Arch. Ryb. Pol.	Archives of Polish Fisheries	Vol. 7	Fasc. 1	53 - 63	1999

THE INFLUENCE OF THERMAL CONDITIONS DURING TANK REARING ON FURTHER GROWTH OF WHITEFISH LARVAE (*Coregonus lavaretus* L.) IN ILLUMINATED CAGES

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ABSTRACT. Whitefish larvae were reared in tanks and cages for 8 weeks. Tank rearing lasted 3 weeks and was carried out in two tanks, at 14°C (tank A), and 18°C (tank B). The larvae were fed artificial feed. Higher temperature resulted in better fish growth (17.4 mm, 27.9 mg) comparing to lower one (15.7 mm, 19.1 mg). Subsequent rearing was carried out in illuminated cages; it lasted 5 weeks. The fish fed only on zooplankton attracted by light.

Results of the experiment revealed considerable impact of water temperature during tank rearing on later growth of whitefish larvae in cages. Average body weight of the fish pre-reared at 18°C was 380.0 mg at the end of the experiment, and length 37.6 mm, and of the fish from 14°C – 232.2 mg and 32.6 mm respectively.

Key words: WHITEFISH LARVAE, REARING, WATER TEMPERATURE, ILLUMINATED CAGES

INTRODUCTION

Tank-and-cage rearing is a new technology of producing coregonid stocking material, combining the advantages of both: tank (artificial feeding and water temperature control) and cage rearing (using natural food resources) (Champignelle, Rojas-Beltran 1990, Mamcarz, Kozłowski 1991). Controlled conditions of rearing, especially in the initial phase, enable shortening of the production cycle compared to other methods.

One of the main issues in applying this technique is adaptation of larvae to lake environment after their transfer from tanks to cages. Whitefish development (embryonic phase and tank rearing of fry), and thus also possibility of adaptation to cage environment, are considerably affected by thermal conditions. This is true of both: egg incubation and rearing of larvae in tanks. The aim of the present study was to compare the effect of tank rearing of whitefish larvae at two temperatures on their further growth in cages.

MATERIAL AND METHODS

Tank-and-cage rearing of whitefish larvae was carried out in March-May 1991, in the „Dgał" Experimental Fish Hatchery of the Inland Fisheries Institute. It lasted 8 weeks. Eyed eggs obtained from Olecko Hatchery (Fish Farm in Ełk) were placed in two Weiss apparatuses and incubated at constant temperature of 10^{o}C. Eleutheroembryos (free embryos) of whitefish (Balon 1975), hatched at the end of March, were transferred to two tanks, about 30 thousand individuals in each. Initial stock density was estimated from the volume of eggs in the apparatuses. Plastic tanks, 0.8 m^3 each, were supplied with filtered and sterilized water from a deep well; a recirculation system was used. Water temperature was maintained at constant levels of 14 ± 1^{o}C (tank A), or 18 ± 1^{o}C (tank B). Photoperiod lasted from 7 a.m. to 9 p.m. The fish were fed every 3 minutes with starter of identical composition as the control feed used by Poczyczyński et al. (1995). Automatic feeders were used (Mamcarz, Kozłowski 1989) and the feeding rate was about 40 g a day per tank. Samples of 50 fish were collected from each tank twice a week to estimate growth rate, body length and weight. The fish were preserved in 4% formaldehyde and analysed in the laboratory. The tanks were cleaned daily to remove non-consumed feed and faeces. Dead fish were also counted and removed. Beginning from the 16th day of rearing, water temperature was gradually lowered to reach about 10^{o}C at the end of tank rearing (day 21st) in order to acclimate the larvae to lake environment.

Cage rearing was carried out in Legińskie Lake belonging to the former Łężany Experimental Farm of the Olsztyn Academy of Agriculture and Technology. On April 19, the larvae from the two tanks were transported separately and released into two illuminated cages (4.7 m^3 each) (Mamcarz, Nowak 1987), suspended in surface layer of Legińskie Lake. The lake belongs to the intermediate type between mesotrophy and eutrophy (Mamcarz 1990). Cage rearing lasted 5 weeks, from the third decade of April to the end of May. The fish fed exclusively on the zooplankton attracted by light (60 W/ 24 V bulb placed over the water surface). The fish were counted before stocking into the cages and at the end of rearing. The cages were replaced and cleaned once a week. Dead fish were recorded daily and removed. Similarly as during tank rearing, 50 fish were sampled weekly from each cage for growth rate estimation and body weight and length measurements. The fish were preserved in 4% formaldehyde, and then measured up to 0.01 mm and weighed up to 1 mg. Water temperature was measured daily, at 0.2, 1.5, and 3.0 m., and average temperature of epilimnion was calculated.

Specific growth rate (SGR) was calculated for each phase of rearing according to the formula:

$$SGR \quad \frac{100 \quad (\ln W_1 \quad \ln W_0)}{W_t}$$

where:

W_1 – average final body weight of an individual,

W_0 - average initial body weight of an individual,

W_t – rearing duration (days).

Specific biomass growth rate (SBR) was calculated using a similar formula:

$$SBR \quad \frac{100 \quad (\ln n_1 W_1 \quad \ln n_0 W_0)}{W_t}$$

where:

W_1, W_0, W_t – as above,

n_0 – initial number of larvae,

n_1 – final number of larvae.

Statistical significance of the differences of fish body weight and length between the experimental groups was estimated using t-Student test.

RESULTS

Stocking densities, fish survival, biomass, body length (l. t.) and weight at the beginning and at the end of the tank rearing are shown in Table I.

Growth rate of whitefish reared in tanks on artificial feed, at two temperatures, is shown in Figs. 1, 2. Average body length and weight of fish in the first two weeks were similar at both temperatures – larvae reared at 18^{o}C (tank B) were only slightly bigger than those reared at lower temperature. Later on, statistically significant differences ($p<0.001$) were noted (Tab. 1). On the last day of tank rearing, larvae reared in lower temperature (tank A) reached 19.1 mg and 15.7 mm, while those reared at 18^{o}C (tank B) attained 27.9 mg and 17.4 mm (Tab. 1). Difference of specific growth rate were also noted. SGR coefficient for the larvae from 18^{o}C tank was equal to 8%/d, and for those from 14^{o}C - to only 6.28%/d (Tab. I).

Fish mortality until day 13 was under 10 % in each tank (Fig. 3). Later on, mortality considerably increased at higher temperature, and reached 32.8% at the end of tank rearing, while at 14^{o}C it was equal to 14.4%. Despite higher mortality, specific bio-

TABLE I

The results of tank rearing of whitefish larvae in 1991. Different letters indicate statistically significant ($p<0.001$, t-Student test) differences. Standard deviations in parentheses

Date	Parameters	Experimental variant	
		A (14°C)	B (18°C)
Stocking (28 march 1991)	Number of larvae (n)	30500	29000
	Length Lt (mm)	9.8 (0.9)	9.8 (0.9)
	Weight (mg)	4.8 (0.8)	4.8 (0.8)
	Biomass (kg/m^3)	0.2	0.2
Catch (18 April 1991)	Number of larvae (n)	26100	19500
	Length Lt (mm)	15.7^a (1.5)	17.4^b (1.8)
	Weight (mg)	19.1^a (6.6)	27.9^b (11.4)
	SGR (%/d)	6.3	8.0
	Biomass (kg/m^3)	0.6	0.7
	SBR (%/d)	5.4	6.1
Survival (%)		85.6	67.2

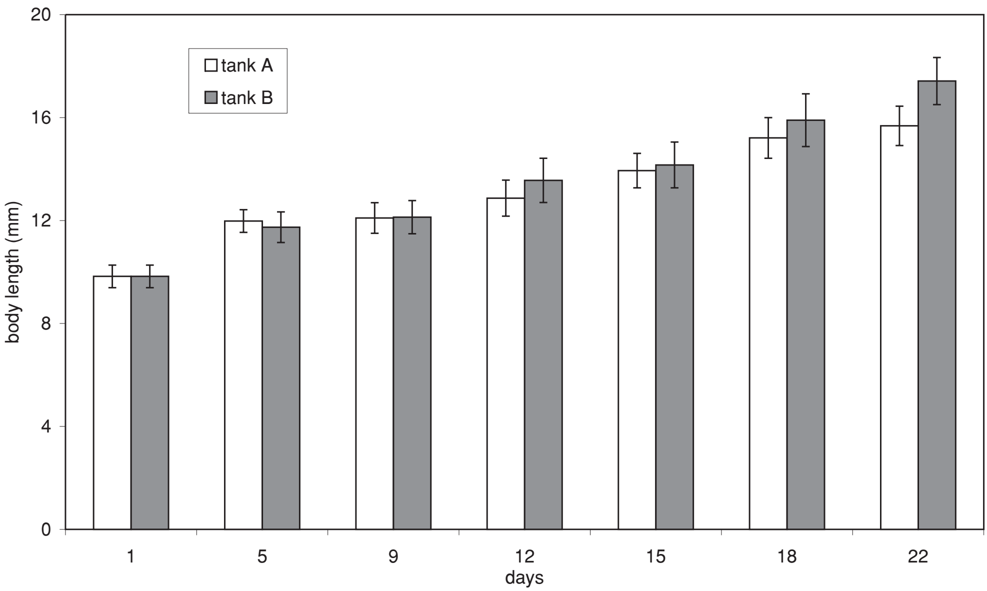

Fig. 1. Mean length (l.t.) of *Coregonus lavaretus* larvae during rearing in tanks

mass increase rate (SBR) was higher at 18^{o}C (6.14%/d) compared to that in 14^{o}C (5.38% / d). Higher mortality of fish in group B was compensated by considerably higher individual growth rate at higher temperature (Tab. I).

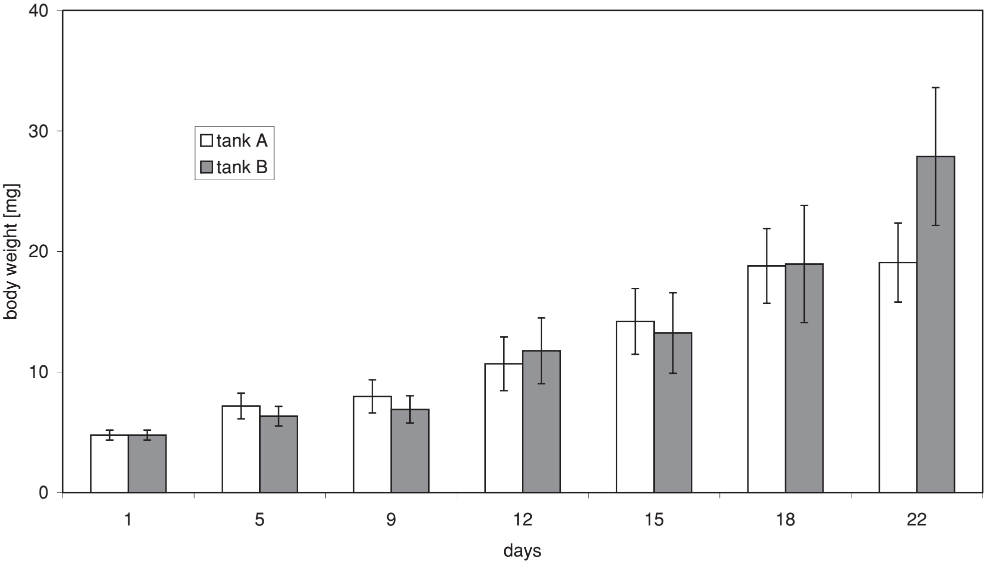

Fig. 2. Mean weight of *Coregonus lavaretus* larvae during rearing in tanks

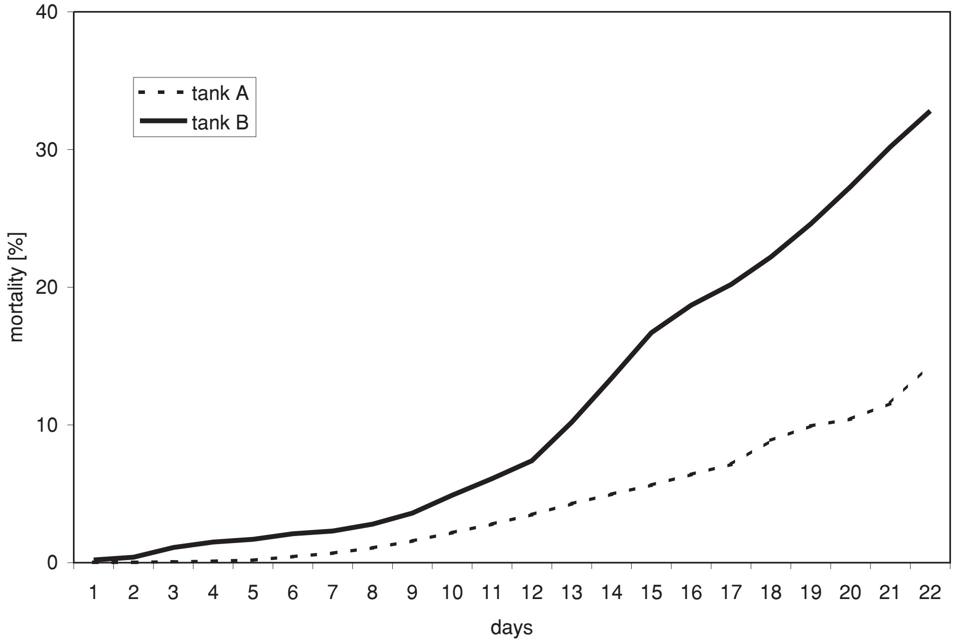

Fig. 3. Cumulative mortality of *Coregonus lavaretus* larvae during rearing in tanks

Fish mortality increased on the first day of cage rearing. Water temperature of lake epilimnion was about 7°C. Particularly high fish losses occurred in case of larvae pre-reared at 18°C (up to 20% in group B) (Fig. 4). Later on, no more sudden fish mortality was observed. Overall mortality of larvae during cage rearing was 16.4% for group A and 31.9% for group B (Fig. 4, Tab. II).

TABLE II

The results of rearing whitefish larvae in illuminated cages in 1991. Different letters indicate statistically significant ($p<0.001$, t-Student test) differences. Standard deviations in parentheses. A – fish pre-reared in tanks at 14°C. B - fish pre-reared in tanks at 18°C

Date	Parameters	Experimental variant	
		A	B
Stocking (28 march 1991)	Number of larvae (n)	25913	19229
	Length Lt (mm)	15.7 (1.5)	17.4 (1.8)
	Weight (mg)	19.1 (6.6)	27.9 (11.4)
	Biomas (kg/m^3)	0.6	0.7
Catch (18 April 1991)	Number of larvae (n)	21400	13100
	Length Lt (mm)	32.6^a (3.0)	37.6^b (3.5)
	Weight (mg)	232.2^a (74.9)	380.0^b (101.6)
	SGR (%/d)	6.6	6.9
	Biomass (kg/m^3)	1.1	1.1
	SBR (%/d)	6.1	5.9
Survival (%)		83.6	68.1

Fish growth rate decreased considerably after their transfer to the cages, and was almost constant until the beginning of May (Figs. 5, 6). In this period the larvae pre-reared at 18°C (cage B) were bigger. Water temperature increased in the next phase of the experiment, and food resources improved, so fish growth rate became higher, and statistically significant differences ($p<0.001$) between the groups were observed. At the end of the experiment, the fish of group A attained 232.2 mg and 32.6 mm, and those of group B - 380.0 mg and 37.6 mm (Tab. II). SGR coefficient for the entire cage period was 6.57%/d for group A and 6.87%/d for group B. SGR values changed weekly, and ranged from 5.8 (A) to 12.3%/d (B). Specific biomass increase rate (SBR) also fluctuated weekly, and was 6.1 %/d (A), and 5.9%/d (B) for the entire cage rearing (Tab. II). At the end of the experiment, fish biomass in the two cages was almost equal and reached 5.2 kg per cage (1.1 kg/m^3).

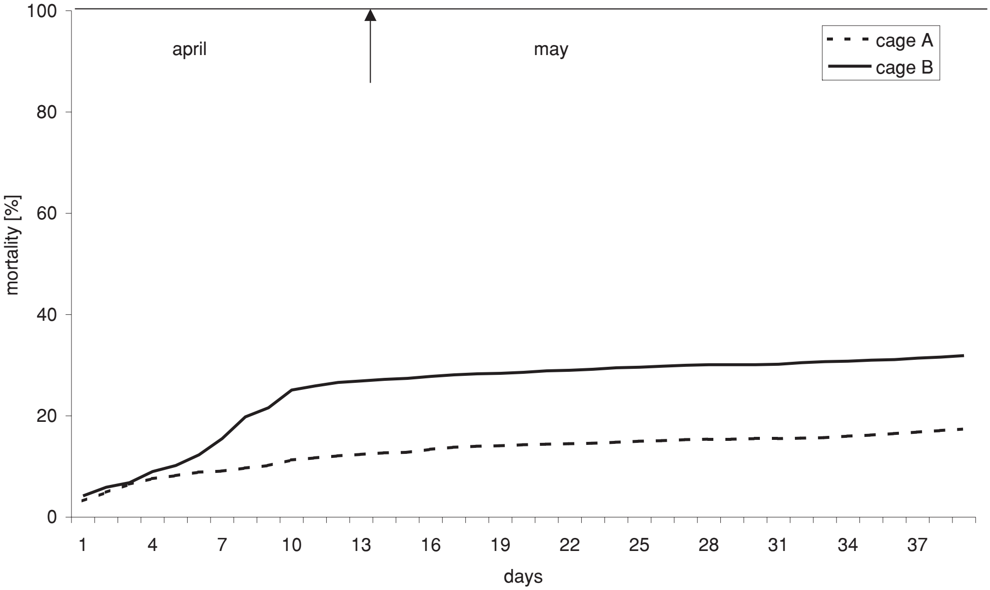

Fig. 4. Cumulative mortality of *Coregonus lavaretus* larvae in illuminated cages (Lake Leginskie, 1991)

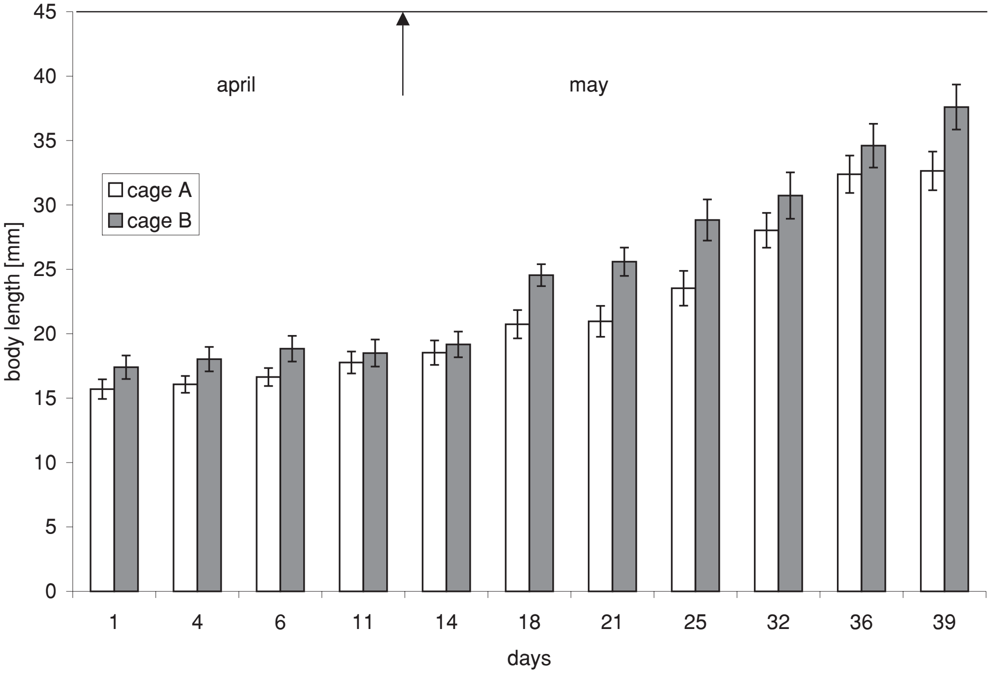

Fig. 5. Mean length (l.t.) of *Coregonus lavaretus* larvae during cage rearing

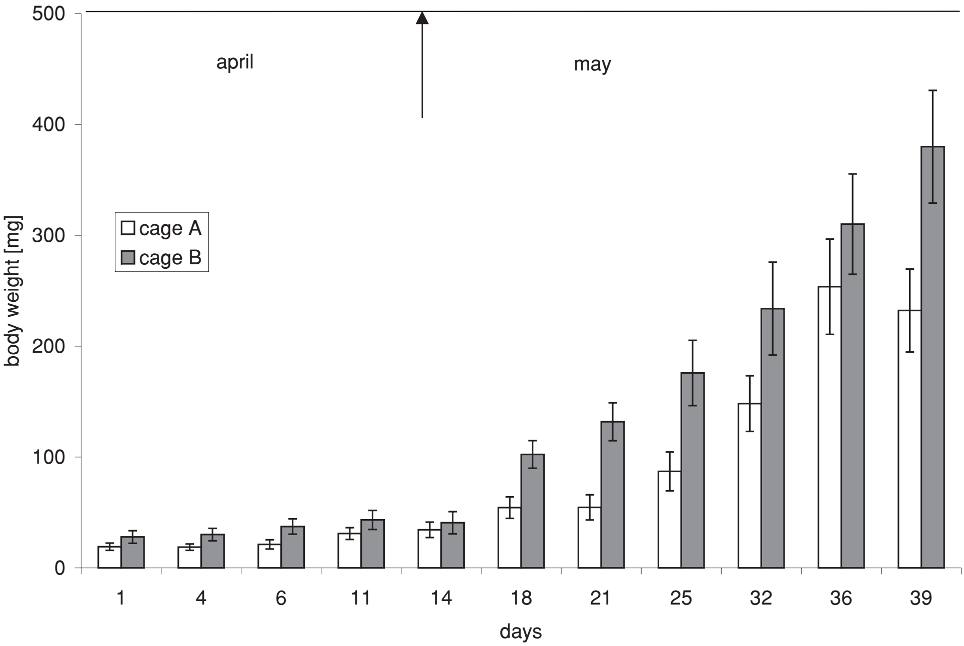

Fig. 6. Mean weight of *Coregonus lavaretus* larvae during cage rearing

DISCUSSION

Water temperature is the main factor affecting fish metabolism rate (Fry 1971). This was confirmed by the results of tank rearing, during which water temperature determined whitefish development and survival. The fish reared at higher temperature (18^{o}C) were longer and heavier but mortality was higher (31.0%). Lower water temperature (14^{o}C) resulted in slower fish growth but reduced mortality (14.4%). The effect of thermal conditions on growth and survival of coregonid fish juveniles was observed also by other authors. Mc Cormick et al. (1971) noted increasing growth rate of *Coregonus artedii* larvae at water temperatures 13-18^{o}C. Kniazeva et al. (1984) observed that the larvae reared at 12.7^{o}C for 34 days attained 19.5 mm and 40 mg, and survival was 60%, while those grown at 5.8^{o}C were only 15 mm long, weighed 22 mg, and survival was 64%. Kozłowski (1993) obtained 20.5 mm and 43.8 mg fish at 16^{o}C for 21 days, and mortality was under 20%. In the present experiment, fish growth rate was similar to that observed by Champigneulle, Rojas-Beltran (1990), and Kozłowski (1993). According to

Łuczyński (1987, 1990) optimum water temperatures for coregonid growth range from 15 to 20°C. For whitefish, for example, temperature increase from 15.3°C to 19.8°C resulted in daily net biomass increase of the larvae of 1.9%, and individual body weight was 67% higher after 21 days (Łuczyński 1987). The highest values were noted at 18°C, when high growth rate compensated for increased mortality. According to Łuczyński (1987), the highest growth rate of whitefish reared at various constant temperatures occurred at 19.8°C. High individual growth rate at temperatures higher than 22.1°C did not compensate for very high mortalities (Łuczyński 1987).

Efficiency of fish rearing under tank-and-cage conditions depends to a large extent on successful switching of the larvae from high metabolic rate (induced by high temperature and artificial feeds during tank phase) to slower rate under cage conditions. The results obtained by Kozłowski (1993) in Legińskie Lake indicate that coregonid larvae easily adapt to rapid changes of water temperature and food composition (maximum 15-25% fish losses during acclimation). Also in the present experiment, higher mortality was observed at the very beginning of cage rearing (up to 20% in B group), and growth rate considerably decreased in both groups. Water temperature in the lake at the beginning of rearing (7-10°C) was sub-optimum for coregonids. Łuczyński (1987) observed that temperature decrease from about 20°C to 5°C reduced 6-7-fold daily net biomass increase of whitefish larvae.

In later weeks of rearing, water temperature and amount of food consumed by the fish increased, and this resulted in faster growth, especially of the larvae pre-reared at higher temperature. Body weight of the whitefish larvae pre-reared at 18°C was significantly higher ($p<0.001$) compared to the fish from 14°C. Larger fish (thus, most of the 18°C group) were able to consume larger prey than smaller ones. Mamcarz (1990) and Kozłowski et al. (1992) observed that 16-18 mm long whitefish may capture zooplankters of 0.6-0.8 mm, which enables them to catch prey inaccessible for the larvae from natural spawning. Feeding of smaller fish (from 14°C tank) was initially limited by mouth size, this resulting in food preference for smaller and less energetic prey (Shirota 1970, Ponton, Muller 1990). Thus, applying controlled thermal conditions and artificial feed, it is possible to grow fish able to use most of the energy content of the zooplankton. This results in increased growth rate of larvae in subsequent phase of cage rearing.

CONCLUSIONS

- Water temperature during tank rearing considerably affected growth rate of whitefish larvae. At the end of rearing, the larvae from higher temperature were longer and heavier than those from lower temperature. Increased mortality at 18°C was compensated by much faster individual growth of the fish.
- During the entire cage rearing period, the larvae pre-reared at higher temperature were larger comparing to those from lower temperature.

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STRESZCZENIE

WPŁYW RÓŻNYCH WARUNKÓW TERMICZNYCH PODCZAS PODCHOWU BASENOWEGO NA DALSZY WZROST LARW SIEI (*Coregonus lavaretus* L.) W SADZACH OŚWIETLONYCH

Wykonano 8-tygodniowy basenowo-sadzowy podchów larw siei. Podchów basenowy trwał 3 tygodnie. Prowadzono go w dwóch basenach zasilanych wodą o różnej temperaturze (basen A- średnia 14°C i basen B 18°C). Larwy żywione paszą sztuczną w wyższej temperaturze były większe (17.4 mm i 27.9 mg) niż ryby podchowywane w niższej temperaturze (15.7 mm i 19.1 mg). Drugi etap podchowu odbywał się w sadzach oświetlonych i trwał 5 tygodni. Ryby odżywiały się wyłącznie zooplanktonem przyciąganym przez światło.

Wyniki eksperymentu wskazują na znaczny wpływ temperatury wody w trakcie podchowu basenowego na późniejszy wzrost larw siei w sadzach oświetlonych. Na koniec doświadczenia ryby podchowywane w basenach w temperaturze wody 18°C osiągnęły średnią masę 380.0 mg przy długości 37.6 mm, natomiast sieje z podchowu w temperaturze 14°C odpowiednio 232.2 mg i 32.6 mm.

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