-Beltran 1990, Kozłowski et al. 1996). Results of selected studies on rearing whitefish larvae in two lake types are presented in table 1. Stocking material in these experiments consisted of feeding larvae or larvae which had been first reared in recirculation systems and on artificial feeds. To estimate the obtained results, the following parameters were taken into account: mean individual fish weight, survival, fish biomass. The results presented in table 1 suggest considerable effect of lake trophy on individual growth rate of the fish. For example, in a eutrophic Lake Legiñskie, water temperature during coregonid rearing (April-June) was lower and food resources poorer than in a polytrophic Lake Mutek (Mamcarz 1990, Lossow et al. 1991). This resulted in slower individual growth of fish in the eutrophic lake notwithstanding the same method of rearing.

TABLE 1

Selected results of studies on cage and tank-cage rearing of peled (Mamcarz 1990, Mamcarz et al. 1990 a, b) and whitefish (other citations) in eutrophic Lake Legiñskie and polytrophic Lake Mutek

Duration of rearing (days)	Mean initial individual weight (mg)	Mean final individual weight (mg)	SGR [%·d^{-1}]	Final biomass [kg/m^3]	Mortality (%)	Author
Lake Legińskie						
63-79 *	7-10	126.6-435.3	5.64-9.42	0.50-1.30	82.9-94.3	Mamcarz 1990
54-67 *	4,1-4.2	110,1-675,3		0,22-1,28	68,2-96,3	Mamcarz i in.. 1990a
20 + 41 **	32.2	355.0	6.16	1.05	36.4	Poczyczyński i in. 1995
20 + 41 **	19.1-27.9	232.2-380.0	6.23-6.87	1.06-1.69	16.9-31.9	Dostatni 1997
19 + 63 **	40.8	1732.5-2023.9	5.95-6.20	2.39-3.24	24.6-35.0	Niniejsza praca
63 **	5.0	475.0-648.0	7.23-7.72	0.64-1.06	19.3-32.3	j.w.
Jezioro Mutek						
73 *	4.2	1813.0-5470.0		0.56-0.92	91.2-94.4	Mamcarz i in. 1990b
56-78 *	7-10	632.3-1823.0	8.96-13.90	0.40-3.30	51.0-99.3	Mamcarz 1990
19 + 63 **	23.9	4909.4-5500.0	8.45-8.63	0.76-1.72	79.8-92.0	Kozłowski i in. 1996
63 *	4.8	2223.4-2467.7	9.74-9.91	0.88-0.89	64.7-80.3	j.w.
19 + 22 **	40.8	96.2-103.0	3.90-4.21	0.00	100.0	j.w.
22 *	5.0	25.1-25.7	7.33-7.44	0.00	100.0	j.w.

** Cage rearing*
***Tank-cage rearing. The first value refers to tank rearing duration, the second to cage rearing duration*

Average body weight of whitefish reared using tank-cage method was in both lakes almost three times higher than of the control fish (Kozłowski et al. 1996, fig. 1). At the same time, average weight of fish reared in the eutrophic lake was similar to the values obtained during control fish rearing in the polytrophic lake (Kozłowski et al. 1996, Mamcarz 1990). The obtained values of average weight of fish reared using a traditional method did not deviate from the results obtained by Mamcarz et al. (1990a, 1990b) and Champigneulle and Rojas-Beltran (1990) who carried out their experiments in similar conditions (duration of rearing, temperatures, fish densities). These results reveal considerable differences in the growth rate of coregonids depending on environmental conditions. Factors such as water temperature, food resources, algae blooms (and concentration of algal toxins), levels of detritus or parasite invasions affect not only the fish growth, but also their survival (Własow 1993). Fish survival is decisively higher in eutrophic than in polytrophic lake; fish mortalities in the latter may reach even 100 %. In the described experiments there was no relationship between larvae size and their survival irrespective of the lake type (Tab. 1).

Fish biomass (especially using the tank-cage method) obtained in Lake Legiñskie is comparable to the best results described in the literature (Radziej et al. 1978, Mamcarz 1990).

Duration of larval development correlates strictly with the temperature and growth rate (Łuczyński 1988). There is a clear dependence between lake fertility (polytrophy, mesotrophy) and duration of larval development (Mamcarz 1990, Kozłowski 1993). End of metamorphosis in the case of fish reared in a „traditional" way and using the tank-cage technique took place in the plytrophic lake between day 37 and 63 of rearing (Kozłowski et al. 1996), while in the eutrophic lake and the tank-cage system the larval period ended before 63rd day of rearing.

The results of tank-cage rearing obtained in Lake Legiñskie suggest a possibility of rapid and complete adaptation of coregonid fish to conditions of constantly illuminated cages. This method of producing stocking material of whitefish can be well used in eutrophic lakes.

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STRESZCZENIE

BASENOWO-SADZOWA METODA PODCHOWU LARW RYB SIEJOWATYCH. II. JEZIORO EUTROFICZNE

Celem badań było określenie możliwości zastosowania kombinowanej basenowo - sadzowej metody podchowu larw ryb siejowatych w jeziorze eutroficznym. Badania przeprowadzono 1990 roku. Podchów basenowy przeprowadzono w Ośrodku Zarybieniowym Dgał, sadzowy w eutroficznym jeziorze Legińskim. Podwyższając temperaturę wody w czasie inkubacji ikry, przyspieszano wykluwanie się larw o około 3 tygodnie. Wylęg podchowywano na paszy sztucznej w temp. 16±1°C przez 19 dni. Następnie podchów był kontynuowany w sadzach toniowych, gdzie ryby odżywiały się zooplanktonem. Grupę kontrolną stanowiły larwy wyklute w normalnym terminie. Podchów sadzowy trwał 63 dni.

W okresie badań rejestrowano tempo wzrostu, śmiertelność, LDS i biomasę ryb. Na koniec podchowu basenowego ryby miały średnią masę 41 mg. Narybek po podchowie sadzowym osiągnął w grupie doświadczalnej średnią masę jednostkową od 1732 do 2023 mg a w kontrolnej od 475 do 648 mg. Przeżywalność ryb wahała się od 65 do 80%. Ryby z grupy doświadczalnej zakończyły rozwój larwalny po 42 dniach, natomiast część ryb z grupy kontrolnej nie zakończyła rozwoju do 63 dnia podchowu. Uzyskano wysokie wartości biomasy ryb w sadzach w podchowie basenowo - sadzowym (2,39-3,24 kg·m^{-3}). Wyniki badań wskazują że, basenowo-sadzowa metoda podchowu materiału zarybieniowego larw ryb siejowatych może być z powodzeniem stosowana w jeziorach eutroficznych.

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