The JSFS 85th Anniversary-Commemorative International Symposium
"Fisheries Science for Future Generations"

Symposium Proceedings, No. 07008

Original article

Land-based aquaculture of salmon trout using spring water from undersea tunnel in north Japan

Hikari Izumi [1], Kosuke Suzuki [2], Satoru Fukuda [1], Yutaka Maeda [3], Koichi Okamura [2] and Naotsune Saga [1,*]

[1] *Institute for Food Sciences, Hirosaki University, Aomori, Aomori, 038-0012, Japan*
[2] *Okamura Foods Co., Ltd., Aomori, Aomori, 030-0912, Japan*
[3] *Inland Water Fisheries Research Institute, Aomori Prefectural Industrial Technology Research Center, Towada, Aomori, 034-0041, Japan*
* Correspondence: nsaga@hirosaki-u.ac.jp; Tel.: +81-17-763-5922

Keywords: Salmon trout; Rainbow trout; Land-based aquaculture; Seawater farming.

Received: 18 July 2017 / Accepted: 4 September 2017

Introduction

Salmon trout, large rainbow trout (*Oncorhynchus mykiss*), farmed in seawater, is one of the most popular seafoods, and stable commercial production of the species is required in Japan. Although year-round seawater farming can provide a stable supply of salmon trout, the period suitable for salmon farming in the sea surrounding Japan is limited. This is because the sea surface temperature during summer is too high for salmon trout [1, 2].

Land-based aquaculture systems have certain advantages for controlling captive conditions; however, the costs of running land-based seawater farms are higher than those for marine aquaculture. In north Japan, approximately 1.2 million liters of seawater per hour are pumped from an undersea tunnel (the Seikan tunnel) and released on ground [3]. Utilization of the spring water pumped from undersea tunnels for land-based aquaculture could reduce the costs of year-round seawater farming. However, it is not known whether a land-based aquaculture system using spring water for salmon rearing would be viable. In this study, we investigated seasonal changes in the survival and growth performance of salmon trout reared in a land-based aquaculture system using spring water pumped from an undersea tunnel.

Materials and methods

In this study, we used the Donaldson strain of *O. mykiss* [4], which has undergone long-term cultivation at the Inland Water Fisheries Research Institute, Aomori Prefectural Industrial Technology Research Center (Towada, Aomori, Japan). Immature fish (body weight: 441 g, n = 140) were reared in a 10-m^3 tank at the breeding facilities of Okamura Foods Co., Ltd. (Sotogahama, Aomori, Japan) using spring water pumped from the Seikan undersea tunnel from May 27, 2016 to March 4, 2017. Water quality parameters during the experimental period were as follows: flow rate, 150–200 L/min; salinity, 26–28‰; and dissolved oxygen, 6.2–8.5 mg/L. The fish were fed commercial aquaculture feed ad libitum.

The experimental period was divided into four seasons: season1, May 27–July 15, 2016; season2, July 16–October 7, 2016; season3, October 8–December 20, 2016; and season4, December 21, 2016–March 4, 2017. Body weight and number of surviving fish were recorded after each experimental period. Mortality, daily growth rate (DGR), and feed conversion rate (FCR) were calculated using the following formulae:

$$\text{Mortality (\%)} = 100 \times (N_i - N_t)/N_i$$
$$\text{DGR (\%)} = 100 \times (W_t - W_i)/[(W_t + W_i)/2 \times T]$$
$$\text{FCR} = \text{total diet fed}/[(W_t - W_i) \times (N_t + N_i)/2],$$

where T is the length of each experimental period in days, N_t and N_i are the final and initial number of surviving fish for each experimental period, respectively, and W_t and W_i are the final and initial individual weights of the fish, respectively.

Results

The temperature of the spring water was lower than that of the surface of the sea surrounding Aomori Prefecture (41°25′N, 140°34′E) in summertime (highest temperature: 21.9°C), whereas it was higher in wintertime (lowest temperature: 11.5°C) (Fig. 1).

The highest mortality rate (16.9%) was recorded in season2. The DGR value remained low after season2, whereas the FCR value decreased in season3 (Table 1). At the end of the experimental periods, 73% of the fish had survived and the average body weight of these fish had reached an optimal size for shipment (2.5–3.5 kg)

(Table 1).

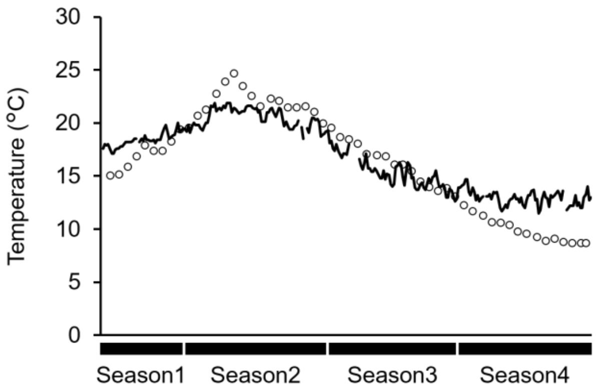

Fig. 1. Seasonal changes in water temperature. Solid black line, temperature of the spring water pumped from an undersea tunnel; open circle, temperature of the surface of the sea surrounding Aomori Prefecture.

Table 1. Seasonal changes in mortality, growth factors, and average water temperature

Parameters	Season1	Season2	Season3	Season4
Mortality (%)	2.9	16.9	11.5	3.0
DGR (%)	1.27	0.61	0.41	0.60
FCR	0.86	1.05	0.50	1.07
Body weight (kg) [1]	0.90±0.14	1.43±0.32	1.93±0.63	3.06±0.47
Temperature (°C) [2]	18.1±0.7	20.1±1.1	14.8±1.3	12.9±0.7

[1] Average body weight (Mean ± S.D., n = 10)
[2] Average spring water temperature (Mean ± S.D.)

Discussion

Herein, we report the seasonal changes in survival and growth performance of salmon trout reared in a land-based aquaculture system using spring water pumped from an undersea tunnel. Generally, the optimal temperature range and upper threshold temperature of rainbow trout are 10–22°C and 26.5°C, respectively [1]. Although the seasonal range of the spring water temperature fell within the optimal temperature range of rainbow trout, the survival and growth of these fish were still low during summer and autumn. One of the factors influencing survival and growth is water temperature [5, 6]. Moreover, it has recently been reported that thermal performance differs in different trout strains [7]. Thus, the high-temperature conditions during summer may be unsuitable for the trout strain used in this study; consequently, the survival and growth performance decreased. Further research on the relationship between captive conditions, such as temperature, and growth performance in this strain is needed in order to efficiently produce salmon trout.

In conclusion, our results suggest that a land-based aquaculture system using spring water pumped from an undersea tunnel can be used for year-round seawater farming of salmon trout, although it will be necessary to optimize captive conditions in summertime. We hope that this information will lead to advances in the production of salmon trout in Japan.

Acknowledgements

This research was supported by grants from the Project of the NARO Bio-oriented Technology Research Advancement Institution (the special scheme project on regional developing strategy).

References

1. Barton BA (1996) Principles of Salmonid Culture, 1st ed. (Pennell W, Barton BA, eds), Elsevier Science, Amsterdam, pp. 29–95
2. Novotny AJ, Pennell W (1996) Principles of Salmonid Culture, 1st ed. (Pennell W, Barton BA, eds), Elsevier Science, Amsterdam, pp. 569–608
3. Ikuma M (2005) Tunn Undergr Sp Tech 20: 143–149
4. Hines NO (1976) Fish of Rare Breeding: Salmon and Trout of the Donaldson Strains. Smithsonian Institute Press, Washington, DC
5. Brett JR (1979) Fish Physiology, vol. 8 (Hoar WS, Randall DJ, Brett JR, eds), Academic Press, London, pp. 599–675
6. Ojolick EJ et al. (1995) Aquaculture 131: 177–187
7. Hartman KJ, Porto MA (2014) Trans Am Fish Soc 143: 1445–1454