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# The Early Development of Brook Trout *Salvelinus fontinalis* (Mitchill): Survival and Growth Rates of Alevins

Nadir BAŞÇINAR
Central Fisheries Research Institute, 61001, Trabzon - TURKEY

İbrahim OKUMUŞ*
Karadeniz Technical University, Faculty of Marine Sciences, Department of Fisheries, 61530 Trabzon - TURKEY

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**Abstract:** In this study, data on the incubation of eggs, survival rates and development of brook trout (*Salvelinus fontinalis*, Mitchill 1814) larvae and alevins were evaluated. Durations of eyeing, hatching and swim-up were 245, 415 and 675 degree-days at a temperature range of 4-12 °C, while survival rates from fertilisation to hatching and from fertilisation to swim-up stage were 56.5% ± 24.28 and 52.0% ± 23.67, respectively. Alevin weight exhibited a positive relationship with egg size ($r = 0.945$, $P < 0.01$).

**Key Words:** Brook trout, *Salvelinus fontinalis*, incubation, early development, survival rate

### Kaynak Alabalığı (*Salvelinus fontinalis*, Mitchill)'nda Erken Gelişim: Alevinlerin Yaşama ve Büyüme Oranı

**Özet:** Bu çalışmada, kaynak alabalığı (*Salvelinus fontinalis*, Mitchill 1814) yumurtalarının kuluçkalanması, larva ve yavrularının yaşama oranları ve büyümesi irdelenmiştir. Yumurtaların gözlenme, çıkış ve serbest yüzme süreleri 4-12 °C'de sırasıyla, 245, 415 ve 675 gün-derece; yaşam oranı ise, döllenmeden çıkışa kadar % 56,5 ± 24,28 ve döllenmeden serbest yüzmeye kadar % 52,0 ± 23,67 olarak belirlenmiştir. Yavru ağırlığı ile yumurta çapı arasında pozitif bir ilişki bulunmuştur ($r = 0{,}945$, $P < 0{,}01$).

**Anahtar Sözcükler:** Kaynak alabalığı, *Salvelinus fontinalis*, kuluçka, larval gelişim, yaşama oranı

## Introduction

*Salvelinus species* of the family Salmonidae have been the subject of much research due to their commercial, recreational and ecological importance in North America and Europe. In particular, the production of Arctic charr (*Salvelinus alpinus* L.), which has been farmed in countries such as Canada, Denmark, Finland, Iceland, Norway and Sweden, is a fast-growing business. These species grow fast at low temperatures and high densities and in both fresh and brackish water (1). It is important to note that the culture of other important species such as brook trout or charr (*Salvelinus fontinalis*) is relatively new, and attempts to culture these fish to date have been inconsistent and research under commercial conditions has been minimal (2,3).

Culturing Salvelinus species appears to be very different from salmon and trout culture, and future work needs to identify the unique biological and environmental requirements of the species. As with other finfish species (1), it is also vital for the culture of brook trout to study the potential factors influencing early development and survival. Many factors, including species and strain, temperature variation, egg size, stripping, fertilisation and incubation procedure and handling may affect the duration of development stages, survival and initial size and growth of larvae or alevins (4,5).

Egg size is one of the important determinants of egg and larval quality (6). Gall (7) showed that egg size was positively correlated with both the survival of egg and fry and also with growth rate. However, the lasting effects of egg size on subsequent stages are not clear. According to Springate and Bromage (6), 4 weeks after first feeding the relationship between egg size and fry weight was lost, and there was no clear correlation between survival and

* Correspondence to: i.okumus@gul.net.tr

egg size. In rainbow trout *Oncorhynchus mykiss*, hatchability is positively correlated with egg size (8), and in Arctic charr, *Salvelinus alpinus*, it has been found that egg size affects the survival of alevins from emergence through first feeding (9). However Jónsson and Svavarsson (5) found no significant relationship between egg size and survival from fertilisation through first feeding. Similarly, in brook trout embryonic survival was not correlated with egg size, but egg size was positively correlated with survival during the first 50 days of exogenous feeding. Thus, it is important for offspring survival (10).

In this study, durations of brook trout eggs under ambient temperature variations, the survival of embryos and alevins from fertilisation through first exogenous feeding, and the relationship between egg size and alevin size have been examined.

## Materials and Methods

The eggs were collected from eight 3-year-old female broods with a mean weight of 318 ± 80.2 g (195-485) on a private trout farm in Fındıklı, Rize. Eggs from each female were fertilised with milt from 2 males at 4 °C and all fertilised eggs were transferred to the Research Station at the Faculty of Marine Science, Karadeniz Technical University, on the same day, i.e. in 8 January, 1999. Egg size was measured with a Von Bayer trough (11) and 2 different egg size groups with mean diameters of 4.1 and 4.6 mm were chosen to assess the relationships between egg size and initial larval size and growth performance. Hatching was conducted in 3 wooden trays of 47 x 23 x 10 cm set in aquaria with dimensions of 85 x 25 x 35 cm. Around 1 l/min of freshwater was supplied to the aquaria. After hatching and the absorption of the yolk sac, the trays were removed and water velocity was increased to 2 l/min. The eggs were subjected to a 2 ppm malachite green bath for 1 h twice a week from fertilisation until the eyed stage, at which time dead and unfertilised eggs were removed and counted. Fecundity was determined in terms of either total (numbers of eggs per female) or relative fecundity (number of eggs/kg body weigh) by counting dead eggs, larvae and alevins, and survivors. Water temperature was measured 3 times a day by mercury thermometer. Observations of the eggs and alevins were made together with the temperature readings. The eyed-egg stage was defined as when the eyes were clearly visible as black spots. The 50% hatch time was defined as when 50% of the embryos were swim-up larvae. The swim-up stage was taken as being when approximately 50% of the alevins were starting to feed and were actively swimming up in the water for food intake. Growth performance (increase in weight) and specific growth rates (SGR = $[(\ln W_{t2}-\ln W_{t1})/t] \times 100$) were determined periodically (W: weight, mg; t: time, day).

## Results

Total and relative fecundities were 919 ± 324 (521-1569) eggs/brood and 2843 ± 479 (2006-3572) eggs/kg, while egg size ranged from 4.1 to 4.9 mm with a mean value of 4.58 ± 0.254. There was no significant relationship between brood live weight and egg size.

The durations of development stages of eggs are given in Table 1. survival from fertilisation to hatching and from fertilisation to swim-up was 56.5% ± 24.28 and 52.0% ± 23.67, respectively (Table 2). Alevin weight exhibited a positive relationship with egg size (Alevin W = -107.09 + 41.73 Egg size; $r = 0.945$, $P < 0.01$) (Figure 1), and egg size also had a significant effect on the growth rates of alevins ($P < 0.001$) (Table 3).

Table 1. Duration of eyed-egg, hatch and swim-up phases and temperatures.

| | |
|---|---|
| Eyed-egg stage | 29 days (245 degree-days) |
| Temperature of fertilisation-eyed-egg stage (°C) | 8.45 ± 0.71 (6.0-9.5) |
| Eyed-egg-hatching | 52 days (415 degree-days) |
| Temperature of fertilisation-hatch (°C) | 7.98 ± 1.20 (4.0-9.5) |
| Swim-up | 81 days (675 degree-days) |
| Temperature of fertilisation-swim-up (°C) | 8.33 ± 1.33 (4.0-12.0) |

Table 2. Survival of eggs and larvae at different life stages and survival to first feeding.

| Survival (%) | Mean ± sd | (min-max) (n = 8) |
|---|---|---|
| In first 36 h | 80.46 ± 12.38 | (65.71-97.16) |
| Fertilisation to eyed-egg stage | 67.35 ± 21.36 | (31.67-95.73) |
| Fertilisation to hatching | 56.51 ± 24.84 | (14.59-92.56) |
| Fertilisation to swim-up | 52.05 ± 23.67 | (12.67-91.93) |

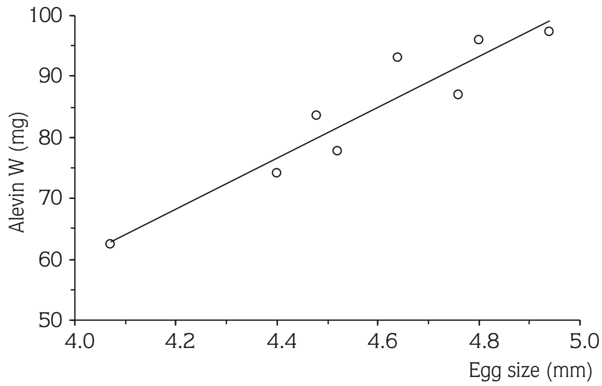


Figure 1. Relationship between egg size (mm) and alevin weight (mg) (n = 8).

## Discussion

Durations of the embryonic and larval development stages as heat-sums (number of degree-days) reveal differences in salmonids (Table 4). For brook trout, incubation periods (from fertilisation to hatching) were reported as 440 (12), 503.4 (4) and 235-444 degree-days (13), while the periods of the larval or swim-up stage were given as 707.4-1110 degree-days (14) and 387-618 degree-days (13). Incubation temperature and its variability during these periods are probably the main factors controlling the durations of early development stages of fish embryos and larvae. For example, the mean hatching duration for rainbow trout has been reported as 310 degree-days, although it may take 103 days (361 degree-days) at 3.5 °C, 80 days (400 degree-days) at 5 °C or 19 days (285 degree-days) at 15 °C (15,16). Grande and Andersen (13) reported that the heat sum in

Table 4. Development of eggs of some salmonids (degree-days).

| Species | Eyed-egg | Hatch | Swim-up |
|---|---|---|---|
| Shepherd and Bromage (12) | | | |
| *Salmo salar* | 250 | 430 | 800 |
| *Salvelinus fontinalis* | - | 440 | - |
| *Salmo trutta* | - | 410 | - |
| *Oncorhynchus tshawytscha* | 250 | 420 | 890 |
| *Oncorhynchus keta* | 420 | 560 | 960 |
| *Oncorhynchus kisutch* | 250 | 420 | 970 |
| *Oncorhynchus clarki* | 150 | 300 | - |
| *Salvelinus namaycush* | - | 490 | - |
| *Oncorhynchus gorbuscha* | 420 | 500 | 805 |
| *Oncorhynchus mykiss* | 160 | 310 | 500 |
| *Oncorhynchus nerka* | 500 | 670 | 1000 |
| Grande and Andersen (13) | | | |
| *Salvelinus fontinalis* [a] | 276 | 444 | 618 |
| *Salvelinus fontinalis* [b] | 260 | 320 | 416 |
| *Salvelinus fontinalis* [c] | 273 | 407 | 505 |
| *Salvelinus fontinalis* [d] | 195 | 235 | 387 |
| *Salmo salar* [a] | 276 | 497 | 765 |
| *Salmo salar* [b] | 274 | 350 | 585 |
| *Salmo salar* [c] | 273 | 458 | 656 |
| *Salmo salar* [d] | 195 | 270 | 387 |
| *Salmo trutta* [c] | 273 | 406 | 610 |
| *Salmo trutta* [d] | 195 | 250 | 387 |
| *Salvelinus fontinalis* * | 245 | 415 | 675 |

[a] Deep water (20 m) (2.4-8.2 °C) (experiment 1), [b] surface water (1 m) (0.5-8.2 °C) (experiment 1), [c] Deep water (20 m) (2.4-6.2 °C) (experiment 2), [d] surface water (1 m) (0.5-6.2 °C) (experiment 2), * present study.

Table 3. Growth of alevins of different egg size (W, mg) (n: individual number), specific growth rate (SGR; %), water temperature (T; °C).

| Date | T (°C) | | Egg size: 4.1 mm | Egg size: 4.6 mm |
|---|---|---|---|---|
| April 01 | | W(n) | 62.4 (687) | 93.1 (597) |
| | 9.50 ± 1.15 (8.0-12.5) | SGR | 4.71 | 3.98 |
| April 16 | | W (n) | 126.5 (675) | 169.8 (529) |
| | 12.37 ± 1.44 (9.0-14.5) | SGR | 3.14 | 4.59 |
| April 30 | | W (n) | 202.5 (432) | 337.9 (435) |
| | 12.05 ± 2.17 (8.0-14.5) | SGR | 5.67 | 5.56 |
| May 20 | | W (n) | 630.0 (432) | 1029.0 (434) |
| | 14.50 ± 1.45 (12.0-17.0) | SGR | 2.84 | 3.54 |
| June 03 | | W (n) | 937.0 (428) | 1690.0 (418) |

degree-days was much lower in cold surface water than in warmer deep water. Genetic make-up can also affect the lengths of incubation periods (4).

The survival of eggs and larvae recorded in the present study was lower than that previously reported for some salmonids (Table 5). Survival rates of salmonid eggs during the incubation may range from almost 0% to 100% for salmonid species (17-19). In addition, survival in brook charr eggs seems to be lower than in the other salmonids, particularly rainbow trout and Atlantic salmon, which have been cultured for a long time and are almost domesticated. As reviewed by Bromage (17), many factors have been suggested as possible determinants of egg quality. Among these the nutritional status of the broodstock, husbandry conditions (particularly water quality) of both broodfish and fertilised zygotes, sperm infertility, bacterial colonisation of the surfaces of the eggs, the genetics of the broodstock and overripening of eggs (i.e. the ageing process of eggs between ovulation and fertilisation) are considered primary factors. Water quality in the incubation unit of the present study was not ideal for brook charr eggs. For example, the suspended solid content of the water and temperature variations were quite high. According to Marten (20), to maximise the survival rate the incubation temperature for brook trout should be maintained within temperature values of 3-8 °C, particularly until the eyes appear.

The effects of egg size on the survival and growth of alevins or juveniles are still controversial. Some researchers suggest that egg size is one of the determinants of egg quality (17,21), although many argue that size has no significant effect, at least on fertilisation and survival rates. For example, Springate and Bromage (6) reported that there is no relationship between egg size and the survival rates of the eggs and fry to eyeing, hatch and swim-up, and as fry or yearling fish for rainbow trout. Similarly, Jónsson and Svavarsson (5) found no significant relationship between egg size and survival from fertilisation through first feeding in Arctic charr, but suggested that egg size affects offspring survival through differences in hatchability and early survival after the first feed. The differences between authors most probably arise from varying conditions under which the trials were conducted, variations in the ripeness of the eggs used and other uncontrolled factors (21).

Egg size, however, can have significant effects on the size of first-feeding fry, and the present study has also demonstrated that egg size has a significant effect on the growth performance of the alevins. In other words, larger eggs produce larger larvae with a larger yolk-sac, and this may have positive effects on later development. In the present study, the size differences arising from egg size were maintained after 2 months with increasing absolute values (Table 3); however, as reported by Springate and Bromage (6), this size advantage can be lost after 4-5 months.

In brief, it seems that there are still important variations and/or differences among the results of various

Table 5. Survival of some salmonid eggs (%) (1: fertilisation - first 36 h, 2: first 36 h -eyed-egg, 3: eyed-egg - hatch, 4: hatch - swim-up).

| | Stages | | | | |
|---|---|---|---|---|---|
| Species | 1 | 2 | 3 | 4 | Authors |
| Brown trout | - | 97.1 | 90.5 | 94.1 | McKay et al. (22) |
| Rainbow trout | 75.1 | 87.8 | 96.4 | 98.9 | Kurtoğlu et al. (18) |
| Rainbow trout | 98.4 | 88.8 | 80.3 | 95.1 | Okumuş et al. (19) [a] |
| Rainbow trout | 95.8 | 86.9 | 91.7 | 96.6 | Okumuş et al. (19) [b] |
| Brook trout | 85.8 | 82.7 | 90.1 | 95.2 | Dumas et al. (23) |
| Brook trout | - | 72.2 | 97.3 | 93.1 | McKay et al. (22) |
| Brook trout | - | 75.3-90.5 | 78.7-89.2 | - | Marten (20) |
| Brook trout | 82.5 | 85.8 | 85.7 | 90.3 | Present study |

a: stocking in sea cage group, b: stocking in freshwater pond group.

studies with respect to lengths of early development stages, survival and significance of egg size, not only with regard to brook charr but also to other salmonid species. Variables such as survival and growth have a major importance for commercial aquaculture and can be improved through environmental and genetic manipulation.

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