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AN ATTEMPT TO DETERMINE THE SUITABILITY OF THREE ARTIFICIAL FEEDS FOR THE FEEDING OF BALTIC WHITEFISH LARVAE (*Coregonus lavaretus* L. *forma baltica*) IN THE CONDITIONS OF SALMONID RESEARCH LABORATORY IN RUTKI

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A B S T R A C T. Studies were carried out to determine the possibility of using three selected artificial feeds available at Polish market to feed Baltic whitefish larvae. Insufficient enzymatic apparatus in the initial stages of fish development, together with low temperature and unsuitability of dry feeds for *Coregoninae* result in the fact that it is necessary to use natural food. It appeared that cod starter (FK) as well as artificial plankton (Argent) were not better feeds in the case of whitefish than trout starter (FK). On the other hand, it was confirmed that trout pellets could well be used to feed whitefish larvae bigger than 20 mg (body weight) in optimal temperatures above 15°C.

Key words: WHITEFISH, LARVAE, ARTIFICIAL FEEDS

INTRODUCTION

Density of Baltic whitefish (*Coregonus lavaretus L. f. baltica*) populations in South Baltic has been reduced to a critical level due to overfishing and deteriorating environmental conditions (Schulz et al. 1993). Hence, there is a need for a complex and intensive project aimed at a restitution of this species in our coastal waters, and especially in the Gulf of Puck and Szczecin Lagoon.

Coregoninae are a sensitive index of the changes in an aquatic environment. Degradation of natural ecosystems affects balance of these fish stocks in the first place (Mamcarz et al. 1992). Water temperatures lower or higher than the optimum for embryonal development, predatory invertebrate fauna and fish, oxygen deficits, mud, sedimentation, as also different quality of the sexual products in particular years result in the fact that survival of whitefish eggs on the spawning grounds is very low (Żuromska 1982a, 1982b). Increasing populations of predators, especially of stickleback, affect also *Coregoninae* larvae and fry in later stages of development. In view of

this it becomes necessary to use bigger stocking material, which has been reared for some time.

Mass production of *Coregoninae* stocking material is limited, among others, by a lack of suitable artificial feeds on Polish market although there have been successful experiments on rearing *Coregoninae* larvae using artificial feeds (Champigneulle 1988, Dąbrowski et al. 1984, Dąbrowski and Poczyczyński 1988, Poczyczyński et al. 1990, Rosch and Appelbaum 1985). There are also methods of rearing stocking material in the illuminated lake cages (Bryliński et al. 1975a, Bryliński et al. 1975b, Mamcarz 1990, Mamcarz and Nowak 1987, Mamcarz and Szczerbowski 1984a, 1984b). However, they are not fully satisfactory, so it is quite justified to look for a simple method of producing coregonid stocking material in tanks, with the use of commonly available artificial feeds.

The present experiment has been treated as an attempt to determine the suitability of three artificial feeds for the feeding of Baltic whitefish larvae.

MATERIAL AND METHODS

Comparisons of three different artificial feeds were made in the Salmonid Research Laboratory in Rutki. The tested feeds were: trout and cod starter feeds produced by „FK" (Norway), and artificial plankton of the firm „Argent" (USA); they were used to feed Baltic whitefish larvae. The experiment was divided into three parts depending on the fish age, the type of feeds, and the rearing temperature.

In the first part of the experiment all types of feeds were tested. Fish larvae (batches of 1000 specimens) were stocked into 20 l tanks with water flow rate 5.4 l/min. Water temperature was maintained at a constant level 7.5°C. The fish were fed in four variants, each with a repetition, until 21st day of life. The variants differed between each other as to the duration of initial larvae feeding with *Artemia salina* :

A - without feeding with live food,
B - fed Artemia for 7 days,
C - fed Artemia for 14 days,
D - fed Artemia for 21 days.

Whitefish larvae in variant „D" represented the control group for the fish fed artificial feeds.

In the second part of the experiment only the feeds produced by FK were tested (cod and trout starter) on whitefish larvae aged 21 days, which had earlier been given Artemia. The larvae were stocked into 6 tanks at a rate of 1000 fish in a tank. Rearing conditions were identical to those in part one of the experiment. The fish were fed in three variants, with one repetition each. The variants differed as to the duration of the initial feeding with Artemia (*Artemia salina)* starting form hatching:

A - fed Artemia for 21 days,

B - fed Artemia for 28 days,

C - fed Artemia for 35 days.

Rearing was completed after 4 weeks,when the fish were 49 days old.

The third part of the experiment was a continuation of whitefish larvae rearing from part one viz. dealing with artificial plankton, but the rearing conditions have been changed. Water was heated to 14°C (+/-0.5), and the fish were given trout starter exclusively . Four variants of initial larvae rearing on Artemia and artificial plankton were used, complying to their rearing in the first part of the experiment:

A - without Artemia feeding, 21 days of feeding with artificial plankton;

B - 7 days of feeding with Artemia; 14 days of feeding with artificial plankton;

C - 14 days of feeding with Artemia, 7 days of feeding with artificial plankton;

D - 21 days of feeding with Artemia, without artificial plankton.

Relative condition coefficient (Kn) of Le Cren (Opuszyński 1983) was used to estimate the effectiveness of assimilating different feeds by the whitefish larvae. It is calculated from the equation:

$$K_n = \frac{W}{W'}$$

where: W - average fish weight,

W′ - average weight of a standard fish calculated from the equation:

$$W' = a\,L^b$$

where: L - average length of a standard fish,

a, b - equation factors.

It was assumed that growth of the fish fed Artemia only (fig. 1, variant D) represents the standard model of the growth rate. Curve of the weight-length relationship of these larave is presented in fig. 4. Empirical values of the equation factors are:

$$a = e^{-7.55318}, \quad b = 3.78065.$$

Fish were fed *ad libitum*. Dead whitefish larvae were counted and removed from the tanks. In order to prevent fish diseases, the larvae were subjected to prophylactic bathing in T chloramine (1:100 000) and formalin (1:10 000).

Fish samples were collected every 7 days. Each sample numbered 30 fish. They were preserved in 4% formalin solution, and individual weight was then determined up to 0.5 mg. The results were subjected to bifactorail analysis of variance (ANOVA) (Tab. 2, 4, 6) depending on:

- type of the feed used in the experiment,
- duration of the initial period of feeding with Artemia.

RESULTS

PART ONE OF THE EXPERIMENT

After 21 days of rearing , variant „A" yielded the fish of individual weight: 10.5 mg - the fish fed cod starter, 11.1 mg - those fed trout starter, and 10.1 mg - the fish fed artificial plankton (Tab. 1, fig. 1). The respective weights in variant „B" were: 14.1 mg, 13.1 mg and 12.9 mg, and in variant „C": 18.2 mg, 18.3 mg and 18.1 mg. Whitefish larvae fed Artemia only attained in the same period 28.3 mg.

Analysis of variance revealed highly significant differences (P=99.9%) between weight of whitefish larvae in particular variants. On the other hand, there were no sta-

TABLE 1

Results of rearing whitefish larvae in part I of the experiment

Fish age (days)	Variant of feeding with Artemia (days)	Cod starter			Trout starter			Artificial plankton		
		Weight (mg)	Kn	P(%)	Weight (mg)	Kn	P(%)	Weight (mg)	Kn	P(%)
Alevins	-	7.9	1.02	100.0	7.9	1.02	100.0	7.9	1.02	100.0
21	A - 0	10.5	0.87	74.4	11.1	1.03	66.6	10.1	0.79	89.2
	B - 7	14.1	0.93	92.7	13.1	0.82	91.6	12.9	0.79	91.9
	C - 14	18.2	0.83	87.6	18.3	0.85	90.9	18.1	0.93	90.0
	D - 21	-	-	-	-	-	-	28.3	1.08	91.3

Kn - relative coefficient of condition after Le Cren

P - survival

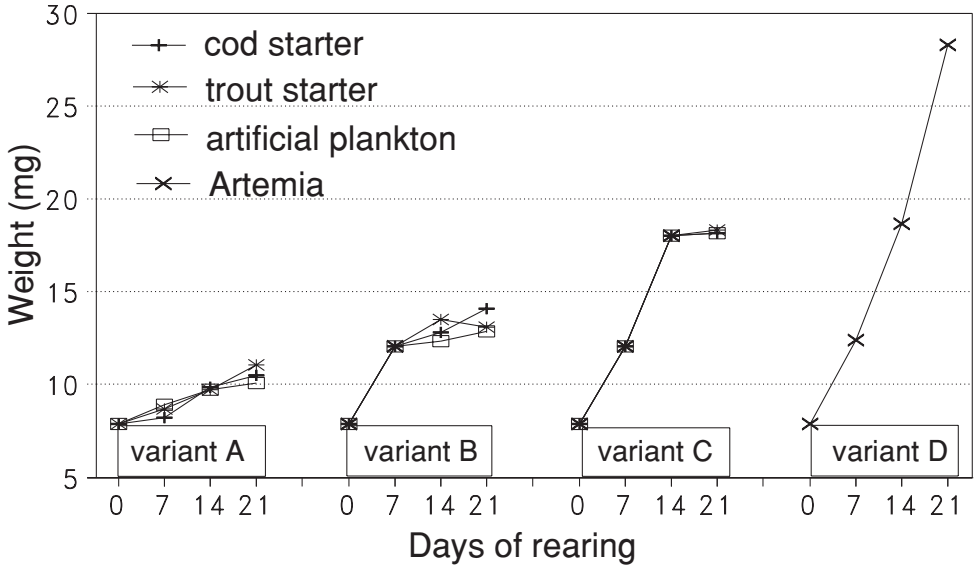

Fig. 1. Weight increments of whitefish larvae. Part I of the experiment.

TABLE 2

Bifactorial analysis of variance „ANOVA" of the results in part I of the experiment.

Experimental factor	df	mean square of deviations	Confidence level
Feed type	2	7.8037	<95.0%
Variant of feeding	2	1351.0481	>99.9%
Error	261	9.9959132	-

tistically significant differences (P<95%) between the fish fed different artificial feeds in particular variants (Tab. 2).

Coefficient of condition (Kn) in variant „A" was 0.87 for the fish fed cod starter, 1.03 for those fed trout starter, and 0.79 for those given artificial plankton. The respective values in variant „B" were: 0.93, 0.82 and 0.79, and in variant „C": 0.83, 0.85 and 0.93. Kn of the fish given natural food amounted to 1.08. Survival of the larvae fed cod and trout starters and artificial plankton was respectively: 74.4 %, 66.6 % and 89.2 % in variant „A", and 92.7 %, 91.6% and 91.9 % in variant „B". Rate of survival of the whitefish larvae fed Artemia only was 91.3%.

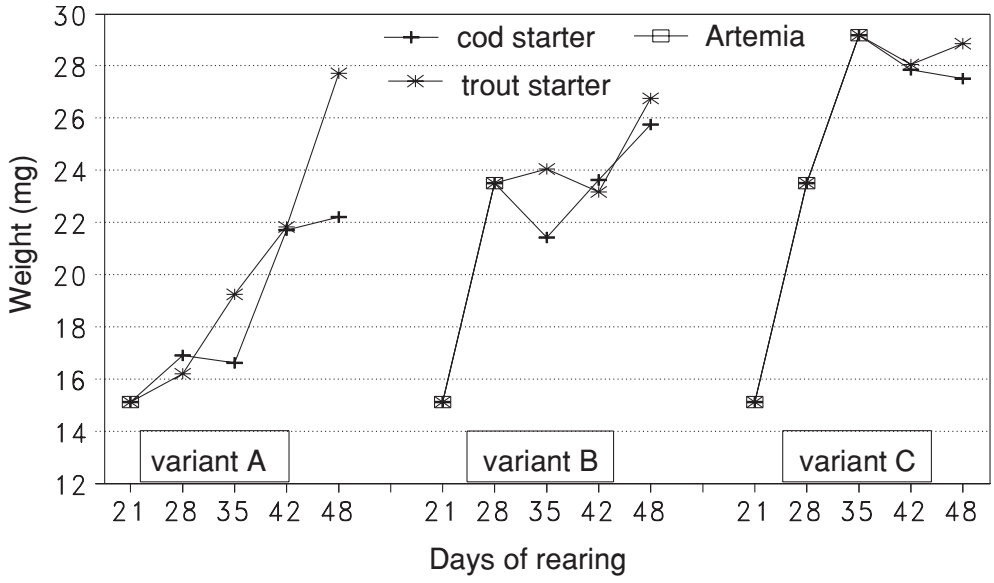

TABLE 3

Results of rearing whitefish larvae in part II of the experiment

Fish age (days)	Variant of feeding with Artemia (days)	Cod starter			Trout starter		
		Weight (mg)	Kn	P(%)	Weight (mg)	Kn	P(%)
21	21	15.1	0.87	93.3	15.1	0.87	93.3
49	A - 21	22.2	0.76	46.0	27.7	0.83	50.5
	B - 28	25.8	0.79	46.6	26.8	0.85	65.4
	C - 35	27.5	0.77	36.9	28.9	0.74	42.9

Kn - relative coefficient of condition after Le Cren
P - survival

PART TWO OF THE EXPERIMENT

At the end of part two of the experiment the fish fed cod and trout starters attained individual weights of respectively 22.2 mg and 27.7 mg in variant „A", 25.8 mg and 26.8 mg in variant „B", and 27.5 mg and 28.9 mg in variant „C" (Tab. 3, fig. 2).

Type of the feeds used affected significantly (P>99%) growth rate of whitefish larvae in particular variants. Statistically significant differences (p<95%) were also observed between the variants of initial feeding with Artemia (Tab. 4).

TABLE 4

Bifactorial analysis of variance „ANOVA" in part II of the experiment.

Experimental factor	df	mean square of deviations	Confidence level
Feed type	1	308.11250	>99.0%
Variant of feeding	2	157.85972	>95.0%
Error	174	40.106178	-

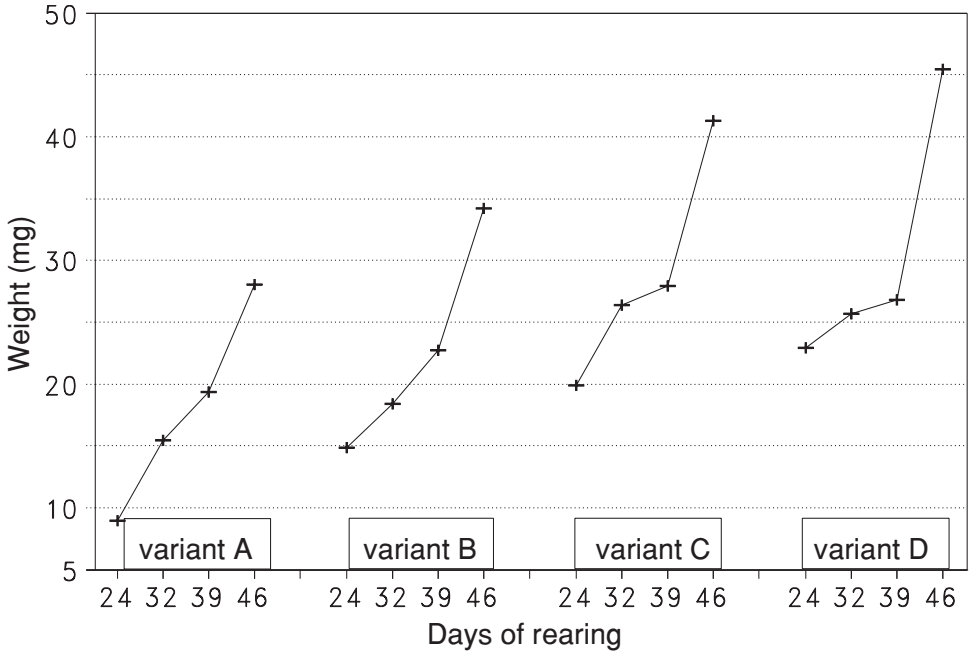

Fig. 2. Weight increments of whitefish larvae. Part II of the experiment.

Coefficient of condition (Kn) of the fish given cod and trout starters was respectively: 0.76 and 0.83 in variant „A", 0.79 and 0.85 in variant „B", and 0.77 and 0.74 in variant „C". Survival of these fish was respectively: 46% and 50.5 % in variant „A", 46.6 % and 65.4 % in variant „B", and 36.9 % and 42.9 % in variant „C".

PART THREE OF THE EXPERIMENT

At the end of part three of the experiment the fish reached individual weight of 28 mg, 34.2 mg, 41.3 mg and 45.5 mg in variants „A", „B", „C", and „D" respectively (Tab. 5, fig. 3).

TABLE 5

Results of rearing whitefish larvae in part III of the experiment

Variant of feeding with Artemia (days)	Fish age (days)					
	21			46		
	Weight (mg)	Kn	P(%)	Weight (mg)	Kn	P(%)
A - 0 / 21	10.1	0.79	89.2	28.0	0.78	60.1
B - 7 / 14	12.9	0.79	91.9	34.2	0.84	42.0
C - 14 / 7	18.1	0.93	90.0	41.3	0.82	51.3
D - 21 / 0	28.3	1.08	91.3	45.5	0.79	33.9

Kn - relative coefficient of condition after Le Cren
P - survival

TABLE 6

Bifactorial analysis of variance „ANOVA" in part III of the experiment.

Experimental factor	df	mean square of deviations	Confidence level
Feed type	3	1780.8432	>99.9%
Error	115	148.4684	-

Statistically highly significant differences (P>99.9%) were found between fish weight in particular variants (Tab. 6).

Coeffcient of condition (Kn) was 0.78, 0.84, 0.82 and 0.79 in variants „A", „B", „C", and „D". The respective survival rates were: 60.1 %, 42.0 %, 51.3% and 33.9%.

DISCUSSION

The best results of rearing were obtained with the „FK" trout starter, the worst - with artificial plankton. In parts one and two of the experiment, fish condition decreased noticeably with all tested artificial feeds as the feeding period progressed. This was most probably caused by too slow digestion of the feeds. Gas bubbles were observed in the fish digestive tracts which might have originated from the undigested feeds. As a result the fish lost weight and their mortalities increased. In part three of the experiment, when „FK" trout starter was used, which proved to be the best feed, an

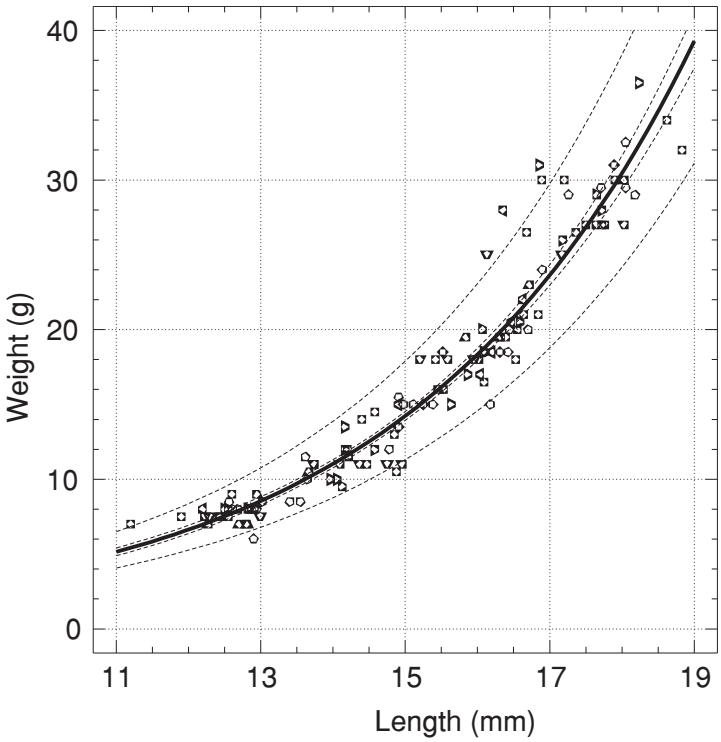

Fig. 3. Weight increments of whitefish larvae. Part III of the experiment.

increase of water temperature improved assimilation of artificial feeds. Fish condition in variants „B" and „C" was satisfactory (Kn=0.8), but not so in variant „A" (Kn=0.78), in which high mortalities were also noted. This was probably caused by too weak fish condition at the begining of part three of the experiment.

Studies on artificial feeds for fish larvae showed that the feeds were consumed by the majority of the fish species, but their use decreased the growth rate and resulted in high mortalities since larvae hatching until the end of metamorphosis. The reasons for these phenomena are not fully understood (Hofer 1985). It is probable that natural food contains some unknown exogenous substances which are indispensable for larvae development and metamorphosis (Hofer 1985, Rembold and Fluchter 1988). In addition to this, short and primitive digestive tract of juvenile fish will undoubtedly result in worse food utilization than in adults (Hofer 1985, Lauff and hofer 1984).

In coregonid fish stomach develops only after 23 days (at 10°C), and this is when excretion glands appear in its middle part. In about 50 days after hatching they began

to operate also at stomach inlet, so that pH decreases. Complete morphological development of stomach in coregonids lasts until about 80th day of life, but effective acidification of the food consumed was observed as late as between 97th and 159th day of life. Consequently, total enzyme activity increases rapidly in course of the ontogenic development, improving absorption of the consumed fats and carbohydrates (Mahri et al. 1983, Dąbrowski 1984).

Bigger whitefish larvae or whitefish fry can well be fed various trout pellets (Dąbrowski and Poczyczyński 1988), but the larvae should not be smaller than 20 mm and 50 mg (Dąbrowski et al. 1986).

Analysis of variance and condition coefficients in the first and the second part of the experiment point to the need of using natural food in the initial period of larvae rearing. Increased mortality at the end of part two of the experiment was probably caused by too slow passage of the food in the digestive tracts, followed by an appearance of digestive tract diseases. Increase of water temperature in part three of the experiment, from 7.5°C to 14°C, increased the efficiency of feed assimilation.

Optimal temperature for coregonid growth is 15-20°C, and the larvae grow more rapidly in temperatures close to the upper limit (Łuczyński 1987).

Summing up, it can be stated that from among the three feeds tested, „FK" trout starter proved to be the best one, and that rearing of Baltic whitefish on artificial feeds seems to be possible in properly high temperatures (above 14°C). This can be achieved using recirculation systems with regulated water temperature, or applying the techniques which delay larvae hatching until the end of April or the beginign of May (Łuczyński 1984a, 1984b, 1987, Łuczyński et al. 1986). In addition to this, use of natural food, especially in the initial stages of larval development, has a beneficial effect on the results of rearing.

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STRESZCZENIE

PRÓBA OKREŚLENIA PRZYDATNOŚCI TRZECH RODZAJÓW PASZ SZTUCZNYCH W ŻYWIENIU LARW SIEI BAŁTYCKIEJ (*Coregonus lavaretus f. baltica* L.) W WARUNKACH PHRŁ RUTKI.

Przełowienie, jak również degradacja środowiska naturalnego spowodowały znaczne obniżenie się liczebności populacji siei bałtyckiej w wodach południowego Bałtyku. Toteż konieczne jest opracowanie programu masowego zarybiania tych wód, a zwłaszcza Zatoki Puckiej i Zalewu Szczecińskiego podchowanym materiałem zarybieniowym.

Uzyskane wyniki wskazują na starter pstrągowy (FK)jako najlepszą z trzech użytych pasz w doświadczeniu. Ważny jest przy tym okres wstępnego żywienia siei pokarmem naturalnym. Dopiero starsze ryby po 3-tygodniowym podchowie zaczęły reagować w istotny sposób na rodzaj podawanej paszy sztucznej. Podwyższenie temperatury podchowu z 7. 5°C do 14°C spowodowało gwałtowny wzrost przyrostów masy i długości przy względnie stałym współczynniku kondycji.

Została tutaj potwierdzona możliwość podchowu starszych larw siei, powyżej 20 mg jednostkowej masy ciała, wyłącznie na starterze pstrągowym, jednak przy zachowaniu optymalnych warunków termicznych, powyżej 14°C.

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