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THE INFLUENCE OF WATER TEMPERATURE ON THE GROWTH, SURVIVAL, CONDITION AND BIOLOGICAL QUALITY OF JUVENILE BURBOT, *LOTA LOTA* (L.)

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ABSTRACT. Growth, survival, condition (Fulton's coefficient) and biological quality (salinity stress test) were compared in 2-month-old burbot (20 mg BW, 10.9 mm TL) reared at 12, 15, 18, and 21°C. At 15°C, the fish showed the best growth in BW and TL (170 mg and 24.5 mm, respectively), and the highest final survival rate (97%), whereas their condition coefficient and tolerance to salinity proved to be the second best. This may indicate that a temperature of 15°C should be used for the practical purposes of juvenile burbot mass production under controlled conditions.

Key words: *LOTA LOTA*, JUVENILES, TEMPERATURE, GROWTH, SURVIVAL, BIOLOGICAL QUALITY

INTRODUCTION

The natural range of burbot, *Lota lota* (L.) has been continuously decreasing since the beginning of the twentieth century. This has been accompanied by a considerable fall in fish number mainly due to years of overfishing and the lack of stocking programs (Steiner et al. 1996).

Studies carried out in the last decade (Guthruf et al. 1990, Ryder and Pesendorfer 1992, Ghan and Sprules 1993) have finally reversed the opinion of burbot as a pest which devours the eggs of valuable lacustrine and riverine commercial fish species. This has resulted in an increased interest in burbot biology, and in possibilities of producing stocking material in earthen ponds. In some European countries, attempts have also been made to use tank-reared juvenile burbot as stocking material (Steiner et al. 1996).

The rather abundant data regarding the pond production of burbot stocking material directly from the larval stages indicate that this method is very inefficient, especially in terms of survival. According to Harsányi and Aschenbrenner (1992), Štipek (1992), Kainz and Gollmann (1996), and Wolnicki et al. (1999b), the survival of burbot reared in ponds from the yolk-sac until the autumn fry stage usually does not exceed 6-8%. Therefore, other, more efficient methods of burbot pre-rearing under controlled conditions should be developed (Steiner et al. 1996, Wolnicki et al. 1999b).

The aim of the present study was to evaluate the effect of temperature on the growth, survival and condition of burbot juveniles reared under controlled conditions. Moreover, the effect of temperature on the biological quality of fish was evaluated using the salinity test (Dhert et al. 1992a, b). These issues are of key importance for developing the optimum technology for mass producing burbot stocking material.

MATERIAL AND METHODS

The burbot larvae used in the investigations were the offspring of numerous males and females harvested from the Odra River system. From the age of ten days post-hatch (average TL 4.0 mm), the larvae were reared under controlled conditions for 30 days before the experiment. Approximately 2500 individuals were kept in a glass flow-through tank with a volume of 40 dm^3. The water was continuously recirculated and passed through a biological diatomite filter (Wolnicki 1993). The water temperature in the rearing tank was 12 ± 0.5°C. The fish were fed newly hatched brine shrimp *Artemia franciscana* nauplii (INVE Aquaculture, Belgium) five times daily at 08.00, 11.00, 14.00, 17.00, and 20.00. Between 08.00 and 22.00 the tanks were illuminated with bright, artificial light at about 2000 lx at the water surface. At the end of the initial period, the fish reached an average total length of 10.9 ± 0.9 mm (TL ± SD) and body weight of 20.0 ± 5.8 mg (BW ± SD). These fish were transferred to eight flow-through aquaria (V = 20 dm^3) divided into four groups. Each tank was stocked with 300 fish. One pair of aquaria was left in the water recirculation system where the temperature remained unchanged. The other three pairs of aquaria were placed in three separate identical rearing systems with water recirculation.

The experiment began with the first feeding soon after stocking, and lasted for 20 days. At the same time, the water temperature was gradually increased in the three systems to the final levels of 15, 18, and 21°C (± 0.5°C) at the end of the first day.

The fish were fed the same food in the same way as during the initial rearing period. Light conditions were also the same. Each amount of brine shrimp nauplii, which was the same for each tank, was established by observing the fish showing the fastest growth and the greatest appetite. All the fish were fed *ad libitum*, which ensured that each portion of food was available for three hours until the next feeding.

Complete water exchange in the aquaria lasted about 1.5 h. The water temperature and dissolved oxygen saturation were measured twice daily, and the water pH, nitrite and ammonia concentrations were measured every several days. None of the parameters exceeded acceptable values.

Unconsumed food and feces were removed from the bottom of the aquaria every night. Fish mortality was monitored continuously, and the dead fish were counted and immediately removed.

Samples of 25 fish were taken from each aquarium every fifth day, and on the last day of the experiment 50 were collected. Each fish was weighed to the nearest 0.1 mg, and the fish from the final sample were also measured (TL to within 0.01 mm). All the fish were counted at the end of the experiment. The burbot growth rate was calculated according to the formula: $\mathbf{ITL = (L_n - L_0)/ n}$, where $\mathbf{L_n}$ and $\mathbf{L_0}$ – final and initial TL in mm, respectively, and **n** – rearing duration in days. The condition of juvenile burbot was evaluated using Fulton's condition coefficient (**K**) and calculated according to the formula: $\mathbf{K = 100 \quad W \ L^{-3}}$, where **W** – BW in mg, and **L** – TL in mm.

The significance of the differences in fish growth (total length, body weight, growth rate), and condition (K coefficient) among the experimental groups was evaluated using Duncan's test ($P \leq 0.05$). The final results of fish survival as expressed in percentages were recalculated using arcus sinus transformation (Sokal and Rohlf 1969), and the differences were assumed significant at $P \leq 0.05$.

The biological quality was evaluated indirectly using the salinity test (Dhert et al. 1992a, b, Myszkowski and Wolnicki 1998a, b, Wolnicki and Myszkowski 1998), commonly applied in aquaculture. It is assumed that the individuals which are more tolerant to an extremely strong stressor, namely sodium chloride (NaCl), are also more tolerant to other environmental factors, thus exhibiting higher biological quality. The working concentration of sodium chloride, or that which causes a reaction in all tested specimens in approximately 60 min (Dhert et al. 1992a, b), was established in preliminary tests, and was equal to 30 mg NaCl dm^{-3}. The test was carried out at a temperature of 12 ± 0.5°C, which was the same as that in the Żabieniec ponds in central Poland during the last days of the experiment and on the test day. The fish reared at 15, 18, and 21°C were acclimated to this temperature for 16 h, following a gradual temperature decrease in the rearing tanks for 8 h. Thirty six (3 × 12) fish from each temperature were used in the test.

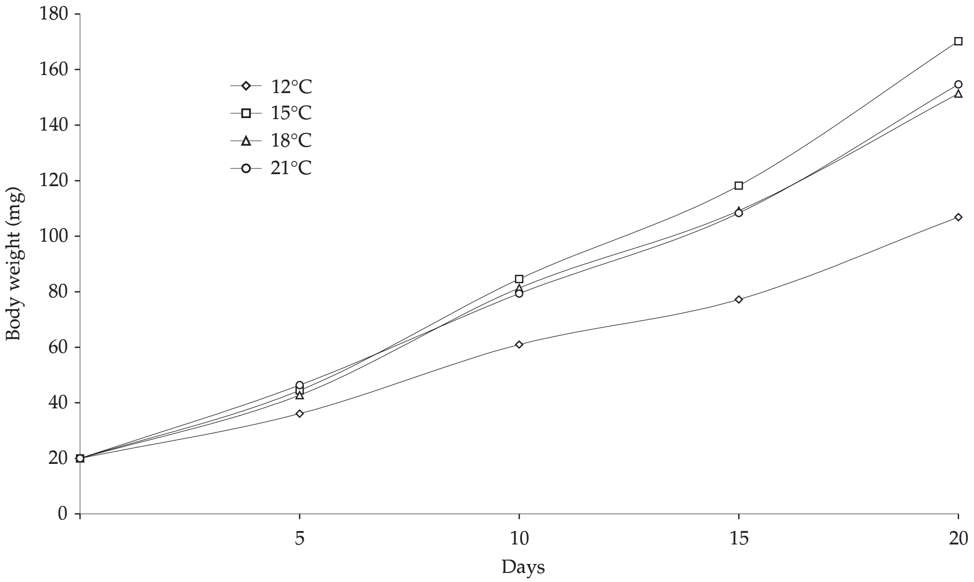

Fig. 1. Growth in body weight of burbot juveniles reared at different water temperatures.

RESULTS

GROWTH AND SURVIVAL

The burbot growth rate at 12°C was lower than at higher temperatures (Fig. 1). At the end of the experiment, the fish reared at 15°C had a significantly ($P \leq 0.05$) higher body weight (170 mg, Table 1). The rate of total length increase of burbot reared at 15, 18, and 21°C did not significantly differ, and was about 0.7 mm d^{-1}.

TABLE 1

Average body weight (BW), average total length (TL), increment in total length (ITL), survival rate (S), and average Fulton's coefficient (K) of burbot juveniles reared at different water temperatures

Temperature (°C)	BW (mg)	TL (mm)	ITL (mm d^{-1})	S (%)	K
12	107^{c}	19.9^{b}	0.45^{b}	97^{a}	1.33^{a}
15	170^{a}	24.5^{a}	0.68^{a}	97^{a}	1.16^{b}
18	151^{b}	24.2^{a}	0.67^{a}	94^{b}	1.05^{c}
21	155^{b}	24.6^{a}	0.69^{a}	92^{b}	1.02^{c}

Data with the same superscripts do not differ significantly at a level of 0.05.

Fish mortality was low in all the groups and occurred mainly in the initial period of rearing. The cause of death is unknown except in several cases when fish sustained body injuries during tank cleaning. The mortality was slightly higher at 18 and 21°C than at the lower temperatures. The final fish survival ranged from 92% at 21°C to 97% at 12 and 15°C (Table 1).

CONDITION

The fish reared at the lowest water temperature showed the highest Fulton's coefficient value (K = 1.33, Table 1) with a statistical significance of $P \leq 0.05$. The K values of fish from 21 and 18°C did not significantly differ and were lower than at 15°C (K = 1.16).

TOLERANCE TO SALINITY

The fish from the 18°C group were significantly ($P \leq 0.05$) the most salinity-tolerant (S.I. = 3.3, Table 2). Average reaction time (death) did not, however, differ between the 18 and 15°C groups (40.5 and 38.5 min, respectively). The fish reared at the highest and lowest temperatures were the least tolerant, and their reaction time and stress index did not differ.

TABLE 2

Response to salinity in juvenile burbot reared at different water temperatures (lower S.I. values mean higher tolerance to stressor)

Rearing temperature (°C)	Mean response time* (min)	Stress index** S.I.
12	34.2^{b}	4.5^{c}
15	38.5^{a}	3.8^{b}
18	40.5^{a}	3.3^{a}
21	34.2^{b}	4.3^{c}

*Data with the same superscripts do not differ significantly (Duncan's multiple range test, P > 0.05; *N = 36; **N = 3)*

DISCUSSION

Several reported attempts of rearing burbot juveniles under at least partially controlled conditions have been carried out at temperatures of up to 12°C (Vachta 1990, Steiner et al. 1996). However, the results of recent studies indicate that higher temperatures are necessary for optimum burbot growth.

According to Wolnicki et al. (1992a), burbot larvae grew faster at 15-21°C than at 12 and 24°C was assumed to be the upper limit of the thermal optimum for juvenile burbot growth.

The results of the present study clearly show that the thermal demands of early post-larval burbot are similar to those of burbot larvae. The results of the investigation indicate that juvenile burbot grow best at 15°C; this is especially apparent in terms of body weight (Fig. 1, Table 1). Specimens reared at this temperature had a higher condition coefficient value in comparison to fish reared at higher temperatures, although it was lower than that of specimens reared at 12°C. No data are available in the literature regarding the relationship between the Fulton's coefficient, which describes fish condition, and the value of fish as stocking material. It should be assumed, however, that higher values of this coefficient are advantageous, just as, undoubtedly, larger individual size is also preferable. The data in Table 1 indicate that rearing burbot at temperatures above 15°C does not produce faster growth and may also cause higher mortality. A similar effect was observed for burbot larvae (Wolnicki et al. 1999a), but in that experiment mortality was obviously induced by parasitic protozoa (*Chilodonella* sp.) which developed most quickly at temperatures from 18 to 24°C.

The data above and the results of the salinity test (Table 2) indicate that 15°C is not only the optimal temperature for burbot growth, but it also seems to be optimal for practical purposes. It is noteworthy that considerable changes in water temperature and the short acclimation period prior to the salinity test apparently did not reduce the biological quality of burbot reared at 15-21°C in comparison to fish reared and tested at 12°C.

The evaluation of the actual usefulness of burbot reared at various temperatures to further pond rearing or stocking in natural waters is impossible without field studies. The salinity stress test is only an indirect method to assess the biological value of aquatic animals (Dhert et al. 1992 a, b). Therefore, it cannot be excluded that statistically significant qualitative and quantitative differences among the experimental groups of burbot observed in the present study are of little practical value. Even if this is the case, the mass production of stocking material should be carried out at the optimum growth temperature at least to shorten the rearing period. According to Steiner et al. (1996), burbot of 45 mm TL are appropriate for stocking. These authors obtained such fish after 96 days of rearing at temperatures up to 12°C, which means that the average daily growth rate was about 0.42 mm. Rearing burbot at the optimum temperature of 15°C during the larval (Wolnicki et al. 1999a) and post-larval periods (Table 1) would allow the stocking material production period to be shortened by about 20 days.

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STRESZCZENIE

WPŁYW TEMPERATURY WODY NA WZROST, PRZEŻYWALNOŚĆ, KONDYCJĘ I JAKOŚĆ BIOLOGICZNĄ MŁODOCIANEGO MIĘTUSA, *LOTA LOTA* (L.)

Wyjściowym materiałem badawczym był młodociany miętus, *Lota lota* (L.), w wieku 40 dni od wyklucia, o średniej masie ciała i długości (L.t.) odpowiednio 20,0 mg i 10,9 mm. Ryby podchowywano przez 20 dni w stabilizowanej (± 0,5°C) temperaturze wody 12, 15, 18 i 21°C, w przepływowych 20-litrowych akwariach, w obsadzie 15 sztuk na dm^3. Pokarmem miętusa były żywe naupliusy *Artemia franciscana*. Ocenę wpływu termicznych warunków podchowu na ryby przeprowadzono w oparciu o ich końcowe rozmiary, przeżywalność, kondycję (współczynnik Fultona) oraz – po aklimacji wszystkich osobników do 12°C – oporność na ekstremalne stężenie chlorku sodu (30 mg NaCl dm^{-3}) w tak zwanym teście stresu zasolenia. Najlepszy wzrost miętusa stwierdzono w temperaturze 15°C, w której ryby osiągnęły średnią masę ciała 170 mg, przy długości 24,5 mm. W tej temperaturze zanotowano także najwyższą przeżywalność (97%, tak jak w 12°C) oraz drugą w kolejności najlepszą kondycję. Największą opornością na zasolenie wody charakteryzowały się ryby z temperatury 15 i 18°C. W świetle wszystkich wyników badań temperatura 15°C jest nie tylko optymalną dla wzrostu młodocianego miętusa. Można ją również uznać za optymalną temperaturę podchowu. Z tych względów zasługuje ona na rekomendację do celów produkcyjnych.

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