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Fish culture

**AN ATTEMPT OF CAGE REARING OF VENDACE
(*COREGONUS ALBULA* L.) ORIGINATED FROM POPULATIONS WITH
DIFFERENT GROWTH RATES**

**PRÓBA PODCHOWU SADZOWEGO SIELAWY
(*COREGONUS ALBULA* L.) POCHODZĄCEJ Z POPULACJI O RÓŻNYM
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An attempt to compare the growth and survival of *Coregonus albula* L. larvae and fry, originated from 3 populations with differentiated naturally growth rate (Narie, Maróz and Isąg lakes) was conducted in cage rearing in environment of Legińskie Lake. During the rearing in illuminated cages vendace larvae from fast and slow growing stocks reached the comparable size, but mortality was higher in fast growing fishes. Possible causes of differences and their significance for fishery management are discussed.

INTRODUCTION

Vendace (*Coregonus albula* L.) is an important object of lake fishery management in Poland. It occurs in 420 lakes with total area of about 127 000 ha (Bernatowicz et al., 1975). Wide morphometry and trophic differentiation of lakes accompany by large differentiation in growth of vendace occurred (Bernatowicz, 1953; Marciak, 1970). It is effect of environmental factors (thermal, trophic), however genetic differences are not out of the question (Bernatowicz, 1953, 1961; Kamler et al., 1982; Vuorinen and Łuczyński, 1991). Comparative studies of vendace populations with fast and slow growth rates have

been carried out by several authors. Among others, growth of few populations (Kalinowska, 1985; Komorowski, 1987; Mackowicz, 1985), differences in maturity and course of spawning (Długosz and Worniało, 1985), quality of eggs and offspring (Wilkońska and Żuromska, 1988; Wilkońska, 1992) have been characterized.

Despite the significant increase of stocking with vendace larvae, conducted to neutralise the decline in natural populations abundance, Polish fish farm have not used till now the methods of cage rearing of this species, introduced to improvement of stocking effectiveness of coregonids (Bryliński et al., 1979; Mamcarz, 1990; Mamcarz and Kozłowski, 1990, 1991).

Taking into account these facts, an attempt has been conducted about cage rearing of vendace originated from populations described as fast (Isąg and Maróz lakes) and slow growing (Narie Lake). The rearing was carried out in environment of Legińskie Lake to compare the growth and survival of fish in the same conditions.

CHARACTERISTICS OF VENDACE FROM PARTICULAR LAKES

All lakes with vendace studied are distributed in the Masurian Lakeland area and according to fishery typology are classified as typical vendace-type water bodies.

Narie Lake (surface area of 1240 ha, maximal depth of 43.8 m), located in the Miłakówka-Pasłęka River drainage, is one of the most productive vendace lakes in Poland (Bernatowicz et al., 1975). The average yield of vendace in 1952–1970 was 13.4 kg/ha. At the beginning the lake was α -mesotrophic character, but after significant changes in the environment actually is classified as an eutrophic type. Environmental changes have probably caused the yield decrease of vendace. In 1976–1986 vendace yield averaged 8.7 kg/ha only (Komorowski, 1987). Vendace from Narie Lake belongs to slow growing populations with short life cycle. According to Radziej (1965) the body weight of specimens at age of 3 years ranged from 22 to 49 g, and body length ranged from 15 to 19 cm. There is strong influence of significant fluctuations in vendace generations abundance on the growth of age groups.

Maróz Lake (surface area of 332.5 ha, maximal depth of 41 m), lies in Marózka-Lyna River drainage and has eutrophic character. In 1957–1960 vendace yield in the lake ranged from 9.4 to 18.7 kg/ha (Bernatowicz and Radziej, 1974). During 1974–1984 significant increase in the yield (to 21.9 kg/ha) has been noted., mainly as an effect of intensive stocking (Mackowicz, 1985). According to Ciepielewski (1974), in the half of 60's, vendace from Maróz Lake reached at third year of life the body length of 18–19 cm. Growth rate at that time was described as fast in comparison to other Polish lakes. The effects of last studies (Mackowicz, 1985) show significant worsening of vendace growth in

the lake (length of 18.1 cm at third year of life). It is probably caused by overcrowding in fish abundance in relation to existing food resources.

Isąg Lake have an area of 395.7 ha and maximal depth of 54.5 m. It is β -mezotrophic lake, located in Pasłęka River drainage. In 1947 vendace was introduced there to create a new population (Bernatowicz, 1953a). Directly after introduction vendace catch was high (36.4 kg/ha), however in 1960–1961 average yield decreased to level of 3.8 kg/ha (Kalinowska, 1985). In 1975–1984, in effect of intensive stockings at rate of 5.9 mln larvae per year, the vendace catch in Isąg Lake have increased to 14.2 kg/ha (Kalinowska, 1985). In 50's vendace from Isąg Lake reached length of 22.5 cm and weight of 139 g at third year of life (Bernatowicz, 1953). Actual average size of fish is 21.9 cm and 70.1 g (Kalinowska, 1985).

Legińskie Lake (area of 228.3 ha, maximum depth of 37.2 m) lies in the Sajna–Łyna–Pregoła River drainage and has an intermediate mezotrophic–eutrophic character. In 1951–1959 annual vendace catches have ranged from 1.0 to 7.0 kg/ha. At third year of life vendace reached mean length of 21.4 cm and weight of 140 g (Ciepielewski, 1961). Growth rate had not changed till actual time (Tymoszczuk, 1978).

MATERIALS AND METHODS

Incubation of vendace eggs, originated from particular lakes and initial monthly rearing of larvae in tanks on zooplankton, were conducted at experimental hatchery of Inland Fishery Institute in Olsztyn, as part of studies on effect of spawners from different lakes on broodstock quality and quantity (Wilkońska and Żuromska, 1988).

Further rearing (described in this paper), was carried out in illuminated cages in Legińskie Lake (April–July 1985). Vendace was kept in 3 surface cages with volume of 8 m³ each and initial mesh size of 1.0 mm. Initial densities were 3127 and 3475 indiv./cage (vendace from Maróz and Isąg lakes) and 3581 indiv./cage (Narie Lake). The initial number of fish in rearing was an effect of survival in the first phase of experiment (Wilkońska and Żuromska, 1988). After 1 month fish were transferred to cages with mesh size of 1.8 mm, and in July – to cages with mesh size of 5.5 mm. Each cage was illuminated by one electric bulb (60 W/24 V) immersed at the depth of 1.5 m and photocell-controlled.

Exchange of cages to ensure continuous zooplankton passing into, was carried out weekly. Each day the water temperature (from depths of 0.5, 1.5 and 3.0 m) and transparency were measured. The water temperature in lake epilimnion was averaged from these three measurements. Each the oxygen content in the water at the depth of cage immersion was measured by Winkler method. At the same time zooplankton samples were taken near cages and food organisms composition was analysed. On the basis of mean

length of specimens (unpubl. data) and calorific equivalents (Bottrell et al., 1976; Vijverberg and Frank, 1976; Densen, 1985) energetic value of zooplankton was calculated.

Samples (20–60 indiv.) were collected weekly to study fish growth rate. Fish were caught randomly at the night from the cages. After preservation in 4% formaldehyde all specimens were measured (± 0.5 mm) and weighted (± 1 mg). Initial densities were counted by a photographic method (Uryn, 1976), while the final fish number was found by counting all specimens. Specific growth rate in weight was calculated according to the equation (Dąbrowski and Poczyczynski, 1988):

$$\text{SGR} = 100[(\ln w_l - \ln w_o)/t]$$

where : w_o – initial weight,
 w_l – final weight,
 t – rearing duration in days.

The significance of the differences in fish size from particular stocks was evaluated by Duncan's test. Significance of the differences for length–weight relationships, calculated for all rearing period according to the equation $W = aL^b$, was evaluated by parallelism of regression straights test after earlier converting the relationships to logarithmic form (Elandt, 1964).

RESULTS

Environmental conditions and food resources

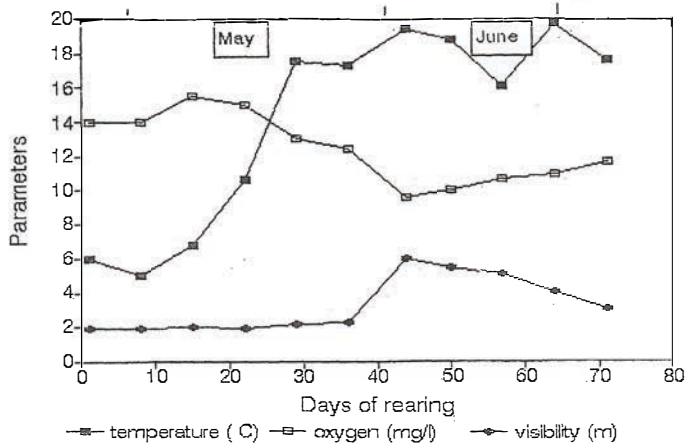


Fig. 1. Environmental conditions in Legińskie lake during rearing of *Coregonus albula* L. in illuminated cages in 1985

The course of changes in basic physical–chemical parameters of water (temperature, oxygen, transparency) in Legińskie Lake was little differentiated. From the April–May the rapid increase of water temperature in lake epilimnion was observed to level of 15°C in mid May (Fig. 1). Till the end of cage rearing the water temperature has oscillated

between 16 and 20°C. Directly before the beginning of thermal stratification oxygen

content in the water was about 15 mg/l, decreasing slowly during following months.

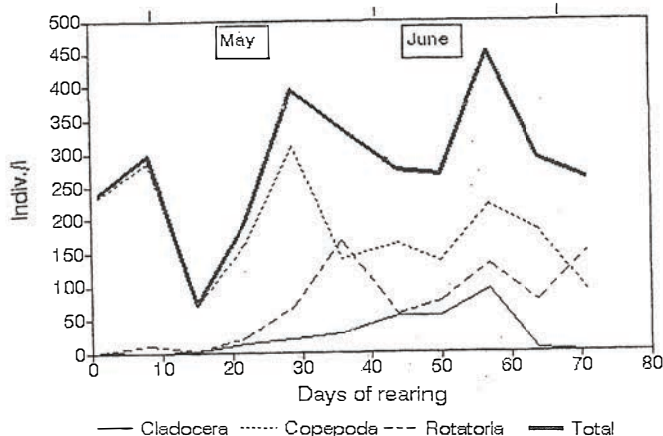


Fig. 2. Changes of numerical composition of zooplankton in Legińskie lake during rearing of *Coregonus albula* L. in illuminated cages in 1985

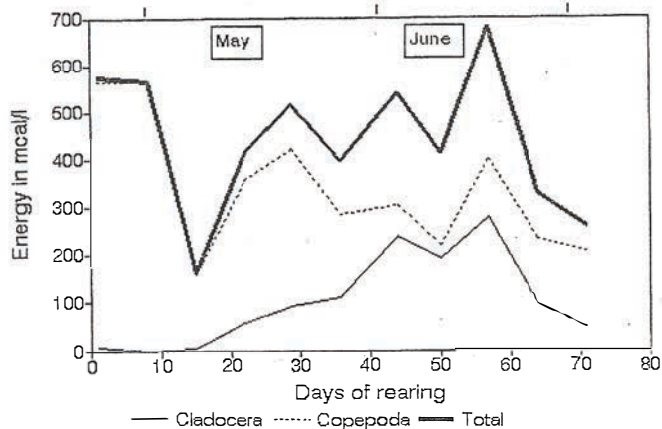


Fig. 3. Changes in energetical composition of zooplankton in Legińskie lake during rearing of *Coregonus albula* L. in illuminated cages in 1985

Changes in transparency of water in Legińskie Lake were similar as in earlier years (Mamcarz, 1982). After spring minimum (about 2 m), the rapid increase of transparency to 6.0 m in June was observed, and then it decreased to 3–4 m.

In 1985 the small amount of cladocerans was found in the zooplankton of Legińskie Lake. Maximum in their development (96 indiv./l) occurred in mid June (Fig. 2). Copepods (*Mesocyclops* sp., *Eudiaptomus* sp.), especially juvenile stages, have dominated for all time in zooplankton. Total abundance of all groups of zooplankton was not higher than 450 indiv./l. Maximal energetic value of cladocerans has reached 280 mcal/l (Fig. 3). Cope-

poda were the most valuable energetically group, especially during first weeks of fish rearing. Maximal energetic value of rotifers was lower than 0.2 mcal/l.

Growth and survival of fish

After initial period of rearing in tanks, vendace from Narie and Isag lakes did not differ in size at the time of cage stocking (Table 1). Vendace larvae from Maróz Lake were distinctly smaller.

Table 1

Results of cage rearing of *Coregonus albula* (L.) larvae and fry in Legińskie lake in 1985. Notations: I – Lake Narie, II – Lake Isag, III – Lake Maróz. Standard deviation between brackets. Figures with no common superscript letter are significantly ($p < 0.05$) different (Duncan's multiple range test)

Stocking					Catch					Survival %
Date	No of indiv. in cage	Length	Weight		Date	No of indiv. in cage	Length	Weight		
			indiv. (mg)	total (g)				indiv. (mg)	total (g)	
I	3581	17.4 ^a (3.3)	33.3 ^a (32.2)	119.2	4. VIII	1823	64.1 ^a (8.3)	1823.1 ^a (685.2)	3323.5	50.9
22.IV II	3475	17.1 ^a (3.4)	30.9 ^a (24.4)	107.4		1665	61.0 ^a (7.1)	1856.9 ^a (702.4)	3091.7	47.9
III	3127	15.6 ^b (2.1)	22.9 ^b (15.6)	71.6		873	70.3 ^b (5.7)	2340.7 ^b (565.1)	2122.0	27.9

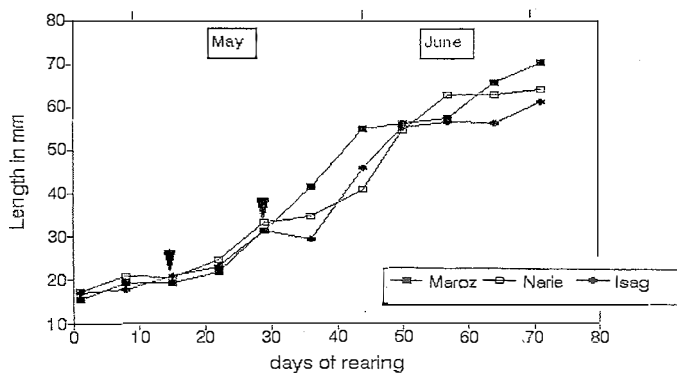


Fig. 4. Growth in body length of *Coregonus albula* L. in illuminated cages (Legińskie lake, 1985) Between arrows – period of no significant differences in growth (Duncan's test, $p < 0.05$)

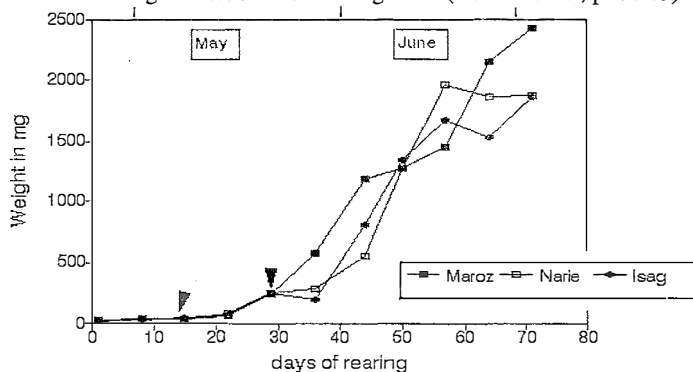


Fig. 5. Growth in body weight of *Coregonus albula* L. in illuminated cages (Legińskie lake, 1985). Notations as in Fig. 4

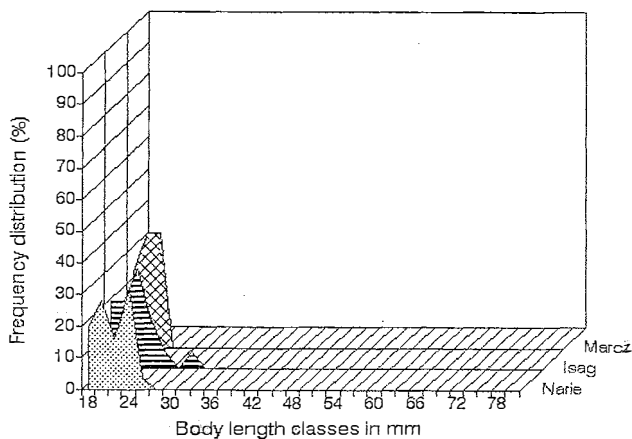


Fig. 6. Length frequency distribution of *Coregonus albula* L. larvae in 15 day of rearing in illuminated cages

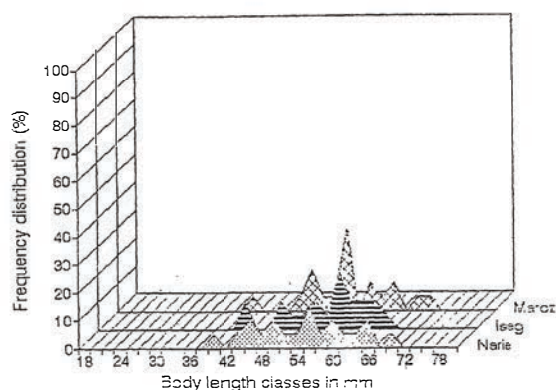


Fig. 7. Length frequency distribution of *Coregonus albula* L. larvae in 50 day of rearing in illuminated cages

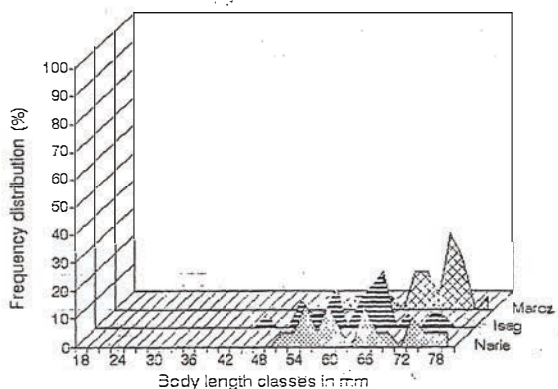


Fig. 8. Length frequency distribution of *Coregonus albula* L. larvae in 71 day of rearing in illuminated cages

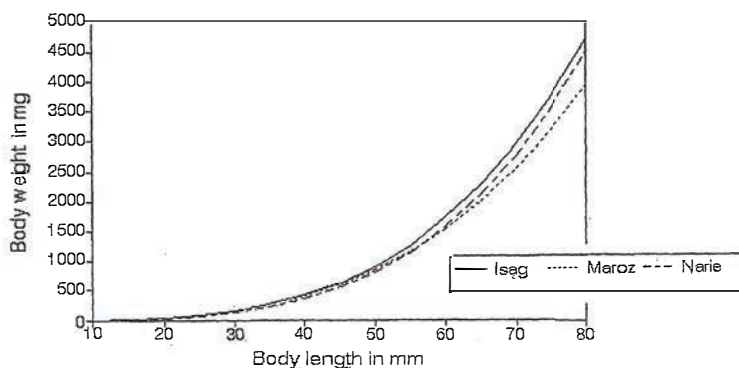


Fig. 9. Length –weight relationship for *Coregonus albula* L. reared in illuminated cages in Legińskie Lake

During the cage rearing in the first half of May (day 15–29) growth in length and weight of vendace, originated from different populations was similar (Fig. 4, 5). Vendace from Lake Maróz grew significantly better ($p < 0.05$) in the further rearing, growth of fish from both remaining lakes was similar. The beginning of size differentiation of fish in particular stocks was also noted at that time. The greatest differences were in vendace from Narie and Isąg lakes (Fig. 6). Significant acceleration of fish growth rate in all stocks occurred from 15 day of rearing (Table 2, Fig. 4). It coincided with the increase in zooplankton abundance in the lake (Fig. 3). The fastest growth rate in weight (11.4 % d) was observed in vendace from Narie Lake till mid May (24 day of rearing). Between 23 and 29 day of rearing indices of fish growth rate reached maximal values (15.7 – 18.6 % d) – Table 2. Vendace from Maróz Lake had maximal growth rate, whereas the slow growing population from Narie Lake was characterized by the lowest rate. In period of growth acceleration further differentiation in size of fish in stock was observed (Fig. 7). After 29 day decrease in growth rate of vendace in cages occurred, principally strong in fish from Narie and Isąg lakes (Table 2). After June 17 (57 day of rearing), when decline in cladocerans abundance in the lake was noted (Fig. 3), retardation of growth rate of fish in all stocks occurred (Table 2, Fig. 4). "The negative growth rate" in vendace from Narie and Isąg lakes was observed, expressing starvation of specimens. Relatively the lowest decrease in growth rate was noticed in vendace from Maróz Lake. Their stocks was also characterised by the smallest differentiation in size of specimens (Fig. 8). The cage rearing was finished in the beginning of July.

The highest survival (50.9 %) was exhibited by vendace from Narie Lake, a little lower (47.9 %) by vendace from Isąg Lake, and the lowest (27.9 %) by fish from Maróz Lake (Table 2). Vendace from Maróz Lake reached the greatest mean size (70.3 mm and 2.4 g), whereas fish from Narie and Isąg lakes reached length of 64.1 and 61.0 mm and weight of 1.8 g, respectively.

The comparison of length–weight relationships for vendace stocks, reared in illuminated cages in Legińskie Lake, showed differences in the course for fish from particular lakes (Fig. 9). Vendace from Isąg Lake has reached during cage rearing (in length range 10–80 mm) greater weight at the same length in comparison with specimens from other lakes. Body weight of vendace from Maróz Lake was relatively the smallest. Differences in length–weight relationships for vendace stocks from particular lakes were significant statistically ($p < 0.05$) (Table 3).

Table 2

Specific growth rate (SGR, % d⁻¹) for total length (TL, mm) and body weight (W, mg) of *Coregonus albula* L. larvae and fry in illuminated cages (Legińskie Lake, 1985)

Days of rearing	Size parameter	Narie Lake	Isag Lake	Maróz Lake
1-8	TL	1.4	1.4	4.3
	W	2.8	0.0	8.6
9-15	TL	0.0	2.8	0.0
	W	-1.4	8.6	0.0
16-22	TL	2.8	0.0	1.4
	W	11.4	4.3	7.1
23-29	TL	4.3	5.7	5.7
	W	15.7	17.1	18.6
30-36	TL	0.0	-1.4	2.8
	W	2.8	-4.3	11.4
37-44	TL	2.5	5.0	3.7
	W	7.5	18.7	10.0
45-50	TL	5.0	3.3	0.0
	W	13.3	8.3	0.0
50-57	TL	1.4	0.0	1.4
	W	7.1	2.8	2.8
58-64	TL	0.0	0.0	1.4
	W	-1.4	-1.4	5.7
65-71	TL	1.4	1.4	1.4
	W	0.0	2.8	1.4

Table 3

Weight (W, mg) – length (L, mm) relationship ($\log W = \log a + b \log L$) for *Coregonus albula* L. (total length 10 – 80 mm) reared in illuminated cages (Legińskie Lake, 1985)

Stock	a	b	Correlation coefficient (r)	Number (n)	F value	F _(0.05) value
Narie	3.6344	-3.2664	0.9804	247	23.8542	3.0000
Isag	3.4799	-2.9529	0.9867	261		
Maróz	3.2453	-2.5845	0.9865	218		

DISCUSSION

In Legińskie Lake, chosen for comparative cage rearing of three stocks of vendace, specimens from natural population of this species have reached mean length of 11 cm at first year (Tymoszczuk, 1978). There are favourable food condition for vendace growth on the level reporting for fast growing populations. In Narie Lake vendace has only just reached at first year length of 9 cm and weight of 8 g (Komorowski, 1987), in Maróz Lake

– 9.7 cm and 13 g (Mackowicz, 1985), and in Isąg Lake – 10.6 cm and 14.1 g, respectively (Kalinowska, 1985).

According to calculations by Dmitrenko (1978), to reach the weight 10–13 g vendace needs 51–101 kcal/individual, which converted to food, respond to 102–170 g. Taking this into account, it seems to be, that the poor food resources are the main factor, limiting the vendace growth in Narie Lake. These resources probably cover vendace needs below the value calculated by Dmitrenko (1978). It was confirmed by fact, that after introduction to Wierzbiczany Lake, more abundant in food, vendace reached record growth for the species (Radziej, 1973). Annual amount of heat cumulated in lake is the factor strongly determining the rate of energetical metabolism of vendace (Kanep, 1976). This factor modify the use of limited food resources. Fast growth rate in weight is the strongest expressed in larval and juvenile life, therefore can be use as an important criterion of quality of reared fry (Dmitrenko, 1978a).

Comparison of three vendace stocks, reared in similar feeding and density conditions, gave possibility to reveal some interesting features in larval development of this species. Larvae and fry, originated from differentiated ecologically stocks (slow and fast growing populations), reared in conditions of common environment grew similar, reaching similar final size. It confirms observations by other authors, showing decisive role of environment impact on growth and morphology of larvae and fry. According Todd et al. (1981), environmentally formed differences between parents and offspring are in some Coregonidae greater than differences between species. On the other hand, Subnikova (1978), showed unifying impact of similar culture conditions on fry, originated from spawners taken from different environments. Considering the growth as an indicator of reared fish quality, it is very difficult to show distinct superiority on of the vendace stocks. An exception was fast growing vendace from eutrophic Maróz Lake, which accelerated growth in the final period of rearing was affected by greater mortality and smaller density in cage.

Survival of vendace from Maróz Lake was nearly half lower in comparison with other stocks. Similarly the course of body length–weight relationship, characterizing the condition of stock from Maróz Lake during the cage rearing, was relatively the worst. Slow growing vendace from Narie Lake was characterized by the highest survival, whereas vendace from Isąg Lake had relatively the best condition during all rearing.

Fast and slow growing populations of vendace differ in many biological features (Kamler and Żuromska, 1979; Kamler et al., 1982; Długosz and Worniało, 1985; Wilkońska, 1992). As Wilkońska and Żuromska (1988) showed, there were also differences in survival of developing embryos. Vendace embryos from Isąg Lake were characterized by the highest survival. Survival of embryos from Narie Lake was the lowest and very variable – and vendace from Maróz Lake has intermediate position.

The effects of vendace cage rearing in Legińskie Lake suggest, that the differences in survival may also prolong to larval development. After the use own energy resources, accumulated in yolk sac, further life of larvae depends mainly on natural food resources in environment and on their foraging ability. In Legińskie Lake, having in trophy an intermediate position between Maróz Lake and both residual, larvae originated from relatively poorer Isag and Narie lakes had significantly better adaptation abilities (described by higher survival and condition). The answer of fast growing vendace from Maróz Lake to decline in zooplankton abundance after 55 day of rearing was rapid increase in mortality.

The cause of phenomenon observed is unknown because of lack of studies on vendace feeding. Despite of this, it seems to show some limits related with introduction of fast growing vendace forms to poorer lakes, in comparison with mother ones. These exertions may be related with significantly higher losses, than in case of introduction of fish from slow growing populations.

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PRÓBA PODCHOWU SADZOWEGO SIELAWY (*COREGONUS ALBULA* L.)
POCHODZĄCEJ Z POPULACJI O RÓŻNYM TEMPIE WZROSTU

STRESZCZENIE

W 1985 r. podjęto próbę podchowu sadzowego sielawy (*Coregonus albula* L.) pochodzącej z populacji określanych jako szybko- i wolnorosnące (jez. Isąg i Maróz) oraz wolnorosnące (jez. Narie). Celem badań było porównanie wzrostu i przeżywalności różnych form sielawy we wczesnej ontogenezie w warunkach nowego dla nich środowiska jeziora Legińskiego, wybranego do przeprowadzenia eksperymentu.

Podchów prowadzono w powierzchniowych sadzach oświetlonych o pojemności 8 m³, stosując obsady około 3000 – 3500 szt./sadz (po wylęgnięciu ryby były przez miesiąc podchowywane w basenach na pokarmie naturalnym). Podchów sadzowy trwał od połowy kwietnia do początku lipca. Porównując wzrost ryb w tym samym czasie podchowu, w oparciu o bazę pokarmową jeziora Legińskiego, stwierdzono wyrównanie rozmiarów sielawy ze stad szybko- i wolnorosnących. W lipcu średnia długość osobnicza sielawy wahała się od 61,0 mm (stado z Isągi) do 70,3 mm (stado z Maróza), przy średniej masie ciała odpowiednio od 1856,9 do 2430,7 mg. Ryby z wolnorosnącego stada z jeziora Narie osiągnęły długość 64,1 mm i masę ciała 1823,1 mg. Przy pogorszeniu się warunków pokarmowych w jeziorze w czerwcu i lipcu, reakcją sielaw szybko- i wolnorosnących, pochodzących z eutroficznego jeziora Maróz był wzrost śmiertelności, natomiast ryby pochodzące z mniej zeutrofizowanych jezior Narie i Isąg miały zdecydowanie większe przeżycie i kondycję. Omówiono przypuszczalne przyczyny różnicujące przebieg podchowu sielawy w porównywalnych warunkach środowiskowych.

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