Arch. Ryb. Pol.	Archives of Polish Fisheries	Vol. 7	Fasc. 1	187 - 199	1999

THE EFFECT OF BODY SIZE AND WATER TEMPERATURE ON THE RESULTS OF INTENSIVE REARING OF PIKE-PERCH, *Stizostedion lucioperca* (L.) FRY UNDER CONTROLLED CONDITIONS

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ABSTRACT. Studies were carried out on the effect of initial size summer pikperch fry, *Stizostedion lucioperca*, (two size groups), water temperature (22 and 24°C), and food type (zooplankton or artificial feeds) upon the results of rearing in controlled conditions. Weight and total length of the fish at the beginning of the experiment amounted respectively to 0.25 ± 0.06 g and 32.9 ± 2.7 mm (group S), 0.53 ± 0.06 g 39.4 ± 1.6 mm (group L). No significant effect of the initial fish size and water temperature on fish survival and losses due to cannibalism was bserved in fish which fed on zooplankton ($p > 0.05$). Statistical analysis revealed significant effect of initial fish size ($p = 0.0011$) as well as water temperature ($p = 0.0001$) on the survival in the groups of fish reared on artificial food. These fish attained bigger size (body weight and length) than fish in the control group (feeding on live zooplankton)($p < 0.05$). Temperature had no effect on growth rate of the fish, those reared on artificial as well as natural food.

Key words: PIKE-PERCH, REARING, BODY SIZE, TEMPERATURE, SURVIVAL, CANNIBALISM

INTRODUCTION

Pike-perch, *Stizostedion lucioperca* (L.), larvae similarly as other Percidae of small-size eggs and hatchlings, such as perch, *Perca fluviatilis* (L.), yellow perch, *Perca flavescens* (L.), or walleye, *Stizostedion vitreum vitreum* Mitchill, are very difficult to grow on artificial feed.

In experimental rearing of pike-perch larvae on artificial feeds alone, survival and growth of fish were very low (Ruuhijärvi et al. 1991, Schlumberger, Proteau 1991, Proteau et al. 1993, Mani-Ponset et al. 1994). Also the results for other related species mentioned above were poor (Awaiss et al. 1992, Fiogbe et al. 1995). It should be stressed that studies on larval rearing are most advenced for *S. vitreum* (Barrows et al. 1993, Moore et al. 1994, Bristow, Summerfelt 1994).

Using of inappropriate and/or indigestible food components seems to be the main reason of unsuccessful rearing of percid larvae (Hofer 1985, Rust et al. 1993). Only fish with alimentary tract and digestive enzymes well developed from the beginning of life (e. g. Salmonidae) grow well on artificial feeds (Halver 1972). In most species, however, enzymatic activity in larvae is much lower compared to the adults, which is true also for pike-perch. Newly hatched larvae of this species have underdeveloped gut, and their digestive glands do not produce all digestive enzymes (Alliot 1981).

Better results were obtained using mixed rearing of these species (first phase in ponds, and second – in tanks). The studies revealed that summer fry of percid fishes harvested from the ponds after several weeks of pre-rearing, and transferred to the tanks were well adapted to the intensive rearing on artificial feed, e. g. trout pellets (Malison, Held 1992, Siegwarth, Summerfelt 1992, 1993, Summerfelt 1995, Zakęś 1995, 1997a, Zakęś, Demska-Zakęś 1996). Pike-perch fry production in ponds varies considerably and is affected by many factors such as: water temperature, availability and quality of natural food, and cannibalism (Verreth, Kleyn 1987, Steffens et al. 1996). In Poland, *S. lucioperca* fry is harvested at body length (L. t.) 30-45 mm. Average number of 50000-150000 ind./ha may be obtained (Zakęś, unpublished). The fish are harvested in June or at the beginning of July, depending on weather conditions (Zakęś 1997a). Further rearing of fry in ponds results in increased fish losses due to cannibalism, and considerable fish size differentiation which promotes even stronger cannibalism. Earlier harvesting of fish (at body length 20-30 mm) might be a good way of maximising summer pike-perch fry production in ponds. The experiments carried out in the Experimental Fish Hatchery „Dgał" showed that harvesting fish at the size of 20 mm increased output to 500000 ind./ha (Zakęś, unpublished). Thus, it seems that efficiency of pike-perch larval rearing on artificial feed might be increased by earlier transfer of the fish from ponds to tanks.

Evaluation of the influence of body size of pike –perch (within the range obtained under pond conditions in Poland), water temperature, and diet on the results of rearing under controlled conditions was the objective of the present study.

MATERIAL AND METHODS

SOURCE AND TRANSPORTATION OF FISH

Pike-perch fry was harvested from the earthen ponds of Mrągowo Fish Farm. The fish were obtained from natural spawning in the ponds. The spawners were transferred from Czarne Lake, Olsztyn region. Pike-perch fry were divided into two size groups: small – S, and large – L. Body mass and total length of S and L fish were 0.25 ± 0.06 g, 32.9 ± 2.7 mm, and 0.53 ± 0.06 g, 39.4 ± 1.6 mm, respectively. Average condition coefficient (K = body weight [g] ·100/standard length Lc^3 [cm]) was equal to 1.23 ± 0.08 for S group, and 1.54 ± 0.14 for L group. The fish were transported to the Inland Fisheries Institute in Olsztyn in plastic bags filled with pure oxygen (20 l of water, and 20 l of oxygen for each 1000 fish). Transportation lasted about 1 hour, at water temperature 20°C. Then, the fish were immersed for 10 minutes in 1% sodium chloride solution. The fry was transferred to 0.2 m^3 tanks with water recirculation system. For the first 7 days (adaptation period) the fish were fed zooplankton. Over this time, water temperature was gradually increased to the experimental values. Then, the fish were transferred to the experimental tanks.

CONDITIONS OF REARING

Laboratory-scale experiment was performed. The fish were placed in 20 l oval plastic tanks of dimensions 36 × 56 × 20 cm. They were divided into two size groups (S and L). Both groups were divided into two subsets: controls, fed zooplankton (SZ, and LZ – in one replicate), and experimental groups fed artificial feed (SA, and LA – in two replicates). Two water temperatures were used for each group: 22 and 24°C. The experiment involved total number of 12 tanks supplied with diatomite-filtered tap water, circulating in a semi-closed system of 1.5 l / min water flow. Water temperature was maintained using electronic thermoregulation. Additionally, temperature was measured twice a day using quick-silver thermometer with 0.1°C accuracy. Water quality was checked every 2-3 days. Average water temperatures and values of water quality parameters (TAN = NH_4-N + NH_3-N, NO_2-N, O_2, and water pH) are shown in Table 1. Over the entire time of rearing, 24-hour photoperiod was used (dispersed light). Light intensity over the water surface ranged from 20 to 30 lux. Initial fish density in S and L groups was equal to 6 ind./l (1.5 g/l), and 5 ind./l (2.65 g/l) respectively. Rearing lasted 28 or 56 days, respectively. Non-consumed food and excrements were removed from the tanks twice a day.

FOOD AND FEEDING

The fish were fed to satiation for 16 hours a day (05:00 – 21:00). Control fish were fed cladocerans (mainly *Daphnia magna* or *Moina branchiata*), and experimental groups – trout pellets (total protein – 50.5-54.0%, fat – 15.5-18.0%, digestible energy – 15.6-16.1 MJ/kg) supplied, every 4 minutes using automatic feeders. The fish of S group were fed for the first week with No 1 feed of pellet size 0.5 – 0.8 mm (feeding rate 12% of fish biomass), and for the next 3 weeks with No 2 feed of 0.8 – 1.2 mm (feeding rate 10 – 8%). In L group feed size increased with fish size: 0.8 – 1.2 mm (3 and 4 weeks of rearing), 1.2 – 1.7 mm - No 3 (next 4 weeks), and feeding rate was reduced to 5% of fish biomass in the last week of rearing.

MEASUREMENTS AND STATISTICAL ANALYSIS OF DATA

Growth rate and condition coefficient were evaluated throughout the experiment. Every 7 days, 10 randomly selected fish from each tank were weighed (with 0.01 g accuracy), and measured (total length L. t., and standard length L. c., with 0.1 mm accuracy). The fish for measurements were anaesthetised with 2 ml/l propanidid solution. Feeding rate was changed according to the fish growth. The fish were counted and total fish biomass was calculated to evaluate survival and losses due to cannibalism. Cannibalism was estimated from the difference between the initial fish number and the number of live and dead fish. Natural mortality (NM) was estimated from daily records of dead fish.

One-way ANOVA was used to evaluate the effect of initial body size, water temperature, and diet on fish growth rate. In cases of statistically significant differences ($P \leq 0.05$) Tukey's test were applied. The effect of initial fish size, and water temperature on survival and cannibalism was evaluated using two-way analysis of variance (MANOVA, $P \leq 0.05$). All percentage data were coverted using arcsin function.

RESULTS

SURVIVAL AND CANNIBALISM

No effects of initial body size or water temperature on survival and losses due to cannibalism were observed in the control groups (SZ, and LZ). In SZ22, and SZ24 groups survival and losses due to cannibalism were 95.8, 1.7%, and 92.7, 3.3% respectively. In L groups the results were: 95.0, 2.0% (LZ22), and 97.0, 1.0% (LZ24). Fish deaths were sporadically observed in the first two weeks of rearing (Fig. 1), including loss due to cannibalism (Fig. 2).

In fish fed artificial feed, the initial fish size and water temperature affected significantly ($P = 0.0011$ and 0.0001, respectively) fish survival, but interaction of the two factors did not play a significant role (Table 2). Analysis did not reveal any influence of fish size or water temperature on cannibalism in fish ($P > 0.05$). However, it was affected by the two factors together ($P < 0.05$, Table 2).

TABLE 1

Water quality during laboratory rearing of pike-perch summer fry – mean, (standard deviation).

Size group	Oxygen concentration at water inflow (mg/L)	TAN (mg /L) at the outflow	NO_2-N (mg/L) at the outflow	pH	Temperature (°C)
Group S	8.1 (0.07) 7.9 (0.07)	0.13 (0.04) 0.19 (0.05)	0.017 (0.003) 0.019 (0.006)	7.9 (0.09) 7.9 (0.10)	22.1 (0.3) 24.1 (0.3)
Group L	8.0 (0.09) 7.9 (0.09)	0.14 (0.06) 0.13 (0.05)	0.014 (0.005) 0.009 (0.003)	7.8 (0.10) 7.9 (0.09)	22.0 (0.2) 24.1 (0.2)

TABLE 2

Survival and cannibalism – mean, (SE) – for two size groups of pike-perch fry (S and L) reared at two water temperatures on artificial feed – two-way analysis of variance [initial fish size (S) , water temperature (T)]

Size group	Survival (%)		Cannibalism (%)	
	22°C	24°C	22°C	24°C
Group S	62.50 (2.50)	19.17 (0.00)	16.67 (1.67)	6.25 (2.08)
Group L	82.00 (2.00)	39.50 (3.50)	10.00 (3.00)	15.50 (1.50)
MANOVA	*F*	*P*	*F*	*P*
Size (S)	70.510	0.0011	0.364	0.5848
Temperature (T)	327.410	0.0001	1.317	0.3152
S×T	0.031	0.8714	13.804	0.0206

In the second week of rearing high mortality was observed in both temperatures in SA group. In LA groups period of increased mortality was more extended, and maximum fish losses in LA24 took place in the third week of rearing (Fig. 1). Losses caused by cannibalism showed a similar pattern (Fig. 2). In S group no fish mortality was observed after 3 weeks of rearing, and in L group – after 4 weeks.

FISH GROWTH AND CONDITION

Daily increment of fish body weight and length at 22 and 24^{o}C ranged within 0.020 - 0.038 g/day, and 0.870 - 1.030 mm/day (SA, LA groups) (Table 3). The fish fed artificial feed (SA, LA) showed faster increase of body weight and length compared to the control groups SZ and LZ ($P < 0.001$). In both size groups (S and L), statistically significant differences in body length and mass between zooplankton (SZ, LZ) and formula-fed (SA, LA) fish occurred already after the first week of rearing ($P < 0.05$). At the end of the experiment, SA and LA fish showed also higher condition coefficient ($P < 0.001$).

Water temperature did not significantly ($P > 0.05$) affect fish growth rate which was true for both control and experimental groups (Table 3). Fish growth was particu-

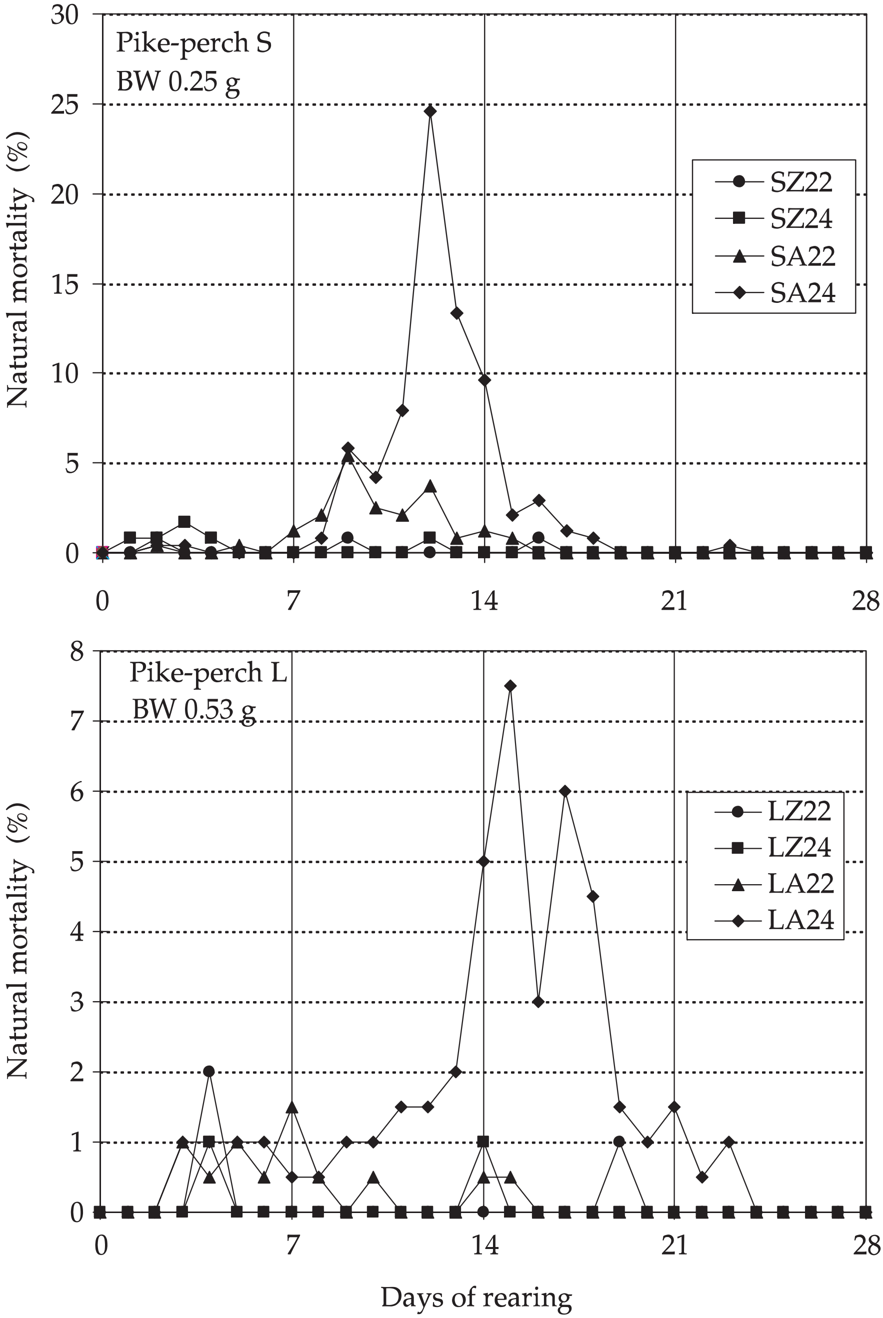

Fig. 1. Natural mortality curves (NM) for two size groups of pike-perch summer fry (S and L) fed zooplankton or artificial feed (Z and A), at 22 or 24°C.

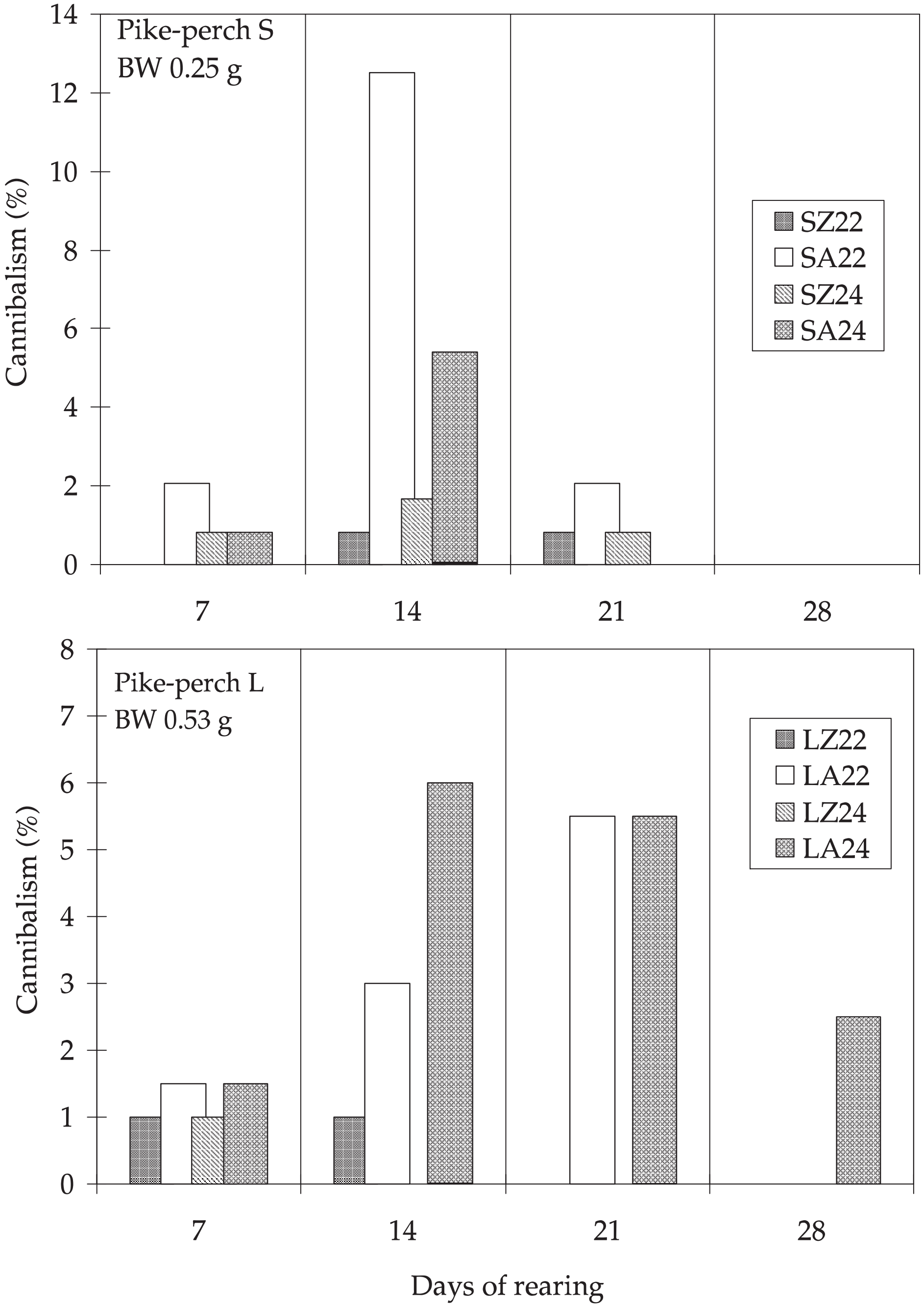

Fig. 2. Fish losses due to cannibalism in two size groups of pike-perch summer fry

larly uniform in the controls – SZ22, SZ24, and LZ22, LZ24. The fish given artificial feed grew better at 22°C for the first two weeks of rearing (P < 0.05), but in the next two weeks (3-4 week of rearing) the differences disappeared (Table 3).

Water temperature did not affect fish condition. The only significant (P < 0.05) difference was observed between LA24 and LA22 group (Table 3).

TABLE 3

Growth rate and condition coefficient – mean (SD) - for two size groups of pike-perch fry (S and L) reared at two water temperatures (22 and 24°C) on artificial feed or zooplankton (A and Z subgroups). Values with stars differ between rows (ANOVA, Tukey test, P ≤ 0.05), n – insignificant differences. Values with identical letter notation do not significantly differ in columns (P > 0.05).

Size group	Temperature (°C)		Mean (for temp.)
	22	24	
Growth (mm/day)			
Group SZ	0.539^a	0.532^a	0.536^n
Group SA	1.030^b(0.047)	1.010^b (0.040)	1.020^n
Group LZ	0.525^a	0.534^a	0.530^n
Group LA	0.870^b (0.048)	0.875 ^{b}(0.020)	0.873^n
Growth (g/day)			
Group SZ	0.020^a	0.020^a	0.020^n
Group SA	0.061^b (0.005)	0.059^b (0.004)	0.060^n
Group LZ	0.036^a	0.038^a	0.037^n
Group LA	0.100^b (0.011)	0.112^b(0.014)	0.106^n
Condition			
Group SZ	1.27^a (0.07)	1.28^a (0.06)	1.28^n
Group SA	1.40^b (0.08)	1.36^b (0.080	1.38^n
Group LZ	1.37^a (0.08)	1.40^a (0.09)	1.39^n
Group LA	1.56^b(0.09)	1.64^b (0.10)	1.60*

DISCUSSION

The results of the present study indicate that initial fish size is very important for successful rearing of fry on artificial feed. Larger fish more readily consumed artificial feed comparing to smaller ones (Table 2). These results are consistent with earlier data obtained for pike-perch in our laboratory (Zakęś 1997b, Zakęś, Demska-Zakęś 1996) (Table 4). Observations revealed, however, that size variability also considerably affected the success of rearing, particularly survival. If fish size varies strongly, loss due to cannibalism tends to increase. In fish group of initial body weight 0.7 g, survival after 8 weeks of rearing dropped to less than 50%. Losses due cannibalism in the first 4 weeks of rearing reached 20-30%. In groups of uniform body weight of 1.1 g, survival was over 90% (Zakęś, unpublished). Considerable size variability took place particularly in fish from natural spawning due to individual variability of egg and larval size, and time of spawning. Thus, material from artificial spawning is more appropriate for rearing; the ponds may be stocked with eyed eggs or larvae.

TABELA 4

Data of various authors on the effect of initial body size of percid fry, and water temperature upon final results of rearing (survival) using artificial feed.

Species	Initial size L.t. (mm)	Initial density (g/L)	Mean water temp. (°C)	Duration of rearing (days)	Survival (%)	Source
S. lucioperca	30.2	0.60 - 1.80	22.0	28	57 – 59	Zakęś (1997b)
	32.9	1.50	22.1	28	62.5	this study
	32.9	1.50	24.1	28	19.2	
	39.4	2.65	22.0	56	82.0	
	39.4	2.65	24.1	56	39.5	
	36.6	1.92	22.0	105	68.9	Zakęś i Demska-Zakęś /1996/
S. vitreum	69.3	0.87 - 2.17	20.1	28	76.5	Kuipers i Summerfelt /1994/
	69.3	0.87 - 2.17	24.9	28	80.0	
	67.9	1.83 - 3.21	20.8	28	85.1	
	67.9	1.83 - 3.21	25.2	28	67.5	
P. flavescens	16.9	0.65	21.0	19	53.3	Malison i Held /1992/
	32.5	2.01	21.0	34	68.3	
	42.6	2.90	21.0	51	55.7	

Similar experiments dealing with the effect of initial fish size on the success of rearing carried out on walleye, *Stizostedion vitreum,* led to similar conclusions. Sanderson (1974) suggested that minimum size of *S. vitreum* fry fed artificial feed should be around 35 mm, and according to Nickum (1978) it should range from 35 to 75 mm. It is often stated that the best results of rearing are obtained when initial fish body size exceeds 50 mm (Cheshire, Steele 1972, Nagel 1985, Nickum 1978, Kuipers, Summerfelt 1994). On the other hand, too long pond rearing causes increased fish mortality due to cannibalism and starvation. For these reasons, Nickum, Stickney (1993) concluded that the fish should be harvested from the ponds at the size of 25-35 mm. Overall effect of mixed rearing in the ponds and in the tanks may be better despite higher losses in the tank phase, since it is compensated by higher efficiency of the pond phase. At *S. lucioperca* size of 40-50 mm, usually no more than 200000 ind./ha may be obtained (Steffens 1986). The output may increase even 2-3 fold when the fish are harvested at 20-30 mm (Zakęś, unpublished). In case of yellow perch, *Perca flavescens,* reared on artificial feed (Malison, Held 1992), fish survival and losses due to cannibalism did not significantly differ among three size groups (16.9, 32.5, and 42.6 mm L. t.) (Table 4). Thus, the authors suggested that rearing was more efficient for smaller fish. Additionally, they observed that period of mortality was shorter in smaller fish. Similar results were obtained also in the present study. The highest fish mortality in S group took place in the second, and in group L – in the third week of rearing (Fig. 1). Fish losses due to cannibalism in large size group lasted longer. In the adaptation period, when fish habituated to new food and environment conditions, growth rate and feed conversion rate were poor. Thus, it seems that shortening of this period (using smaller fish for controlled rearing) should result in growth rate increase, and a decrease of feed conversion rate. Generally, adaptation period of pike-perch summer fry lasts 14-28 days, and depends on initial size of stocking material (Zakęś 1997a, b, c, Zakęś, Demska-Zakęś 1996, 1998). *S. vitreum* fry showed similar adaptation period (Nickum 1978, Nickum, Stickney 1993, Kuipers, Summerfelt 1994).

The present study revealed that the results of rearing of pike-perch summer fry depended also on water temperature (especially during adaptation period) (Table 2). Earlier studies (Zakęś 1997c) showed that temperature under 20°C during that period resulted in considerable reduction of growth rate and survival. Fish reared at 22 and 24°C grew faster but at 24°C high mortality occurred. In the present experiment survival of SA22 and LA22 fish was also 2-3 fold higher than in SA24 or LA24. No effect of temperature was, however, observed on the level of cannibalism (Table 2). In the control groups, fed zooplankton, survival was high (over 90%), and the differences between SZ22, LZ22 and SZ24, LZ24 were insignificant ($P > 0.05$). Increased mortality of pike-perch fry fed artificial feed at higher temperature is difficult to explain. No such mortality was observed in the control group, thus it probably did not result from increased metabolic rate. In higher temperatures fish had difficulties in accepting artificial feed, which resulted in long period of high mortality (Fig. 1) and initially poor growth. After the adaptation period, fish growth rate increased considerably. Average daily increment (g/day or mm/day) was similar as at 22°C (Table 3). For the initial phase of rearing of walleye fry on artificial feed, temperatures about 20°C are recommended (Kuipers, Summerfelt 1994). Experiments revealed that walleye survival at 20.8°C was significantly higher comparing to 25.2°C (85.1, and 67.5%, respectively) (Table 4). However, this was not always true – another walleye cohort reared at 20.1 and 24.9°C did not show such differences (Kuipers, Summerfelt 1994) (Table 4).

RECAPITULATION

The results of the present study confirmed significant relationship between water temperature and success of rearing pike-perch summer fry on artificial feed. It also proved that results of rearing strongly depended on the initial size of the stocking material. On the other hand, taking into consideration the possibility of increasing overall efficiency of rearing, stocking material of 20-30 mm should be used in further studies. Fish survival obtained in this study (62.5%), and in the previous experiments (57-59%) (Zakęś 1997b), for fish of initial body size 32.9 and 30.2 mm respectively, showed that also smaller fish may be successfully reared. Stocking tanks with such small fish would improve overall effect of rearing in mixed pond-tank system.

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STRESZCZENIE

WPŁYW WIELKOŚCI NARYBKU LETNIEGO SANDACZA EUROPEJSKIEGO, *Stizostedion lucioperca* (L.) I TEMPERATURY WODY NA EFEKTY JEGO INTENSYWNEGO PODCHOWU W WARUNKACH KONTROLOWANYCH

Celem przeprowadzonego doświadczenia było określenie wpływu wielkości początkowej narybku letniego sandacza, temperatury wody i diety na efekty jego podchowu w warunkach kontrolowanych. Eksperyment przeprowadzono w skali laboratoryjnej. Doświadczenie składało się z dwóch wariantów (grupy wielkościowe S i L; masa i długość całkowita ryb (L.t.) z Grupy S i L w momencie odłowu wynosiły odpowiednio 0,25 ± 0,06 g i 32,9 ± 2,7 mm oraz 0,53 ± 0,06 g i 39,4 ± 1,6 mm). Każdy wariant wielkościowy składał się z grupy kontrolnej karmionej zooplanktonem (SZ lub LZ - w jednym powtórzeniu) i grupy doświadczalnej karmionej paszą sztuczną (SA lub LA) w 2 powtórzeniach. Ryby podchowywano w dwóch wariantach temperatury wody - 22 i 24°C. W grupach ryb kontrolnych (Grupy SZ i LZ) nie zaobserwowano istotnego wpływu wielkości początkowej ryb i temperatury wody na przeżywalność i wielkość strat spowodowanych kanibalizmem ($P > 0{,}05$). Odmienny charakter miały straty w grupach ryb karmionych paszą sztuczną. Przeprowadzona dwuczynnikowa analiza wariancji wykazała istotny wpływ zarówno wielkości początkowej ($P = 0{,}0011$), jak i temperatury wody ($P = 0{,}0001$) na przeżywalność obsad. Nie stwierdzono istotnej zależności pomiędzy analizowanymi czynnikami a kanibalizmem ryb ($P > 0{,}05$). Okres nasilonych śnięć w grupach ryb SA (w obydwu wariantach temperaturowych) obserwowano w drugim tygodniu podchowu. Natomiast wśród ryb o większej początkowej wielkości okres ten był bardziej rozciągnięty w czasie, a maksymalne śnięcia obserwowano o tydzień później, w trzecim tygodniu podchowu. Ryby karmione paszą sztuczną (Grupy SA i LA) osiągnęły istotnie większe przyrosty masy i długości całkowitej ciała od ryb z grup kontrolnych (SZ i LZ) ($P < 0{,}001$). Temperatura wody nie wpłynęła istotnie ($P > 0{,}05$) na tempo wzrostu ryb - dotyczyło to zarówno ryb z grup kontrolnych, jak i doświadczalnych.

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