First feeding of burbot, *Lota lota* (Gadidae, Teleostei) larvae under different temperature and light conditions

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Abstract

The burbot (*Lota lota*) is the only fresh water member of the cod family, Gadidae, and is adapted to cold waters. The e¡ects of temperature and light on the growth and survival of burbot larvae were investigated under hatchery conditions. Three temperature regimes (12, 16 and 20 1C) were applied under continuous light and darkness during the experiment. Rotifer, *Brachionus calyci£orus* (L.) were fed to the larvae in the ¢rst 10 days and the diet was then replaced with *Artemia* nauplii. At the end of the feeding stage with rotifer, growth in terms of the total length and wet weight were larger at higher temperatures under continuous light. At day 10, survival rates of the ¢sh held at 12 1C under continuous light and darkness regime were higher than those held at 16 1C and 20 1C kept under the same conditions. From day 10 onwards, larval growth improved remarkably after changing the live food from rotifer to *Artemia* in all treatments. At the end of the study, the highest survival rate was recorded among the larvae held at 12 1C exposed to continuous light. Under light condition, the temperature of 20 1C did not result in an improved larval growth compared with 16 1C. This may indicate that high temperature and continuous light are not bene¢cial for larval growth and survival when they reach older stage of development. The results indicate a signi¢cant interaction for the combination of temperature, light and time with respect to survival and wet weight, making unambiguous interpretation of the main e¡ects di⁄cult.

Keywords: burbot, temperature, light

Introduction

The burbot, *Lota lota* L. is a fresh water gadoid adapted to cold waters. In the wild, the burbot is usually inactive during daylight, lying hidden under stones, but emerge to forage at night. Their preferred summer temperature ranges between 8 and 13 1C (Edsall, Kennedy & Horns 1993). Burbot spawn in winter time at a temperature of 1^4 1C (Fabricius 1954; Bonar, Brown, Mongillo & Williams 2000). Embryonic development occurs within a narrow temperature range of 2^6 1C (Jäger, Nellen, Sch˛fer & Shodjai 1980; Kujawa, Kucharczyk & Mamcarz 1999).

Temperature has been identi¢ed to be an important ecological factor for ¢sh, in£uencing almost all aspects of early development (Laurence 1978; Brett 1979; Blaxter 1992; Steinarsson & Bj˛rnsson 1999). Therefore, knowledge on the temperature requirements of a species has important implication for a ecological, ¢shery and aquacultural studies. The e¡ect of temperature on larval development has been studied for several species, but little is known about the environmental tolerance of the early life stages of burbot.

A suitable light level is necessary for active feeding to be successful once exogenous feeding begins, since many ¢sh larvae are visual feeders (Blaxter 1968; Downing & Litvak 1999). Adult burbot prefer darkness and try to hide under bedrock and rubble bottoms in cold waters. Very limited information is found in the literature with regard to the reaction of burbot larvae to light.

The objective of the present study was to identify the optimal conditions of temperature and light for the growth and survival of burbot under hatchery conditions.

Materials and methods

The experiment was carried out in a £ow-through system. Eighteen culture tanks (25 L) were divided among six treatments, each with three replicates comprising three temperatures (12, 16 and 20 1C) in continuous light and three temperatures (12,16 and 20 1C) in total darkness. Temperatures of 12 1C and 20 1C were selected based on the observation of Jäger *et al*. (1980). The authors reported that the food intake by burbot larvae begins when water temperature is above 8 1C. They also observed that the larvae could tolerate up to a temperature of 20 1C.

Three head tanks each containing 300 W heaters were adjusted to deliver a constant water £ow with the desired test temperature (0.2 L min^{-1}) into each of the experimental tanks. In order to obtain absolute darkness (0 mmol $s^{1} m^{-2}$), tanks were covered with blackout cloth. Light was provided by broad-spectrum (400^700 nm) £uorescent tubes mounted at about 500 cm above the water surface and giving a light intensity of 5^6 mmol $s^{1} m^{-2}$. Water originated from a cold spring (10 ± 1 1C). The temperature of the spring water was 12 ± 1 1C upon release of the larvae but gradually, adjusted to 16 1C and 20 1C within 2 days.

Newly hatched burbot larvae were obtained from a semi-industrial hatchery (Hungary). After the yolk-absorption, the larvae were stocked at random in each of the 18 test tanks. The stocking density in the rearing tanks was kept at 1250 larvae per tank (50 individuals L^{-1}). In the ¢rst 10 days of the experiment, all larvae in di¡erent treatments received rotifer *Brachionus calyci£orus* cultured on *Chlorella* sp. using a green water technique (Shiri Harzevili, De Charleroy, Auwerx, Vught, Van Slycken, Dhert & Sorgeloos 2003). At the yolk sac stage they measure 3^4 mm. Small food items are needed to ful¢l the demand of burbot larvae in the early period of exogenous feeding. Algae (*Chlorella* sp.) were added to the larval rearing tank at a concentration of 10^5 cells mL^{-1}. After 10 days, all treatments were given *Artemia* nauplii (4 *Artemia* mL^{-1}). The experiment was terminated after 20 days and every 5 days a random sample of 30 larvae were removed from each tank for measurement of length and wet weight. Fish length was measured to the nearest (0.1 mm) with a binocular equipped with an ocular micrometer. Larval survival was determined on day 10 and on the last day of the experiment (day 20). Due to larval mortality, no length and wet weight was recorded in the treatment group of 20 1C and darkness at the end of the study. The initial larval total length (mean ± SD) and average wet body weight were 4.01 ± 0.28 mm and 0.39 ± 0.02 mg respectively.

Data were analysed with a computerized statistical program (S-PLUS 2000). Data were transformed before analysis. Backwards regression was used as a tool to obtain candidate models. For all the investigated parameters (survival, wet weight, length), mixed models were applied, in which the replicate was considered to be a random factor. Temperature, light and time (day) were tested as ¢xed e¡ects. Temperature was modelled in two forms: as a numeric variables and factor (or class) variables.

Results

Survival

E¡ects of temperature, light, time and their interactions on survival were highly signi¢cant (Table 1). A signi¢cant second order interaction was noted for combinations of temperature, light and time with respect to survival making unambiguous interpretation of main e¡ects di⁄cult.

Survival data reveal that burbot larvae survive better under light condition compared with dark (Figs 1 and 2). At day 10, under light and dark conditions in the larval group kept at 12 1C, survival rates of 88.17% ± and 87.9% ± were recorded respectively. At day 10, larval survival at 20 1C under dark was only 8.5% ±, while under light condition higher survival was recorded (74.7% ±). After 20 days at 12 1C under dark, more mortality occurred (30.6% ±

Table 1 Summary of analysis of variance probability levels for e¡ects of temperature, time, light and their interactions on survival and growth response (length and wet weight) of burbot larvae

	Response variables		
Factor	Survival	Length	Wet weight
Day	o0.0001	o0.0001	o0.0001
Temp.	o0.0001	0.002	o0.0001
Light	o0.0001	0.0002	o0.0001
Day: light	0.12	0.08	o0.0001
Day: temp.	0.0007	0.04	o0.0001
Light: temp.	o0.02	0.65	0.3
Day: light: temp.	o0.0001	0.03	o0.0001

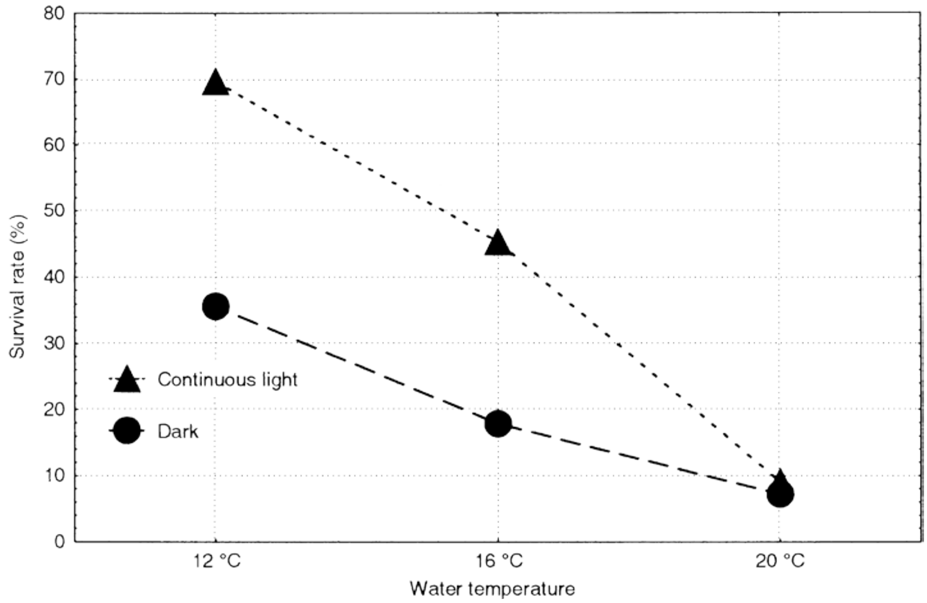

Figure 1 Percentage survival (and standard errors) of burbot larvae after being exposed to di¡erent temperatures under continuous light and dark (day 10).

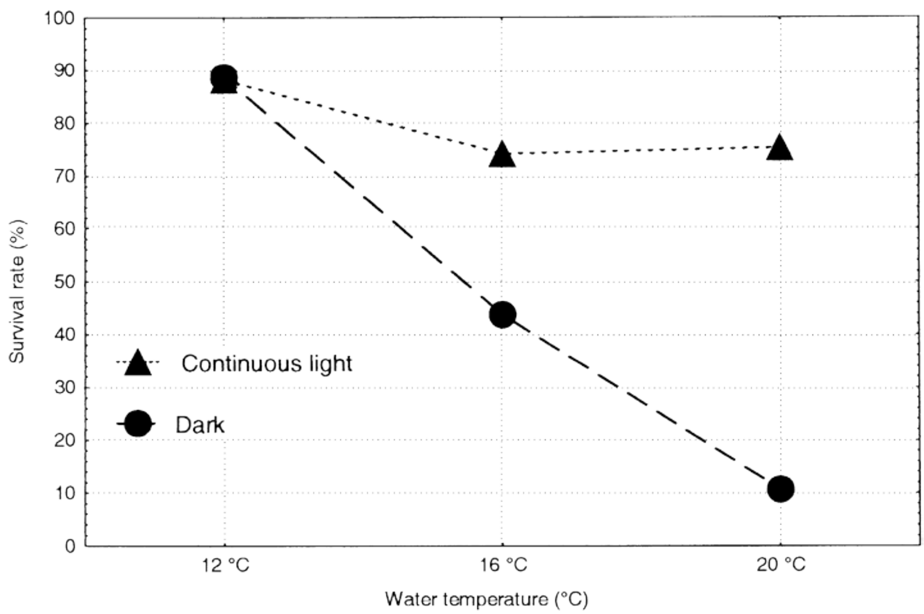

Figure 2 Percentage survival (and standard errors) of burbot larvae after being exposed to di¡erent temperatures under continuous light and dark (day 20).

survival rate for darkness vs. 67.2%± in light condition). The survival rate of the larvae held at 16 1C under continuous light was higher than the larvae housed in darkness on day 10 and at the end of the experiment at the same temperature (Figs 1 and 2). During the feeding stage with *Artemia*, the mortality rate in the group of the larvae held at 20 1C under continuous light increased markedly compared with the larvae held at the same temperature in darkness. At the end of the study, highest survival was observed among the larvae held at 12 1C under continuous illumination (69.6%) (Fig. 2).

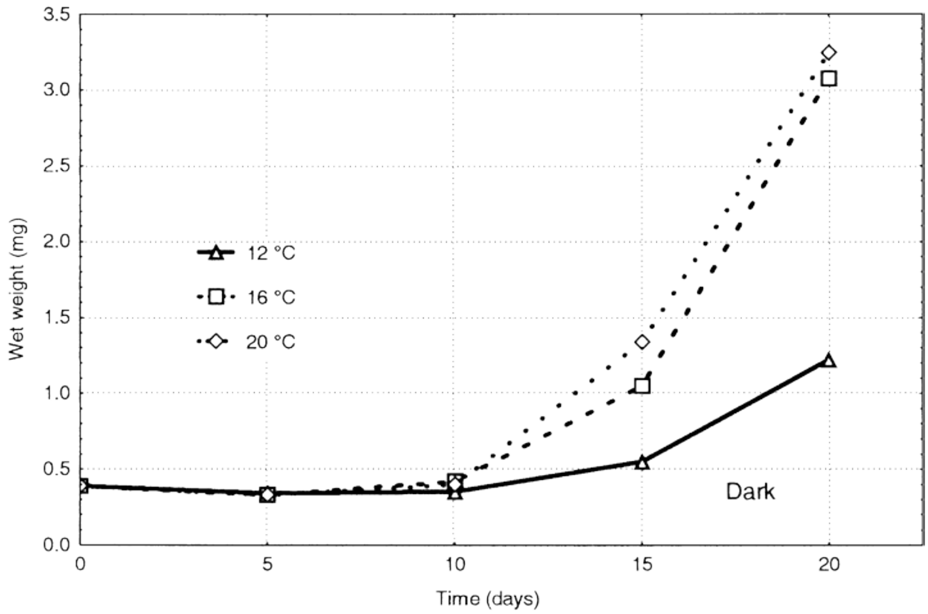

Figure 3 Mean total length of burbot larvae after being exposed to di¡erent temperatures under continuous light.

Length, wet weight

There was evidence that the temperature had no linear impact on the response variables (*P* 5 0.01 for length and *P*o0.0001 for length). E¡ects of temperature, light, time and their interactions on wet weight and length were also signi¢cant (Table 1). A signi¢cant second order interaction was noted for combinations of temperature, light and time with respect to wet weight and length.

At the end of the feeding phase with rotifer (day 10), larvae held at 20 1C under continuous light achieved higher growth (in terms of total length) than that gained at 12 1C and 16 1C under the same light regime (Fig. 3). Fish held at 16 1C under continuous light achieved better growth in total length than that gained at 12 1C. After 10 days, growth in terms of total length in larvae exposed to total darkness held at 12 1C was lower than that achieved in the continuous light at the same temperature (Fig. 4). At day 10, ¢sh kept at 20 1C under continuous light achieved better growth in wet weight than that gained at 16 1C and 12 1C (Fig. 5). At day 10, a negative larval growth in terms of wet weight was recorded at 12 1C under darkness (0.35 ± 0.02 mg wet weight at day 10 compared with wet weight of 0.39 ± 0.02 mg observed at day 0).

From day 10 onwards, larval growth improved remarkably after changing the live food from rotifer to *Artemia* in all treatments (Figs 3^6). At day 20, larvae length under continuous light held at 16 was higher that recorded at 20 1C and 12 1C under the same light regime (Fig. 3). At day 20, ¢sh kept at 12 1C under continuous light achieved better growth in terms of wet weight and length than that gained at 12 1C in dark. At the end of the study, the highest larval length was observed at 20 1C under darkness (Fig. 4). The lowest growth in terms of wet weight occurred at 12 1C for the larvae reared under total darkness.

Discussion

This study demonstrated that under the hatchery conditions described and within the size range of the experimental animals, survival and growth of burbot larvae was in£uenced by both temperature and light conditions. Data reveal that burbot larvae survive and grow better under light condition compared with dark.

Growth (in terms of total length and wet weight) responded positively to increasing temperature under continuous illumination in the range from 12 1C to 20 1C. A similar observation was reported by Wolnicki, Myszkowski & Kaminski (2001). At darkness, response to increasing temperature was more evident from day 10 onwards.

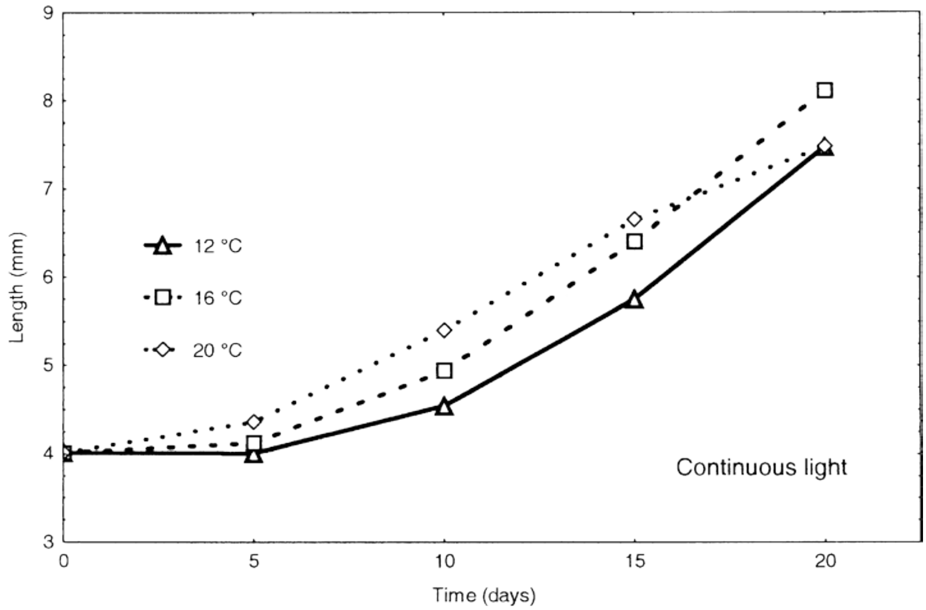

Figure 4 Mean total length of burbot larvae after being exposed to di¡erent temperatures under dark condition.

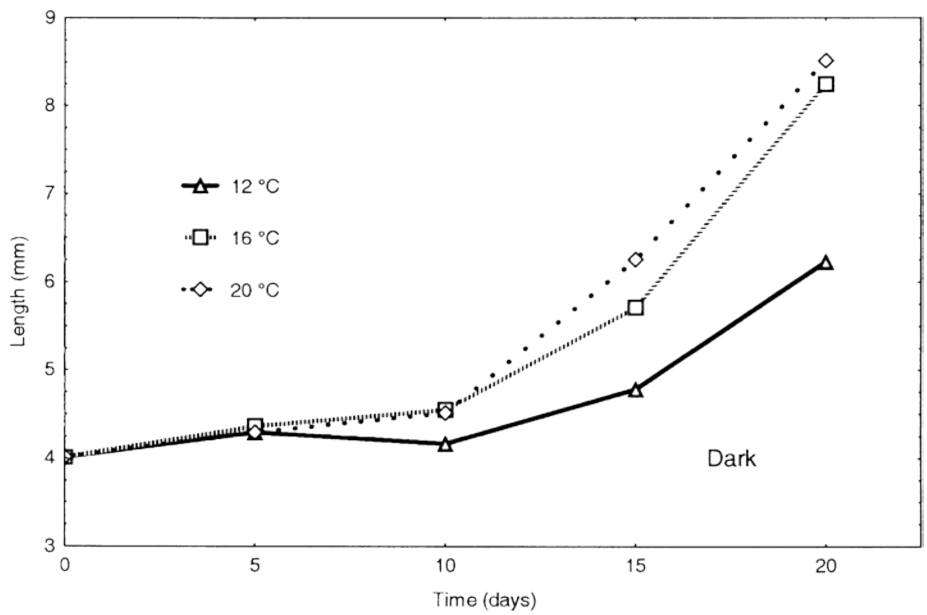

Figure 5 Mean wet weight of burbot larvae after being exposed to di¡erent temperatures under continuous light.

A growth enhancing e¡ect of continuous light was observed. This was particularly evident during the ¢rst 10 days, in which the larvae exhibited better growth compared with darkness. This is in accordance with the ¢nding of Mares (1991). He did not ob- serve burbot photophobia in his study and concluded that young burbot ingest food also under full lighting (cited in Ada£ mek 2000). Under continuous light, lar-vae may have greater opportunities to feed and this should be re£ected in growth performance.

Fish held at 12 1C under darkness showed lower growth. In this condition, even a negative growth

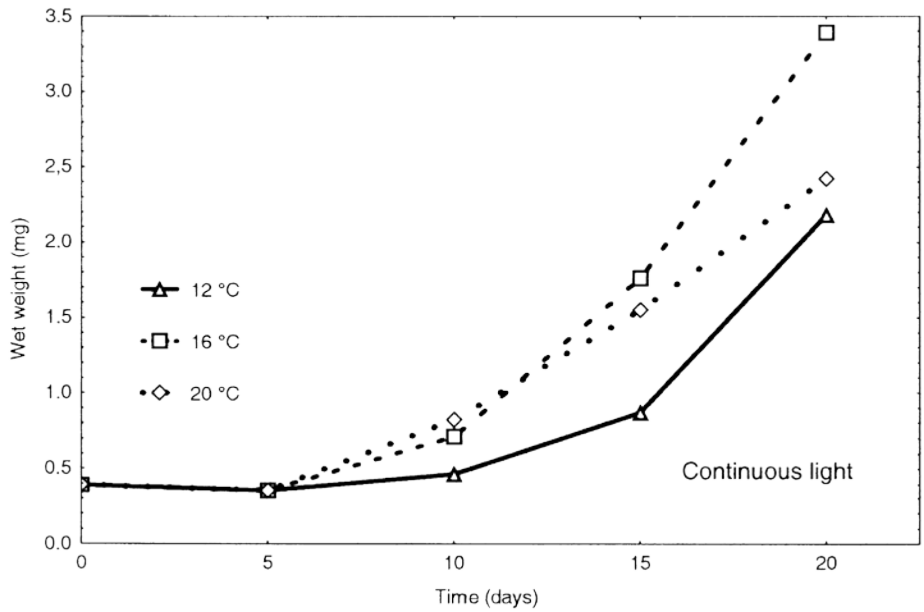

Figure 6 Meanwet weight ofburbot larvae after being exposed to di¡erent temperatures under dark condition.

was observed in the ¢rst phase of the experiment. In contrast to a lower growth of the larvae, a higher survival rate was achieved when the larvae were kept in total darkness. Larval feeding activity during night hours was not monitored in this study. However, evidence of night time activity of burbot ¢sh (AdaŁ mek 2000; Pääkk.nen, Laitinen & Marjomäki 2000) may also indicate that the larvae can exhibit night time activity and are capable of eating, be it at a reduced level in the dark.

High survival of burbot larvae at a higher temperature in the ¢rst 10 days of the experiment suggests that embryos (incubation temperature before the hatching was 4 ± 1 lC; R. ÆŁ rpaŁ d, pers. comm. 2001) and larvae di¡er in their physiological tolerances. Our data suggest that tolerance to high temperature increased rapidly in the ¢rst feeding burbot larvae and exceeded the temperature tolerance of the embryonic stage. According to Jobling (1994), the thermal tolerance may change during the course of growth and development, being very narrow at the beginning of development and widening as development proceeds. He found that newly hatched cod, *Gadus morhua*, larvae su¡er heavy mortality when temperatures exceed 16^17 lC, but larger cod may tolerate temperatures of up to 24^25 lC. In our study, burbot larvae su¡er more mortality during the second phase of the experiment when they were fed with Artemia at high temperature (Wolnicki *et al.* 2001).

The transition of live prey from rotifer to *Artemia* nauplii at temperature regimes of 16 and 20 lC resulted in an increased larval mortality. An increased temperature from 16 lC up to 20 lC did not result in an improved growth in light treatment. This may indicate that high temperature (more than 16 lC) and continuous light are not bene¢cial for larval growth and their physiologically optimum temperature ranges are lower in the later stage of development.

Girsa (1972) showed that a positive reaction to light by burbot larvae would be replaced by a negative phototactic at the later stage of development. He stated that this change coincided with the period when the young burbot leave the upper layers of water and change the nature of feeding.

During the feeding stage with *Artemia*, larvae held at 16 lC under dark exhibited a better growth compared with the larvae kept in light. This high growth may have been due to the lower stocking densities resulting from increased mortality. The enhancement of the growth rate is a common response to density decrease.

It seems that the most appropriate temperature for successful burbot larvae culture is ranged between 12 lC and 16 lC, and represents a trade-o¡ between faster growth with higher mortalities at higher temperatures and slow growth, but higher survival at lower temperatures.

Further research concerning the e¡ects of temperature on larval burbot should include determination of their thermal acclimation rates, their tolerances to high temperatures, and the e¡ects of temperature on larval activity.

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