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Studies on the Osmoregulation of the Chum Salmon, *Oncorhynchus keta* (Walbaum) III. The Tolerance of Adult Fish Reared in a Salt Water Pond to Fresh Water

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Summary

1. The tolerance of adult chum salmon, *Oncorhynchus keta* (Walbaum), reared in a salt water pond to fresh water was examined.
2. The fish transferred to fresh water abruptly can live for a long time. The water content of the blood increased during the initial days after the transfer.
3. Also the osmotic concentration of blood of the fish transferred to fresh water showed a temporary decrease.
4. Both water content and osmotic concentration of blood of the fish in fresh water returned to control level about three days after the transfer.
5. The fish can also adapted to the diluted salt water like the fish transferred to fresh water.

The salmonids change their life environment twice in a lifetime, one is the migration from fresh water to sea water to pass their growth stage and the other is the migration from sea water to fresh water for spawning. Teleost fishes, including slamonids, must regulate the water and salt of the body, because the osmotic concentration of the body is higher than that of the fresh water and lower than that of the sea water. These regulations, in fresh water and sea water, are counter actions each other. Therefore, salmonids must converse their osmoregulatory mechanisms from the fresh water to the sea water type or the reverse at the time of migration.

It has been well known, on the faculty of the osmoregulation of the salmonids, (i) that the fish can not live in sea water at the initial period of the fresh water life after hatching, (ii) that the tolerance of the fish to sea water developes gradually along with their growth, and (iii) that smoltificated fish can live in full strength sea water and balance the water and salt content of their bodies quickly when they are transferred to the sea water from fresh water abruptly. Continuous experiments of these salinity tolerances of salmonids from hatching to seaward migra-

tion have been reported on the Genus *Salmo* by Parry (1) and Conte and Wanger (2), and on the Genus *Oncorhynchus* by Conte et. al (3), Wagner et al., (4) and Kashiwagi and Sato (5).

On sea water life after migration, Vibert (6) indicates that the salmon smolts which have spent two weeks in sea water may be returned to fresh water without ill effects. There is, however, no information at all on the adult fish which pass most of their life in sea water because experimental material is hard to get in the ocean. It is of great interest to us whether or not sea water salmonids can live in fresh water. The authors have been studying chum salmon, *Oncorhynchus keta* (Walbaum), physiologically throughout their entire life cycle by the use of fish reared in the salt water pond as already described in the publications 7, 8 and 9. So the tolerance of adult fish to fresh water was exmained in this paper.

Materials and Methods

The chum salmon used in this experiment were about 25 months old from hatching and had for about 22 months in the salt water pond. They were 30.7 cm (25.5–37.5 cm) in average body length and 370 g (230–780 g) in average body weight. The chlorinity of the salt water was 10.96 per mill at the lowest and 15.95 per mill at the highest during the rearing of the fish (Fig. 1).

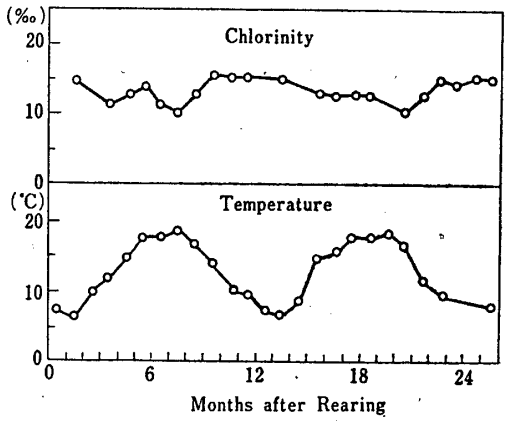

FIG. 1. The chlorinity and temperature of the pond salt water during the rearing of the chum salmon.

To examine the tolerance of the fish to fresh water, 24 fish were transferred to fresh water abruptly, also 13 fish to half salt water which was prepared from the pond salt water and fresh water, and 14 fish were left in the pond salt water as a control for this experiment. The fish were kept five or six per tank of about 60 liters. The chlorinity of the experimental salt water was 14.99 per mill in the control and 6.76 per mill in the half salt water. The water temperature was 10.7°C in all experimental tanks at the beginning of the experiments but it varied from 6.3 to 11.6°C during the experiment. The saturation of dissolved oxygen was 93.4,

65.6 and 55.7 per cent respectively in the fresh water, the half salt water and the control at the beginning. Thereafter it was kept at about 100 per cent by aeration during the experiment. The survival rate of the fish transferred was recorded for five fish of each tank. The water content and the freezing point depression of blood were measured on three to five fish at about 1/2, 1, 2, 3, 4, and 5 days after the transfer, respectively. The blood was collected by cardiac puncture immediately after anesthesia with one per cent urethane solution. The methods of measurement has been described elsewhere (7).

Results

Survival Rate

There were no dead fish in the tank which was used for the experiment of the survival rate in fresh water, the half salt water and the control during the experiments of five days, though two fish died at about 36 hours after transfer to another fresh water tank which was used for the measurement of blood. Moreover, survival was confirmed after one month on the three fish which had been transferred to the fresh water pond after the experiments.

Water Content of Blood

The average percentage of water content in the blood of the control fish was 77.0, 74.9, 75.3 and 75.3 per cent at 0, 20, 66 and 92 hours after the beginning of experiments, respectively. That of the fish transferred to the fresh water showed some increase such as 81.1 per cent at 15 hours and 79.6 per cent at both 25 and

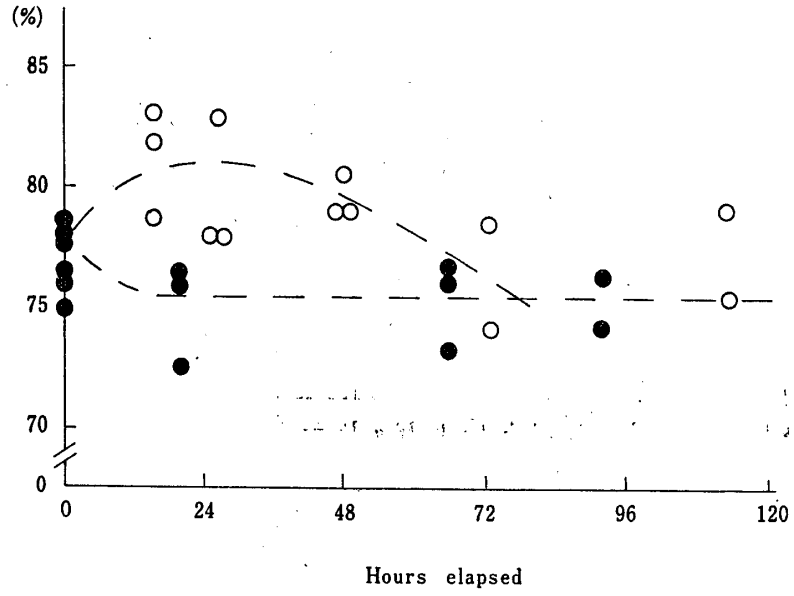

FIG. 2. Changes of water contnt in blood of the chum salmon after transfer from salt water to fresh water. Open and solid circle refers to an individual fish in fresh water and salt water respectively. Solid and dashed lines roughly indicate the changes of each group.

48 hours after the transfer, and then it reached the control level, 76.3 per cent at 43 hours and 77.4 per cent at 113 hours (Fig. 2). There were scarcely any changes in water content of the blood of the fish transferred to the half salt water as compared with that of the control fish, that is 77.0, 72.8 and 77.7 per cent on the average at 24, 43, and 115 hours after the transfer, respectively.

Osmotic Concentration of Blood

The average value of the freezing point depression of blood of the control fish was almost constant at –0.58 to –0.60°C during the experiments. That of the fish transferred to fresh water showed a decrease of their osmotic concentration of blood such as –0.48°C at both 15 and 25 hours, thereafter it returned to the control level, –0.59°C at both 48 and 113 hours (Fig. 3). On the other hand, that of the

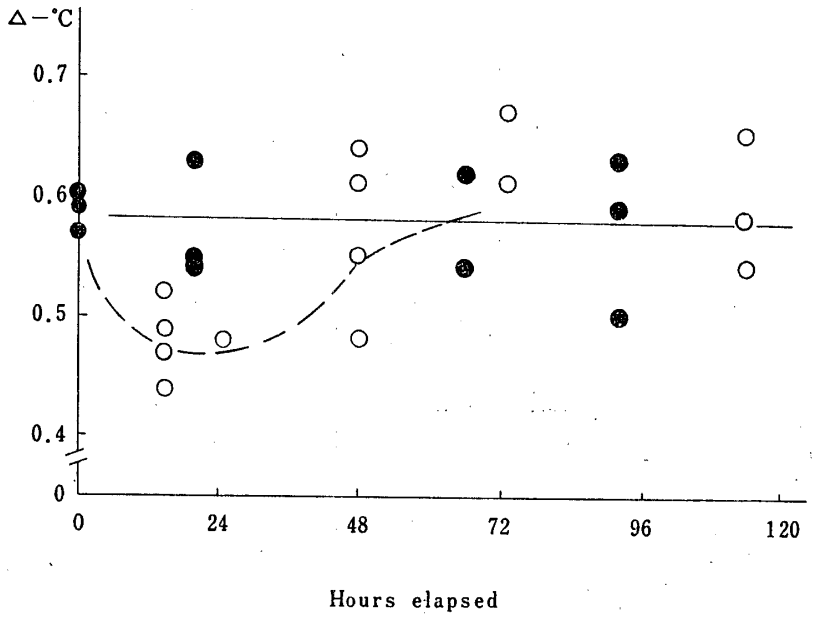

FIG. 3. Changes of freezing point depression in blood of the chum salmon after transfer from salt wster to fresh water. Key as in Fig. 2.

fish in the half salt water showed an increase of osmotic concentration of blood in contrast with that of the control fish,–0.68°C at 24 hours and –0.67°C at 43 hours, then they tended to return to the control level like the fish in fresh water. This change on the initial days after transfer was just the opposite of that of the fish in the fresh water.

Discussion

It is certain that the adult chum salmon transeferred from salt water can live in fresh water and survive not only during the experiment but for a long time after the experiments.

The changes of water content and freezing point depression of blood of the fish on the initial days after the transfer to fresh water are just the opposite of the fish

transferred to sea water as described by Black (10), Parry (1, 11), Gordon (12, 13) and Kashiwagi and Sato (5). It is well known, as reviewed in Black (14, 15), Parry and Potts (16) and Parry (17), that in fish transferred to sea water from fresh water the changes of these osmotic properties for the initial period after the transfer are caused by the diffusion of the salt through the semi-permeable tissues and by the concentration of the salt present because of loss of water, then these concentrations return to the control level by water and salt regulation of the fish when they adjust to the medium but upon failing to return they died. Therefore, it may be said that the changes of water content and the freezing point depression of the experiment are caused by a temporary dilution of the body fluids after the transfer to fresh water. Also it was noted that the time for adaptation to fresh water took about three days for the restoration of their osmotic concentration. With matured salmonids moving into fresh water from sea water in natural conditions, a gradual decline of blood concentration as compared with the sea water level is described by Greene (18), Benditt et al. (19), Parry (20) and Kubo (21, 22).

It is also certain that fish transferred to half salt water can adapt successfully. But there is an increase of osmotic concentration as compared with a decreasing in the fish transferred to fresh water. Marine teleost fishes usually swallow the sea water in order to replace the water lose by dehydration in the hypertonic medium. Although there is no evidene at the present time, it may be considered a possibility that the temporary increase of the osmotic concentration is caused by swallowing the half salt water, which is somewhat hypertonic to the fish, in addition to the laboratory diuresis. This idea does not conflict with the results of the water content which showed little changes as compare with the control fish, because the water content of the blood is not affected by the salt content but rather by the quantity of matter such as protein.

Anyhow, it is said that adult chum salmon which pass most of their life in sea water can adapt to the fresh water or diluted sea water like fish shortly after migration to sea water reported by Vibert (6). But the results of this experiment cannot be considered to be valid for all ocean life periods because of the lack of information based on factors such as seasonal changes or the degree of gonad formation of the fish. These problems remain and it is desirable for us to examine them in order to grasp the entire life cycle physiologically.

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References

1) Parry, G., *J. Exp. Biol.*, **37**, 425. (1960)
2) Conte, F.P., and Wagner, H.H., *Comp. Biochem. Physiol.*, **14**, 603. (1965)
3) Conte, F.P., Wagner, H.H., Fessler, J., and Gnose, C., *Comp. Biochem. Physiol.*, **18**, 1. (1966)
4) Wagner, H.H., Conte, F.P., and Fessler, J.L., *Comp. Biochem. Physiol.*, **29**, 325 (1969)
5) Kashiwagi, M., and Sato, R., *Tohoku J. Agr. Res.*, **20**, 41. (1969)
6) Viberg, R., *J. Conseil*, **15**, 328. (1948)
7) Kashiwagi, M., and Sato, R., *Tohoku J. Agr. Res.*, **19**, 56. (1968)
8) Sato, R., and Kashiwagi, K., *Tohoku J. Agr. Res.*, **19**, 127. (1968)
9) Kashiwagi, M., Yoshida, F., and Sato, T., *Bull. Jap. Soc. Sci. Fish.*, **36**, (in press) (1970) (in Japanese, with English summary)
10) Black, V.S., *J. Fish. Res. Bd. Canada*, **8**, 169. (1951)
11) Parry, G., *Nature*, **181**, 1218. (1958)
12) Gordon, M.S., *J. Exp. Biol.*, **36**, 227. (1959)
13) Gordon, M.S., *J. Exp. Biol.*, **36**, 253. (1959)
14) Black, V.S., *Univ. Tronto Studies Biol. Ser. No.* **59**, 53. (1951)
15) Black, V.S., "*The Physiology of Fishes*", ed. by M.E. Brown, Academic Press Inc., New York. Vol. *I*, p. 163. (1957)
16) Parry, G., and Potts, W.T.W., "*Osmotic and Ionic Regulation in Animals*" Pergamon Press, New York. p 1. (1964)
17) Parry, G., *Biol. Revs.*, **41**, 392. (1966)
18) Greene, C.W., *Physiol. Revs.*, **6**, 201. (1926)
19) Benditt. E., Morrison, P., and Irving, L., *Biol. Bull.*, **80**, 429. (1941)
20) Parry, G., *J. Exp. Biol.*, **38**, 411. (1961)
21) Kubo, T., *Bull. Fac. Fish. Hokkaido Univ.*, **4**, 138. (1953) (in Japanese, with English summary)
22) Kubo, T., *Bull. Fac. Fish. Hokkaido Univ.*, **12**, 189. (1961) (in Japanese, with English summary)