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Short communication

TEMPERATURE-INFLUENCED GROWTH AND SURVIVAL OF BURBOT *LOTA LOTA* (L.) LARVAE FED LIVE FOOD UNDER CONTROLLED CONDITIONS

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ABSTRACT. The growth and survival of burbot *Lota lota* (L.) larvae reared from the first feeding on freshly hatched *Artemia franciscana* nauplii at 12, 15, 18, 21, and 24°C was compared in a 20-day experiment. Nauplii of the commercial strain *Artemia* proved to be an excellent start diet for *L. lota* larvae. The best fish growth was found at 21°C where they attained a final average total length of 14.4 mm and an average body weight of 37.1 mg. The highest final survival rates of 90 and 92% were recorded at 12 and 15°C, respectively. At all higher water temperatures, larval final survival rates were significantly lower, with the minimum value of 41% at 24°C. In light of these results, it is evident that either temperatures lower or higher than 21°C are outside of the optimal range for *L. lota* larvae as they produce relatively slow growth or poor survival or both.

Key words: *LOTA LOTA*, LARVAE, LIVE FOOD, GROWTH, SURVIVAL, TEMPERATURE OPTIMUM

Burbot *Lota lota* (L.), which was widely distributed and abundant in the northern regions of the world a century ago, is presently considered to be one of the most endangered freshwater fish species in many parts of Europe (Harsányi and Aschenbrenner 1992). The principle causes of this include disturbances in habitat, inhibition of spawning migrations, overfishing and the lack of stocking programs (Harsányi and Aschenbrenner 1992, Steiner et al. 1996). To restore natural burbot populations, intensive indoor techniques of stocking material production should be developed (Wolnicki et al. 1999, Wolnicki 2001). However, relatively little is still known about burbot biology in the first months of life (Ryder and Pesendorfer 1992).

The aim of this work was to assess the effect of water temperature on the growth and survival of burbot larvae under controlled conditions. Obviously, knowledge on larval temperature requirements is an essential prerequisite of optimizing live diet-based burbot larviculture.

Burbot larvae, which were the pooled offspring of many wild spawners, were reared from the first feeding (day 10 post-hatch) over a period of 20 days. Larvae of an initial size of 3.61 ± 0.27 mm (average TL ± SD; N = 15) were stocked into 20-dm^3 flow-through aquaria at 18 per dm^3. Five constant water temperatures of 12, 15, 18, 21 and 24°C (range ± 0.5°C), all in duplicate, were employed in the experiment. The water exchange ratio in the aquaria was set at once per 1.5 h. The dissolved oxygen content in the aquaria always exceeded 65% of saturation, the pH varied between 7.5 and 8.0 and the ammonia and nitrite concentrations were maintained below 0.1 and 0.02 mg dm^{-3}, respectively.

The larvae were fed intensively with live, freshly hatched *Artemia franciscana* nauplii (grade III, ARGENT Chemical Laboratories, USA). The food was delivered manually in noticeable surplus five times a day between 08.00 and 22.00. During the same period, the aquaria were artificially lit at approximately 1000 lx at the water surface. The aquaria were cleaned twice a day, but dead larvae were removed and counted immediately after they were seen. All the fish remaining in the aquaria were counted on the final day of the experiment.

The fastest larval growth, either in terms of total length or body weight, was recorded for the temperature of 21°C, whereas at 12°C the larvae grew the slowest (Table 1). When the fish of the former group attained an average TL and BW of 14.4 mm and 37.1 mg, respectively, the latter reached only 9.8 mm and 11.1 mg, respectively. No differences were observed in larval growth in TL between the temperatures of 15, 18, and 24°C or in BW between 18 and 24°C.

A final survival rate of at least 90% was observed for the burbot reared at 12 and 15°C; this figure was significantly higher than that at the other water temperatures (Table 1). The fish reared at 21°C had the second highest survival rate at 72%. Fish losses were noted throughout the experiment at all temperatures (Fig. 1). The highest losses were observed from day 10 onwards at 18°C and up to day 5 at 24°C. Although all the dead larvae were collected at temperatures of 12, 15 and 18°C, 5 and 19% of those at 21 and 24°C, respectively, were not recovered. This was most likely due to the rapid decomposition of their minuscule bodies at night at the outset of the experiment. The parasitic protozoan *Chilodonella* sp. appeared on day 12 at all temperatures. Therapeutic treatments (80 ppm formaldehyde for 30 min - Antychowicz 1996) on days 12 and 15 did not noticeably contribute to a decrease in either high burbot losses at 18°C or the considerably lower ones at 21 and 24°C (Fig. 1). It should be stressed that no cannibalism occurred at any water temperature throughout the experiment, although in this species it may appear at about 12 mm TL (Sorokin 1968).

TABLE 1

Average total length (TL), average body weight (BW), and final survival rate (S) of burbot larvae reared at different temperatures

Temperature (°C)	TL ± SD (mm)	BW ± SD (mg)	S (%)
12	9.8 ± 0.9[c]	11.1 ± 3.6[d]	90[a]
15	12.9 ± 1.6[b]	31.8 ± 12.6[b]	92[a]
18	12.5 ± 1.6[b]	28.3 ± 9.9[c]	57[c]
21	14.4 ± 1.8[a]	37.1 ± 12.9[a]	72[b]
24	12.5 ± 2.1[b]	26.7 ± 11.1[c]	41[d]

In columns, the data with the same superscripts do not differ significantly at P = 0.05. TL and BW - Duncan's multiple range test, N=100; S - normalized using angular transformation (Sokal and Rohlf 1969).

Burbot early larvae are known to have a relatively large mouth opening at a relatively minuscule body size (Ghan and Sprules 1993, Steiner et al. 1996). It is also a well-known fact that feeding larval burbot exclusively with dry diets is rather useless due to the extremely poor acceptance of most formulated feeds (Kainz and Gollmann 1996, Wolnicki et al. unpublished data). However, there are also contradictory opin-

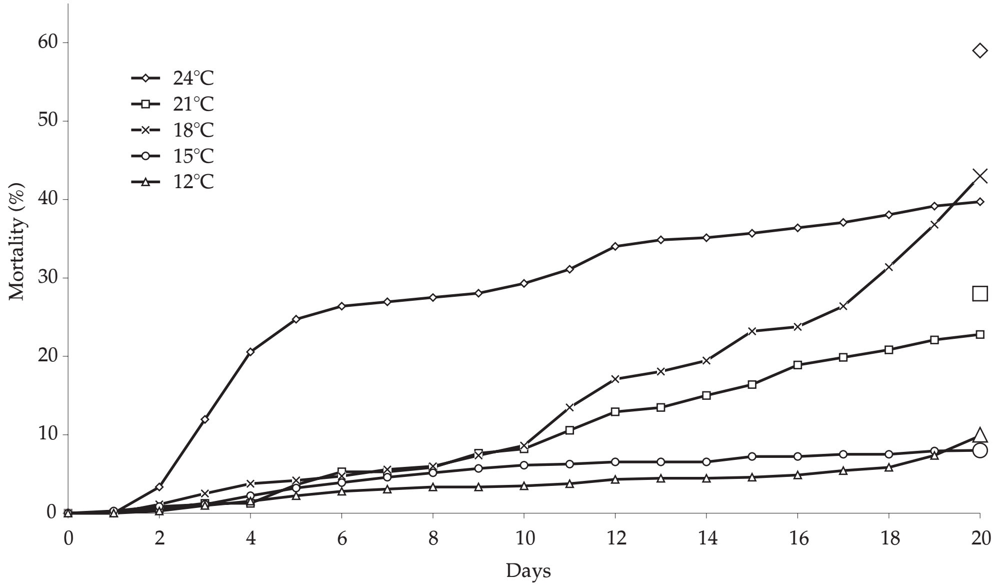

Fig. 1. Cumulated observed mortality and final mortality (larger marks) of burbot larvae at different temperatures.

ions on the usefulness of different live food organisms as the start diet for larvae of this species. According to either Kujawa et al. (1999) or Shiri Harzevili et al. (2000), worse results were obtained when burbot larvae were fed exclusively with *Artemia* nauplii in comparison to protozoan or mixed diets of microalgae and rotifers because the size of the nauplii was too large.

The current experimental results, however, provide evidence to the fact that larval burbot can be successfully reared on live nauplii of the common commercial strain of *Artemia franciscana* from the very onset of exogenous feeding at a wide range of water temperatures. It should be pointed out that even at 18°C, where the burbot final survival rate was only 57% (Table 1), the cumulative losses recorded on day 10 were lower than 10%, i.e. similar to those found on this day at 12 or 15°C (Fig. 1).

The results of the present study show the considerable influence of rearing temperature on burbot growth in length and weight as well as on their survival (Table 1). As evidenced by these results, a temperature of 21°C would be closest to the optimum growth temperature (OGT) for larvae of this species. The results presented here also indicate that a temperature of 18°C or lower and particularly 24°C are out of the optimal range for larval burbot because of either relatively slow fish growth or unsatisfactory survival or both. Our experimental data concur with the results of Kujawa et al. (1999) who observed fast growth and the high survival of burbot larvae at 20°C.

When the results of this study are compared with those obtained for considerably older burbot it can be concluded that the OGT tends to decrease distinctly as this species ages. The OGT for two-month-old burbot juveniles at 150 mg BW was 15°C (Wolnicki et al. 2001).

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STRESZCZENIE

WPŁYW TEMPERATURY NA WZROST I PRZEŻYWALNOŚĆ LARW MIĘTUSA *LOTA LOTA* (L.) ŻYWIONYCH POKARMEM ŻYWYM W WARUNKACH KONTROLOWANYCH

Celem pracy było zbadanie wpływu temperatury wody (12, 15, 18, 21 i 24°C) na wzrost i przeżywalność larw miętusa *Lota lota* (L.) karmionych naupliusami *Artemia franciscana* w kontrolowanych warunkach środowiskowych. Larwy o początkowej średniej długości całkowitej 3,61 mm podchowywano od dziesiątego dnia po wykluciu przez 20 dni w zagęszczeniu 18 sztuk na dm^3. Najlepszy ich wzrost zanotowano w 21°C, w której na zakończenie doświadczenia osiągnęły średnią długość całkowitą 14,4 mm i średnią masę ciała 37,1 mg, przy przeżywalności 72% (tab. 1). Larwy uzyskały najmniejsze średnie końcowe rozmiary w najniższej temperaturze 12°C (długość całkowita 9,8 mm, masa ciała 11,1 mg), jednak przy bardzo wysokiej przeżywalności 90%. Największe śnięcia odnotowano w najwyższej temperaturze, zwłaszcza w początkowych dniach doświadczenia (rys. 1), wskutek czego końcowa przeżywalność miętusa osiągnęła tam zaledwie 41%. Wyniki doświadczenia udowodniły, że świeżo wyklute żywe naupliusy komercyjnego szczepu solowca mogą być doskonałym pierwszym pokarmem larw miętusa, podchowywanych w szerokim przedziale temperatury wody w warunkach kontrolowanych. W świetle wyników naszych badań temperatura 21°C okazała się najbliższą optymalnej dla wzrostu miętusa w larwalnym okresie życia.

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