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THE IMPACT OF WATER TEMPERATURE ON THE GROWTH AND SURVIVAL OF JUVENILE NORTHERN PIKE (*ESOX LUCIUS* L.) REARED ON FORMULATED FEED

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ABSTRACT. The aim of the experiment was to determine the impact water temperature has on the growth and survival of juvenile northern pike, *Esox lucius* L., reared on formulated feed. The initial experimental material weighed 5.7 g and measured 8.8 cm in body length and was stocked into three recirculating systems (water temperature 20, 24, 28°C) and reared for 21 days. The highest final body weight was obtained by the fish reared at 28°C. Statistically significant differences were confirmed between these fish and those reared at a temperature of 20°C ($P < 0.01$), but no such differences were recorded with regard to the group of fish reared at 24°C ($P > 0.05$). At a temperature of 28°C, the survival of the fish was significantly higher at 98.7% ($P < 0.05$). A statistically significant difference ($P < 0.05$) was also confirmed in the feed conversion ratio (FCR) between the groups reared at water temperatures of 20 and 28°C at 0.61 ± 0.05 and 0.71 ± 0.04, respectively.

Key words: NORTHERN PIKE (*ESOX LUCIUS)*, TEMPERATURE, FORMULATED FEED, GROWTH, RECIRCULATION SYSTEMS

INTRODUCTION

Northern pike, *Esox lucius* L., is a widely-distributed species that occurs naturally in the circumpolar regions of three continents (Crossman 1996). Its ecological significance is high as it is a predator that regulates populations of smaller fish. It is also of considerable economic importance and is highly prized by anglers. In many areas, populations of this species are aided by stocking programs that most frequently utilize the youngest development stages (Mickiewicz 2002), which, however, suffer the highest mortality rates (Ivanova and Svirskaya 2002). Cultivated pike stocking material is produced primarily in ponds and illuminated cages (Ziliukiene and Ziliukas 2002). The effects of such cultivation are highly unpredictable, primarily due to substantial variations in environmental conditions, strong cannibalism (Skov et al. 2003), and pressure

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from other aquatic organisms (Louarn and Cloarec 1997). Attempts are also being made to cultivate pike under controlled conditions with formulated feed, although satisfactory results have been achieved thus far only with regard to the youngest development stages (Wolnicki and Górny 1997). The fundamental challenge that occurs in the further rearing of this species is cannibalism. Additionally, there is also a lack of a range of data necessary for determining optimum cultivation conditions. The most important factors contributing to the effectiveness of rearing include feeding and water temperature (Hardy and Litvak 2004). Knowing the appropriate water temperature range for cultivation is of particular importance in recirculating systems as this parameter can be controlled as is required.

The aim of this experiment was to determine the impact water temperature has on growth, survival, and the effectiveness of formulated feed utilization by pike juveniles cultivated in recirculating systems.

MATERIALS AND METHODS

The experimental material was obtained from artificial reproduction and initial larval rearing conducted in spring 2005 at the Dgał Experimental Hatchery of the Inland Fisheries Institute (IFI) in Olsztyn (Poland). Prior to the experiment, the fish were sorted with a bar sorter (SDK Ostróda, Poland) in order to separate out the substantially larger cannibal fish. The age of the fish at the beginning of the experiment was 71 days post-hatch, the mean body weight was 5.7 ± 1.3 g, and the mean body length was 8.8 ± 0.7 cm. The experiment was conducted in three recirculating systems in rearing tanks (a volume of 1 m^3), at water temperatures of 20.0 ± 0.2, 24.0 ± 0.1, 28.0 ± 0.0°C (groups T20, T24 , T28 in replicates of three for each group). The duration of the experiment was 21 days. The water temperature in each recirculating system was maintained with an electronic monitor (Dixell XR 20C) and a system of electric heaters. When the fish were stocked into the tanks the water temperature in the recirculating systems was 19.6°C. The planned experimental temperature was achieved after 32 hours, and this is when feeding was begun. Measurements of body weight (to the nearest ± 0.1 g) and body length (± 1 mm) were performed on 20 fish from each tank at the beginning and end of the experiment. These measurements were performed using the anesthetic Propiscin (IFI Olsztyn, Poland). At the beginning and conclusion of the experiment, all of the fish were weighed in order to determine the total fish biomass in each tank, which was 2005 ± 5 g when the experiment began. The biomass was tracked by monitoring weight every seven days in order to tailor the feed ration to the increasing fish biomass.

The fish were fed the commercial feeds T-T Nutra (52% protein, 20% fat, digestible energy 19.8 MJ kg^{-1}) and T – 1P Sturio (47% protein, 14% fat, digestible energy 18.5 MJ kg^{-1}) manufactured by Nutreco Holding N.V. The initial daily feed ration was 2, 3, and 4% of the fish biomass in groups T20, T24, and T28, respectively. During the course of the experiment the feed ration was gradually reduced in groups T24 and T28 to 2.5 and 3% of the fish biomass, respectively. The fish were fed 24 hours day^{-1} with band feeders. The tanks were illuminated continuously at a water surface light intensity of 232.2 ± 67.0 lx (group T20), 222.2 ± 116.7 lx (group T24), and 211.6 ± 118.2 lx (group T28). The oxygen content at the outflow was measured daily (CyberScan PCD 5500 meter, Eutech Instruments). The contents of total ammonia nitrogen (TAN = NH_4^+-N + NH_3-N) (Nesslerization method) and nitrites (NO_2-N) (sulphanilic acid method) (Hermanowicz et al. 1999) were determined twice weekly. The quantity of these compounds in the water did not exceed the following values of TAN at 0.18, 0.25, 0.35 mg dm^{-3} and nitrite at 0.08, 0.21, 0.22 mg dm^{-3} for temperatures 20, 24, and 28°C, respectively. The water pH ranged from 7.94 to 8.13.

Following the conclusion of the experiment, the following parameters were calculated:

$$FCR = F \times B^{-1}$$

where: FCR – feed conversion ratio, F – quantity of feed (kg), B – fish biomass gain (kg);

$$CV = (SD \times BW^{-1}) \times 100$$

where: CV – coefficient of body weight variation (%), SD – standard deviation (g), BW – mean body weight (g);

$$K = 100 \times BW \times lc^{-3}$$

where: K – Fulton condition coefficient, BW – body weight (g), lc – body length (cm).

Statistical analyses were performed with Statistica 5.0Pl software. The Tukey test was used to verify differences between groups (differences were considered to be significant at a level of P ≤ 0.05).

RESULTS

Water temperature had a significant impact on fish feeding from the beginning of the experiment. In groups T24 and T28, the fish gathered in the location where the first feed was delivered (*i.e.*, 32 hours after they had been stocked in the tank). In group T20, this was noted after a subsequent 24-hour period. Throughout the experiment, the fewest fish gathered near the feeder in the tank with the lowest water temperature. The slowest growth was noted in the fish from group T20, and the final mean body weight was 11.90 ± 1.41 g. This differed significantly statistically from the mean weight of the fish from groups T24 ($P < 0.05$) and T28 ($P < 0.01$) (Fig. 1). No significant differences were noted, however, between the final mean body weights in groups T24 and T28. The coefficient of body weight variation (CV) ranged from 19.4 ± 3.6% (group T24) to 26.4 ± 2.7% (group T20), and the differences noted were not statistically significant ($P > 0.05$). The longest body length was obtained by the fish reared at a temperature of 24°C and the shortest by those reared at 20°C (Table 1). The difference between these groups was statistically significant ($P < 0.05$).

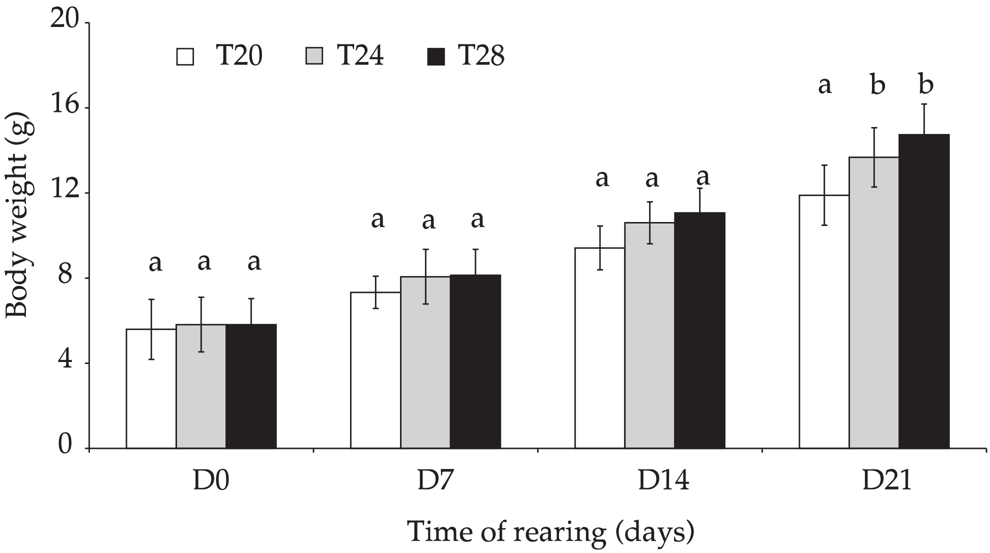

Fig. 1. Growth in body weight of pike juveniles reared in different water temperatures (mean ± SD). Data with the same letter index do not differ significantly statistically ($P > 0.05$).

TABLE 1

Selected final rearing indexes for pike juveniles reared at different water temperatures (mean values ± SD)

Specification	Water temperature (°C)		
	20	24	28
Initial body weight (g)	5.60 ± 1.41	5.81 ± 1.28	5.82 ± 1.23
Final body weight (g)	11.90 ± 1.41[a]	13.68 ± 1.39[b]	14.74 ± 1.45[b]
Daily body weight growth (g d^{-1})	0.30 ± 0.07	0.37 ± 0.07	0.42 ± 0.07
Specific growth rate – SGR (% d^{-1})	3.56 ± 0.59	4.05 ± 0.48	4.42 ± 0.46
Coefficient of body weight variation - CV(%)	26.4 ± 2.7[a]	19.4 ± 3.6[a]	24.2 ± 3.5[a]
Initial body length (cm)	8.70 ± 0.73	8.77 ± 0.65	8.82 ± 0.61
Final body length (cm)	11.24 ± 0.50[a]	11.63 ± 0.44[b]	11.60 ± 0.24[ab]
Daily body length growth (cm d^{-1})	0.12 ± 0.02	0.14 ± 0.02	0.13 ± 0.01
Condition coefficient – K	0.82 ± 0.01[a]	0.86 ± 0.01[ab]	0.93 ± 0.03[c]
Feed conversion ratio – FCR	0.61 ± 0.05[a]	0.70 ± 0.04[ab]	0.71 ± 0.04[bc]
Survival (%)	90.2 ± 3.5[a]	87.0 ± 3.0[a]	98.7 ± 1.6[b]

Data in rows with the same letter index do not differ significantly statistically (P > 0.05)

The survival index was the most advantageous (98.7%) at the highest temperature (Table 1). This difference was statistically significant in relation to the remaining groups ($P < 0.05$). Substantial differences were noted in the condition coefficient of the analyzed groups. The highest values (0.93 ± 0.03) were recorded in the fish from group T28, and the differences in relation to the other groups were statistically significant at $P < 0.05$ at 24°C and $P < 0.01$ at 20°C (Table 1).

The best feed conversion ratio (FCR) was obtained in group T20 at 0.61 ± 0.05, while the highest at 0.71 ± 0.04 was obtained in group T28. The differences between these groups were statistically significant ($P < 0.05$) (Table 1).

DISCUSSION

The ability to produce stocking material depends largely on knowledge of the factors that permit effective fish growth. The results of the current experiment indicate, similarly to those of studies of many other fish species (Kelly and Arnold 1999, Cotton et al. 2003), that water temperature has a substantial impact on the results of pike rearing. The current experiment confirmed that the most advantageous temperature for fish growth within the analyzed range is 28°C. At this temperature, the fish attained the fastest growth rate at a very high survival rate. The optimal temperature for rearing pike juveniles is higher than that confirmed for larvae reared under controlled conditions, which, according to Wolnicki and Górny (1997), is 24°C for this development stage. It is possible that the optimal temperature for larval growth is even higher. This is indicated by the fact that in the current experiment no decrease in growth rate was noted, which is something that occurs when the optimal temperature is exceeded (Kamler 1992, Wolnicki 2005). Rearing at such a high temperature (28°C) is an additional problem for the production of stocking material since this water temperature practically does not occur in the natural environment of pike. For example, the maximum water temperature in the ponds of the Dgał Experimental Hatchery (northern Poland), where the experiment was conducted, did not exceed 26.7°C in the 2001-2005 period (Szczepkowski, unpublished data). This problem is related to the necessity of acclimatizing fish to new thermal conditions, which is undoubtedly more difficult to do than when rearing is done at lower temperatures. Simultaneously, fish reared at high temperatures have substantially larger energy stores (as indicated by the statistically significantly higher value of the condition coefficient), thanks to which the adaptation period of these fish to new and different environmental conditions is longer. This theory requires further verification.

The current experiment confirms that pike are highly flexible with regard to water temperature. Previously, this opinion was applied primarily to the embryos and larvae of this species (Załachowski 2000, Ziliukiene and Ziliukas 2002). However, in the case of these developmental stages, this trait must be viewed as an adaptation to the possibility of substantial temperature variation in the shallow shore waters that are their natural environment during the early stages of individual development. In the current experiment, it was determined that the most advantageous temperature for rearing juveniles is higher than that which occurs in the natural environment. Similar observations have been reported for a variety of other fish species for which it was confirmed that the optimal temperature for growth and the range of temperatures tolerated are both substantially higher than those encountered in the natural environment. One example is the Acipenseridae fishes, including the Siberian sturgeon, *Acipenser baeri stenorhynchus* Nikolski. The optimal temperature for growth in this species is approximately 24°C and the tolerated temperature reaches approximately 30-32°C (Kolman 1999), while the temperature in its natural environment seldom exceeds 17°C (Ruban 1999).

The results of the current experiment also indicate that rearing pike juveniles using formulated feed can be highly effective. The best evidence in support of this is the high survival index values and the fast growth rates that were obtained (body weight doubled at a temperature of 20°C and nearly tripled at 28°C). This was possible thanks to limiting cannibalism; only single cases of definite fish cannibals were noted in the pike stocks. In the opinion of the author, the decrease in cannibalism was the result of the initial size segregation of the fish, which reduced intra-group size variation. According to some authors, too high a degree of intra-group size variation among pike is one of the foremost causes of cannibalism, regardless of environmental conditions (Skov et al. 2003). Similar dependencies were noted during earlier attempts at the initial rearing of pike using formulated feed (Szczepkowski et al. 1999); however, no pronounced territorial behavior, which is characteristic of adult fish, was noted. To the contrary, the majority of the fish gathered in large groups near the feeder in the upper water layer or near the bottom. In earlier rearing experiments, the fish cannibals occupied a separate position (Szczepkowski, unpublished data). Some authors, however, have reported that territorial behavior may be dependent on the season of the year and is significantly weaker during the winter period (Hawkins et al. 2003).

The feed utilization by the fish, expressed by low values of the FCR coefficient, did not differ in the current experiment from that obtained for many other fish species under controlled conditions (Wognarova et al. 2003, Zakęś et al. 2001). The increasing values of the FCR along with increasing temperature could have been caused by the larger feed ration, on the one hand, or by decreased feed utilization resulting from deteriorating oxygen conditions that reduce the ability of the feed to dissolve. In the current experiment, the minimum oxygen content in the water at the tank outflows was 5.5 mg O_2 dm^{-3} at 28°C, 6.5 mg O_2 dm^{-3} at 24°C, and 7.8 mg O_2 dm^{-3} at 20°C. Thus, it cannot be ruled out that the differences noted could have had an impact on the effectiveness of feed utilization.

To summarize, it can be concluded from the results of the current study that effective pike rearing can be conducted within a wide temperature range, which is advantageous from the point of view of rearing biotechnology. However, the possibility of applying this knowledge in practice is largely dependent on determining the fate of this material after it has been released into the natural environment.

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WPŁYW TEMPERATURY WODY NA WZROST I PRZEŻYWALNOŚĆ MŁODOCIANEGO SZCZUPAKA (*ESOX LUCIUS* L.) PODCHOWYWANEGO NA PASZACH SZTUCZNYCH

Celem badań było określenie wpływu temperatury wody na wzrost i przeżywalność juwenalnego szczupaka podchowywanego na paszach sztucznych. Materiał o początkowej masie 5,7 g i długości ciała 8,8 cm obsadzono w trzech obiegach recyrkulacyjnych (temperatury wody 20, 24 i 28°C) i podchowywano w ciągu 21 dni (rys. 1). Największą końcową masę ciała osiągnął narybek podchowywany w temperaturze 28°C – stwierdzone różnice były istotne statystycznie w stosunku do ryb utrzymywanych w temperaturze 20°C ($P < 0{,}01$), ale nie były istotne statystycznie w porównaniu z grupą ryb przetrzymywanych w 24°C ($P > 0{,}05$). W temperaturze 28°C przeżywalność narybku była istotnie statystycznie wyższa i wyniosła 98,7% ($P < 0{,}05$). Stwierdzono istotne statystycznie różnice ($P < 0{,}05$) w wartościach współczynników pokarmowych pasz (FCR) między grupami podchowywanymi w wodzie o temperaturach 20 i 28°C, które wyniosły odpowiednio $0{,}61 \pm 0{,}05$ i $0{,}71 \pm 0{,}04$ (tab. 1).