# Effects of Water Temperature and Day Length on Seawater Tolerance of Yearling Sockeye Salmon (*Oncorhynchus nerka*)

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The early life history of sockeye salmon (*Oncorhynchus nerka*) is characterized by an increase in seawater tolerance preceding seaward migration. This phenomenon usually occurs in spring in response to environmental factors such as day length or water temperature or both. It is possible to change the timing of this phenomenon. For example, underyearling masu salmon exposed to longer day lengths than their natural photoperiod develop their seawater tolerance in autumn (Ikuta et al. 1987). Juvenile chinook salmon reared at 17°C reached maximum seawater tolerance two months earlier than those reared at 9°C (Clarke and Shelbourn 1985). However, less is known about these relationships in sockeye salmon. In this study, the effects of water temperature and day length on seawater tolerance of yearling sockeye salmon were investigated.

In mid-January, 600 yearling sockeye salmon were separated equally into six groups (A to F groups) and moved to 100L tanks. They were reared under a uniform feeding rate at 3% body weight per day until early April. Throughout the experiment, groups A, B and C were supplied with river water (3–5°C), and groups D, E and F were supplied with well water (7–8°C). All tanks were shielded with vinyl cloth, and day lengths were controlled by using artificial lighting (Table 1). The day lengths of groups A and D were gradually increased from 9.5 hrs in mid-January to 12.5 hrs in early April, which simulated the natural photoperiod. The day length of groups B and E were fixed at 11 hrs and 13 hrs respectively from mid-January to mid-February, and groups C and F at 13 hrs and 15 hrs respectively from mid-February to early April. Natural day length at the beginning of the experiment was 9.5 hrs in mid-January. During the experimental period, all groups were used in four monthly seawater challenge tests. For each seawater challenge test, 10 individuals were collected from each tank and transferred directly into seawater for 24 hrs. Blood was continuously drawn from them in order to measure serum sodium concentrations. At the same time, blood samples for the analysis of serum thyroxine (T4) concentration, and gill and kidney samples for the assay of $Na^+,K^+$-ATPase activity were taken from another 10 individuals from each of the six fresh water groups. This was done after measuring fork lengths. Seawater tolerance was assessed by gill and kidney $Na^+,K^+$-ATPase activity, and serum sodium concentration 24 hrs after the transfer of the fish to seawater.

The mean fork length of groups A, B, C and groups D, E, F increased from 108 mm in mid-January to 112–117 mm and 125–131 mm respectively in early April. The serum sodium concentration of groups C and F fell from 195.7 mEq/L in mid-January to 160.0 mEq/L and 157.8 mEq/L in early April. The groups B, D, E and group A had a serum sodium concentration of 164.9–168.0 mEq/L and 180.9 mEq/L respectively. While all groups showed a reduction during the experimental period, the serum sodium concentration of the groups C and F were much lower than those of other groups. Conversely, the gill $Na^+,K^+$-ATPase activity in all groups increased continuously in every month. However, groups E and F showed a much higher increase in the enzyme activity from 3.4 µmols Pi/mg pro./h in mid-January to 14.9µmols Pi/mg pro./h and 20.9 µmols Pi/mg pro./h in early April. The enzyme activities of groups B, C, D and group A were 7.4–8.2µmols Pi/mg pro./h and 5.1µmols Pi/mg pro./h respectively in early April. Group F, which had the longest day length and warmer water than other groups, showed the highest seawater tolerance and gill $Na^+,K^+$-ATPase activity. The kidney $Na^+,K^+$-ATPase activity of all groups fluctuated between 12.5–18.3 µmols Pi/mg pro./h throughout the experiment, but there was no significant difference (using a *t*-test) among the six groups at each collection time. These results indicate that seawater tolerance of yearling sockeye salmon is stimulated by increases in day length, as a result of elevation in the gill $Na^+,K^+$-ATPase activity. Furthermore, longer day length and higher water temperature accelerate the development of these phenomena.

**Table 1.** Rearing condition of Groups A, B, C, D, E and F.

| | Day length | | |
|---|---|---|---|
| Water temperature | 9.5 h–12.5 h | 11 h–13 h | 13 h–15 h |
| 3–5 C, river water | Group A | Group B | Group C |
| 7–8 C, well water | Group D | Group E | Group F |

The serum T4 concentrations of the six groups were 77.6 ng/ml in mid-January, 123.7–129.5 ng/ml in mid-February, 99.2–113.1 ng/ml in mid-March, and 165.2–175.7 ng/ml in early April. Though the mean value fluctuated widely during the experimental period, there were no significant differences (*t*-test) among the six groups in each month. These results indicate that increased day length triggered a secretion of T4 in yearling sockeye salmon. However, there was no correlation between differences in day length and the profile of serum T4 concentration.

From the present study, it is clear that longer day length and higher water temperature stimulate the development of seawater tolerance in yearling sockeye salmon as a result of increases in the gill $Na^+,K^+$-ATPase activity. These phenomena may be correlated with the increase of serum T4, which is triggered by increased day length.

## REFERENCES

Clarke, W.C., and J.E. Shelbourn. 1985. Proceedings of a workshop on salmonid smoltification. Aquaculture 45.

Ikuta, K, K. Aida, N. Okumoto, and I. Hanyu. 1987. Effects of sex steroids on the smoltification of masu salmon, *Oncorhynchus masou*. Gen. Comp. Endocrinol. 65: 99–110.