Arch. Ryb. Pol.	Archives of Polish Fisheries	Vol. 5	Fasc. 2	313 - 324	1997

CONVERTING POND-REARED PIKEPERCH FINGERLINGS, *Stizostedion lucioperca* (L.), TO ARTIFICIAL FOOD - EFFECT OF WATER TEMPERATURE

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A B S T R A C T. Four water temperatures (18, 20, 22 and 24 °C), two feeds (live zooplankton and trout pellets) were evaluated to determine their influence on the results of training pond-reared (W 0.25 g, TL 3.29 cm) pikeperch fingerlings, *Stizostedion lucioperca*, to artificial food under laboratory conditions. The fish were trained to dry diet over a 28-day interval. There were significant differences in survival, cannibalism, condition factors, length and weight gains between temperatures and between diet treatments ($P<0.05$). Best growth and survival rates occured at 22 °C (both in fish fed zooplankton and trout feed).

Key words : *Stizostedion lucioperca*, FINGERLING REARING, ARTIFICIAL FOOD, TEMPERATURE, GROWTH, MORTALITY

INTRODUCTION

Artificial propagation of fingerlings of walleye (*Stizostedion vitreum*), sauger (*S. canadense*) and hybrids walleye x sauger (saugeyes) has become important for maintaining and improving the fishery in North America. Walleye fingerlings have been reared on artificial food for at least 25 years (Cheshire and Steele 1972, Nagel 1974, 1976). Development of intensive culture methods for producing these fingerlings is receiving much attention (Siegwarth and Summerfelt 1990, 1992, 1993, Nickum and Stickney 1993, Kuipers and Summerfelt 1994).

In Europe, production of pikeperch (*S. lucioperca*) fingerlings still depends on extensive and semi-intensive pond culture. The survival and growth of pikeperch in nursing ponds are strongly influenced by the presence of suitable zooplankton organisms, such as copepod nauplii and rotifers (Kovalev 1976, Verreth and Kleyn 1987). Because plankton community dynamics is affected by many biotic and abiotic factors, a predictable production cannot be obtained through this method.

Hence, there has been a considerably growing interest in the development of pikeperch rearing techniques. Knowledge of thermal requirements of fish is required for use in laboratory experiments and for intensive aquaculture. Temperature is considered to be the most important controlling factor (Fry 1971) which induces metabolic processes that include enzyme activity, growth, ammonia excretion, and oxygen consumption (Forsberg and Summerfelt 1992).

Pikeperch require a rather high temperature. In the natural conditions the temperature preferred by nearly 2 cm long juvenile pikeperch is 24°C (Willemsen 1961). Hokanson (1977) reported on the findings of J. Willemsen, who showed that the optimum temperature for one-year-old pikeperch growth ranged between 28 and 30°C.

The aim of this study was to determine the effect of water temperature on growth and survival of pond-reared pikeperch fingerlings held under controlled laboratory conditons and fed artificial diet and live zooplankton.

MATERIALS AND METHODS

SOURCE AND MAINTENANCE OF FISH

Pikeperch spawners were captured in Czarne Lake, Olsztyn District, and transported to earthen ponds in Mragowo State Fish Farm. Fingerlings were reared in ponds to an average body weight 0.25 g and total length 3.29 cm on natural food, and then transported to Inland Fisheries Institute hatchery in Olsztyn, in plastic bags with oxygen (20 L water and 20 L O_2, 1,000 fish per bag). Transportation time was one hour. Water temperature during transportation was maintained at approximately 20°C. After arrival to the laboratory, all fish were given a prophylactic treatment in 1% sodium chloride solution (Prost 1989).

Test fish were randomly divided into twelve lots, placed in 20-liter oval-shaped (36 x 56 cm with 20 cm water depth) tanks supplied with aerated, filtered water at a flow rate of 1.5 L/min (3 tanks per treatment - control and duplicate experimental group, 120 individuals per tank). Constant temperatures of approximately 18, 20, 22 or 24°C were maintained in each of the three tanks by means of Temperature Controller Model MR-electronica ST-01. Fingerlings were acclimated to the final culture temperature for 7 days. Water temperature was measured twice daily over the 28-day rearing intervals, with a laboratory thermometer (±0.1°C). Mean temperatures (SD) for the three tanks at each temperature were 17.9 (±0.25), 19.8 (±0.31), 22.1 (±0.29), and 24.1 (±0.26) ^{o}C. A 24-h light and 0-h dark photoperiod was used. Light intensity at the surface of the tanks was 20.2 (±2.7) lux.

Parameters of water in the tanks were measured at three-day intervals. Dissolved oxygen ranged from 7.9 to 8.3 mg/L, pH from 7.8 and 8.0. Total ammonia and nitrite concentrations did not exceed 0.20 and 0.02 mg/L, respectively.

EXPERIMENTAL PROCEDURE

The fish were trained to a dry diet during a 28-day period. The control groups (Z) were fed to excess with live zooplankton (*Daphnia magna* or *Moina branchiata* predominated). The experimental groups (A) were fed to excess with a commercially available trout feed, delivered at 4-minute intervals from automatic feeders (Mamcarz and Kozlowski 1989) for 16 hours per day. The fish were fed from 05:00 to 21:00 hours (both groups Z and A). They were first fed No. 1 pellets (diameter 0.5-0.8 mm), then (after a week of rearing) No. 2 granules (diameter 0.8-1.2 mm). Initial daily feeding rates of dry diets were approximately 12% of the fish total biomass, then gradually decreased to 8% during the final week of the trial. The proximate analysis of the feed was 54% (No. 1 pellets) - 52% (No. 2) crude protein, 12 - 14% fat and 17.0 - 17.5 MJ/kg metabolisable energy.

Fish were weighed (±0.01 g), measured (±0.1 mm) and counted at 1-week intervals. They were not fed on the day of sampling. Length and weight measurements were obtained on 10 fish from each tank mildly anesthetized with propanidid. After being weighed and measured, anesthetized fish were placed in tank with a continous flow of fresh water. Fish were returned to the rearing tank after a recovery interval of 15 to 20 min.

Specific growth rate of body weight (SGR_W), total length (SGR_{TL}) and total fish biomass (SGR_B) were calculated as $100[(\ln W_1 \text{ or } TL_1 - \ln W_0 \text{ or } TL_0)/t]$, where W_1, TL_1, W_0, TL_0 were fish body weight or total length and „t" the period in days, while SGR_B was estimated from:

$$SGR_B = 100[(\ln n_1W_1 - \ln n_0W_0)/t],$$

where n_1, n_0 were initial and final fish numbers, W_1, W_0, t as in SGR_W.

Mortality (dead fish) was recorded daily throughout the test period. It was called „natural mortality" (NM). The difference between the number of fish at the begining of the experiment and the sum of the number of fish counted during the experiment plus the collected dead fish gave the number of cannibalism victims. Total losses consisted of NM and cannibalism, which was determined at 1-week intervals. The tanks were cleaned daily by siphoning out the faces and waste feed.

Differences in growth, condition and survival between temperature-diet regimes were subjected to analysis of variance. If a significant difference was found (P<0.05), the analysis of variance was followed by Duncan's multiple-range test to identify the treatments that differed from one another.

RESULTS

Total losses were significantly lower in fish fed live zooplankton than in fish fed dry diet (P<0.05). There were no significant differences in mortalities of fingerlings reared at 20, 22, 24 ^{o}C with the zooplankton (the losses were very low), but mortality for fish raised at 18 ^{o}C was significantly higher (P< 0.05) (Table 1). In the experimental groups losses varied from 95.0% (A18) to 37.5% (A22). Total mortality for A22 was threefold lower than at A24.

„Natural mortality" in the first 7 days was low, but increased slightly from the 8-th to the 14-th day (A22 and A24) and from 14-th to the 21-th day (A18 and A20). Of the total observed mortality, 90.0% occured from days 8 to 14 in the experimental group A22 (Fig. 1).

Total losses due to cannibalism have been no higher than 3.33% (groups Z) and 16.67% (groups A) (Table 1). Cannibalism was more prevalent in the 2-nd and 3-rd week of the 28-day rearing interval (Fig. 2).

There were significant differences in both length and weight gains between temperatures and between diet treatments after 1 week and throughout the remainder of the 4 week experiment (P<0.05) (Table 1). At the end of culture interval, the mean total length and average body weight of fish reared on zooplankton ranged between 0.68 g W, 4.44 cm TL (Z18) and 0.80 g W, 4.80 cm TL (Z22). The growth rate of fish from Z22 and Z24 was significantly higher than Z18 and Z20 (P<0.05). On the other hand, the fish Z22 and Z24 grew considerably slower than those in the experimental groups (A22 and A24) (Table 1).

Significantly faster growth was recorded in group A22 and A24 (W 1.95 g, TL 6.18 cm and W 1.90 g, TL 6.12 cm, respectively). Gain in weight by fish fed dry diet and

TABLE 1

Growth and survival data (means ±SD) of fingerling pikeperch in temperature-diet treatments. Means with the same superscript in the same row are not significantly different (P>0.05).

Parameter	Treatments							
	Z18	A18	Z20	A20	Z22	A22	Z24	A24
Initial weight (g)	0.25 (0.06)	0.25 (0.06)	0.25 (0.06)	0.25 (0.06)	0.25 (0.06)	0.25 (0.06)	0.25 (0.06)	0.25 (0.06)
Final weight (g)	0.68^{bc} (0.13)	0.29^{a} (0.10)	0.72^{bcd} (0.13)	0.65^{b} (0.45)	0.80^{bd} (0.14)	1.95^{e} (0.37)	0.80^{d} (0.14)	1.90^{e} (0.51)
Total biomass (kg m^{-3})	3.16	0.09	3.67	0.49	4.60	7.31	4.40	2.19
SGR_W (% d^{-1})	3.57^{bc}	0.53^{a}	3.78^{bc}	3.41^{b}	4.15^{c}	7.34^{d}	4.15^{bc}	7.24^{d}
SGR_B (% d^{-1})	2.66^{cd}	-10.17^{a}	3.20^{cd}	-4.01^{b}	4.00^{cd}	5.66^{d}	3.84^{cd}	1.34^{c}
Initial length TL (cm)	3.29 (0.28)	3.29 (0.28)	3.29 (0.28)	3.29 (0.28)	3.29 (0.28)	3.29 (0.28)	3.29 (0.28)	3.29 (0.28)
Final length TL (cm)	4.44^{bc} (0.29)	3.47^{a} (0.23)	4.57^{c} (0.29)	4.24^{b} (0.88)	4.80^{d} (0.28)	6.18^{e} (0.39)	4.78^{d} (0.28)	6.12^{e} (0.67)
SGR_{TL} (% d^{-1})	1.07^{b}	0.19^{a}	1.17^{b}	0.91^{b}	1.35^{b}	2.25^{c}	1.33^{b}	$2,22^{c}$
Condition factor K[1]	1.32^{c} (0.07)	1.14^{a} (0.25)	1.29^{b} (0.06)	1.27^{b} (0.15)	1.27^{b} (0.07)	1.40^{d} (0.08)	1.28^{b} (0.06)	1.36^{cd} (0.08)
Mortality (%)	20.00^{d}	88.33^{a} (1.67)	5.83^{e}	78.34^{ab} (2.92)	2.50^{e}	20.83^{c} (4.16)	5.00^{e}	74.58^{b} (2.09)
Cannibalism (%)	2.50^{a}	6.67^{a} (1.67)	0.83^{a}	9.16^{ab} (1.67)	1.67^{a}	16.67^{b} (1.67)	3.33^{a}	6.25^{a} (2.08)

[1]*K = body weight (g) x 100/ standard length*^{3} *(cm)*

held at 22 and 24 °C was much higher than that of those at 18 and 20 °C. They reached the significantly smaller final body weight of merely 0.29 and 0.65 g (group A18 and A20, respectively)

The specific growth rate of body weight (SGR_W) was 0.53%d^{-1} (A18) and 7.34%d^{-1} (A22) over the 28 day interval. SGR_{TL} fluctuated from 0.19%d^{-1} (A18) to 2.25%d^{-1} (A22). The differences in SGR_W and SGR_{TL} between treatments were significant (P<0.05) (Table 1). In the best experimental group A22 (the highest survival and the fastest growth rate), SGR_W was 7.07% per day over the first 7 days. Between day 8 and 15 it was 10.91%. SGR_W decreased to 5.15% in the last week of the trial (Fig. 3).

Significant differences were observed also in condition factors of fish fed zooplankton and trout pellets, and in different water temperatures (P< 0.05). The fish A22 and A24 had significantly higher condition factors (P<0.05) (Table 1).

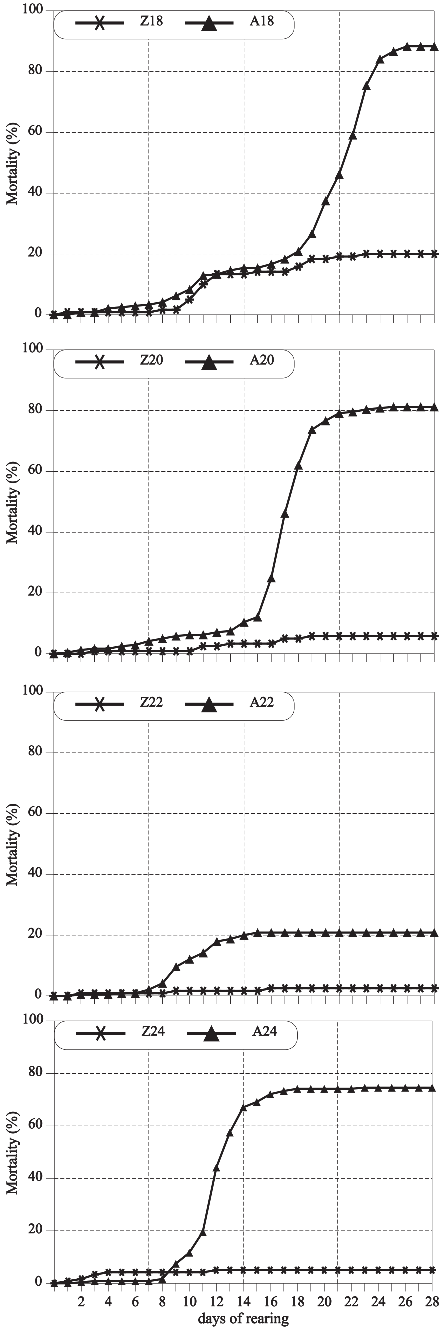

Fig. 1. Cumulative mortality ("natural mortality") of pikeperch fingerlings in various temperature-diet treatments.

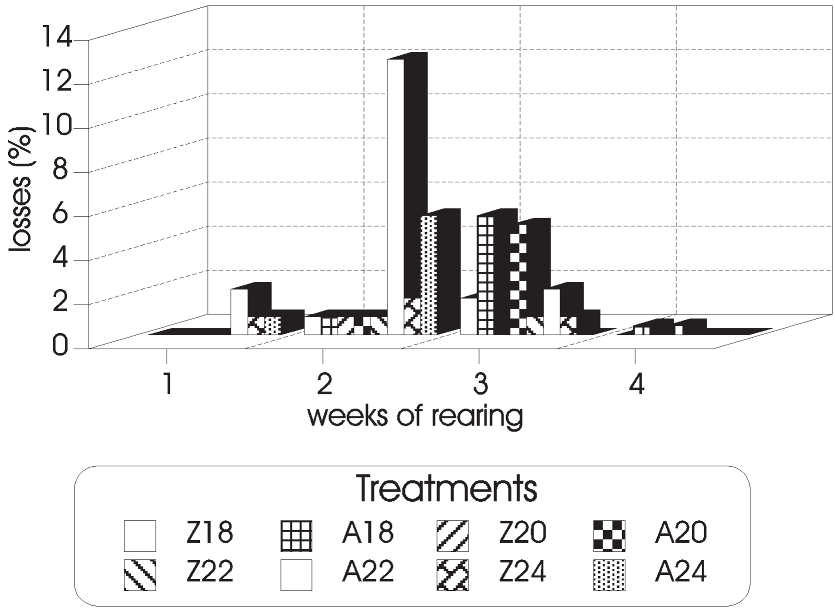

Fig. 2. Losses attributable to cannibalism.

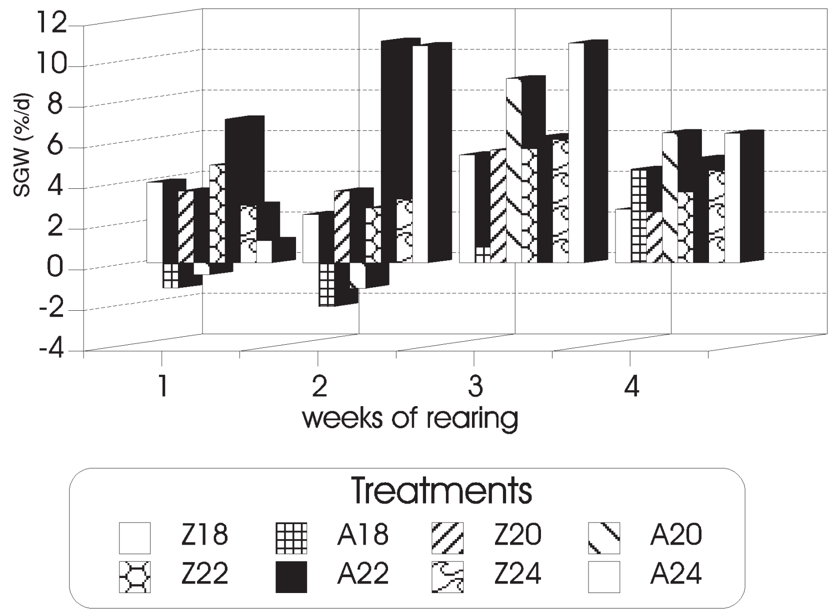

Fig. 3. Effect of various temperature-diet treatments on the specific growth rate of body weight of pike-perch fingerlings during the course of the experiment.

DISCUSSION

The growth and survival rates of pikeperch fingerlings in the experiment were significantly affected by water temperature. Best growth and survival occured at 22 ^{o}C (both control and experimental fish). A satisfactory growth rate and condition of the fish were observed also in group A24, however the survival in this group was low (19.17%). Therefore SGR_B for A22 was fourfold higher than for A24 and total biomass was above threefold higher (Table 1).

The temperatures used in an another study were 22 and 24 ^{o}C, and performance was significantly better at 22 ^{o}C (Zakęś 1995). It seems probable that better growth rate of pikeperch fingerlings at 22 and 24 ^{o} C might be the result of higher conversion efficiency with less energy expenditure than at lower one. However Hilge (1990) reported that pikeperch fry rearing in a laboratory resulted in much better growth at 24-26 ^{o}C than at lower temperatures . Schlumberger and Proteau (1991) raised pikeperch fingerlings from 38 to about 80 mm on standard trout feed at water temperature of 20 - 25 ^{o}C.

A number of studies showed that temperature plays an extremely important role in the rearing of walleye fingerlings on formulated feeds (Nagel 1976, Nickum 1978). Huh *et al.* (1976) found optimal growth and feed efficiency of walleye to be near 22 ^{o}C. Beyerle (1975) reported that walleye growth was almost one-third less at 18 ^{o}C than at 22 ^{o}C. Performances and growths of walleye and saugeyes were better at 21 ^{o}C than 17 ^{o}C (Siegwarth and Summerfelt 1990).

The optimum temperature for growth and survival for pond-reared pikeperch fingerlings fed artificial feed under laboratory conditions was similar in this study to that observed for juvenile walleye. The present data may represent characteristic responses of the pikeperch fingerlings to temperature, but would probably vary with size and age, as well as other rearing conditions.

The 37.5% mortality (A22) observed in this study was higher than 21.0 or 31.1% mortality rates noted in other investigations (water temperature 22 ^{o} C) that were carried out under intensive hatchery conditions (Zakęś 1995, Zakęś and Demska-Zakęś 1996). Total losses for A18, A20 and A24 groups were significantly higher. It is difficult to explain the reasons for differences in mortality rates between the experimental groups in this study. I did not observe any symptoms of disease that would have contributed to the higher mortality of pikeperch from experimental groups reared at 18, 20 and 24 ^{o}C, The 40 - 80% total losses of walleye fingerlings fed artificial feeds was reported by many authors (Cheshire and Steele 1972, Nagel 1974, 1976, Reinitz and Austin 1980). A minimum mortality of 10 - 20% was achieved by Nagel (1985) and Kuipers and Summerfelt (1994).

The curves of cumulative mortality in the present study indicated that in the training period (for A22 and A24 groups) most losses can be expected in the first 2 weeks of rearing. Losses were caused by starvation, cannibalism, tail-biting, secondary diseases and stress caused by cleaning of the tanks. Most of the fish that did not accept trout pellets emaciated within 14 days; these fish were succumb or devoured. It seems, that the phase when the fish begin to accept artificial food may last up to 2 weeks. It has been suggested that walleye fingerlings usually take about 10 days to adapt to pelleted food (Beyerle 1975).

Cannibalism has been recorded in intensive culture pikeperch fry with live food (Breteler 1989). It is also an important source of losses in intensive culture of walleye fry (Li and Mathias 1982, Krise and Meade 1986, Loadman *et al.* 1989). Cannibalism of fingerlings walleye has been mentioned as a major cause of mortality in the period when pond-reared fish were trained to formulated food. For instance, Cheshire and Steele (1972) reported losses due to cannibalism of 13.2 %. Nagel (1976) indicated that about 25 % of the fingerlings were lost as a result of cannibalism and tail-bitting. On the other hand, Kuipers and Summerfelt (1994) noted that the maximum rate of cannibalism averaged only 4%. Cannibalism was also the important cause of losses in the experimental groups in this study. It seems that it is possible to reduce cannibalism - induced mortality by frequent grading of pikeperch by size.

The pikeperch fingerlings, intensively raised in the way as described, reached a mean total length 9.2 cm, and a mean weight 6.9 g at the begining of August (Zakęś 1995), and TL 16.0 cm and W 36.0 g at the begining of October (Zakęś, unpublished data). At that time, autumn fingerlings produced in the ponds usually attained total length of merely 6 - 10 cm (Steffens 1986, Zakęś and Szczerbowski 1995).

This rearing experiment has shown that pond-reared pikeperch fingerling can be trained to feed on trout pellets, and water temperature is a major factor affecting survival and growth rates. Future investigations are needed to evaluate more throughly the effect of fish size to which young pikeperch are kept in pond prior to intensive rearing, the effect of stocking density, and many other factors.

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STRESZCZENIE

PODCHÓW NARYBKU LETNIEGO SANDACZA, *Stizostedion lucioperca* (L.), POZYSKANEGO ZE STAWU, NA PASZY SZTUCZNEJ - WPŁYW TEMPERATURY WODY

Przeprowadzono 28 dniowy laboratoryjny podchów narybku letniego sandacza pozyskanego ze stawów (0.25 g W, 3.29 cm Lt) na paszy sztucznej w czterech różnych temperaturach wody (18, 20, 22 i 24 ^{o}C). Ryby z grup kontrolnych karmiono z nadmiarem zooplanktonem. Grupy eksperymentalne (A) i kontrolne (Z) karmiono przez 16 godzin na dobę (05.00 - 21.00)

Śmiertelność ryb karmionych zooplanktonem i przetrzymywanych w 20, 22 i 24 ^{o} C była niska, a różnice między tymi grupami okazały się nie istotne statystycznie ($P > 0.05$). Jedynie w grupie Z18 straty całkowite („śmiertelność naturalna" i kanibalizm) były większe i po 28 dniach podchowu wyniosły 22.5%. Zdecydowanie większą śmiertelność obserwowano w grupach doświadczalnych. Straty całkowite wahały się od 37.5% (A22) do 95.0% (A18). Analiza przebiegu krzywych śmiertelności skumulowanej („śmiertelność naturalna") wykazała, że w grupach A22 i A24 nasilenie strat obserwowano pomiędzy 8 a 14 dniem podchowu. Natomiast w grupach A18 i A20 zjawisko to odnotowano później, pomiędzy 14 a 21 dniem.

Straty spowodowane kanibalizmem nie przekraczały 3.33% (grupy Z) i 16.67% (grupy A). Nasilenie kanibalizmu - w grupach doświadczalnych, a szczególnie w grupie o najmniejszej całkowitej śmiertelności - A22, obserwowano w drugim tygodniu podchowu.

Już po pierwszym tygodniu podchowu stwierdzono istotne statystycznie różnice w tempie wzrostu i kondycji narybku sandacza, zarówno pomiędzy „wariantami temperaturowymi, jak i żywieniowymi" ($P < 0.05$). Tempo wzrostu ryb karmionych paszą sztuczną i przetrzymywanych w wodzie o temperaturze 22 i 24 ^{o} C było dużo szybsze niż ryb z grup A18 i A20 oraz grup kontrolnych.

Wskaźnik względnego przyrostu całkowitej biomasy obsad - SGR_B (uwzględniający przyrost masy i przeżywalność) najwyższą wartość przyjął dla grupy A22. Wartość tego parametru, obliczona dla ryb z grupy A24, była czterokrotnie niższa - różnice te okazały się istotne statystycznie ($P < 0.05$).

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