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VI. DECREASED AGGRESSIVE BEHAVIOR IN MASU SALMON (*ONCORHYNCHUS MASOU*) DURING THE PARR-SMOLT TRANSFORMATION

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Abstract

Masu salmon *Oncorhynchus masou* showed decreasing levels of overt aggressive behavior (nipping) during the parr-smolt transformation. The highest nipping frequencies were observed in immature parr, and the lowest nipping frequencies in fully-smoltified fish. Desmoltified fish showed a return to aggressive behavior. Plasma thyroxine levels were negatively correlated with frequencies of nipping behavior. Reduced aggression is an important behavioral change in preparation for downstream migration by masu salmon, and also for other salmonid species.

Introduction

Salmonid species have a resident phase in freshwater streams lasting up to several months, one or even more years before migrating to lakes or the ocean. River-resident salmonids form feeding territories in freshwater streams (*e.g.*, Yamagishi, 1962; Grant and Noakes, 1987; Grant, 1990), and aggressive behavior is considered an important part of stream residence (Taylor, 1990). Aggressive interactions between salmonids have been documented by many researchers, including Hoar (1954), Cunjak and Green (1984) and Taylor (1991). Species with the longest duration of river residence show the highest levels of aggressive behavior (Hutchison and Iwata, unpublished data). Nevertheless, salmonids that have migrated to the ocean form schools rather than territories. Smoltification is the preparatory phase for downstream migration by salmonids. Elevated plasma thyroid hormone levels, including those induced by hormone treatment, stimulate various behavioral changes related to smoltification (Iwata, 1995), including salinity preference (Iwata *et al.*, 1990) and phototaxis (Iwata *et al.*, 1989). In this paper we examine changes in aggressive behavior during the parr-smolt transformation of masu salmon and compare frequency of nipping behavior to changes in concentration of plasma thyroxine (T_4).

Materials and Methods

Over the period December 1991 to August 1992, masu salmon held at the Nikko Branch of the National Research Institute of Aquaculture were selected for observation. Selected fish were grouped according to different stages of the parr-smolt transformation. Stages selected were immature parr (stage IV) in December, partially silvered fish with clear parr marks (stage III) in January and February, silvered fish with obscure parr marks (stage II) in

March and April and fully silvered fish with no parr marks (stage I or smolts) in May and June. Silvered fish remaining just after the peak of the migration period in mid June, classified as post-smolts at the end of June, and fish which reverted back to parr-like fish (desmolts) in August were also chosen.

Six pairs of fish from a selected stage were placed in six tanks on the afternoon prior to the day of observation. Differences in body length between the pair were minimized to less than 2% of their total body length. Fish were left to settle overnight. Tank dimensions were 30 x 60 cm and water depth was 15 cm. A netting cover was used to prevent fish from jumping from the tanks. A constant trickle of spring water was supplied to each tank. Water temperatures were within the range 9-10°C throughout the experiments and were the same as those in the stock tanks from which the fish came.

Eight 15-minute observations of nipping behavior of each fish group were made at two-hourly intervals over a two-day period between 0900 and 1500. All observations were recorded on video tape. Tapes were replayed, and the frequency of nipping by each pair of fish during each observation period was calculated.

After the final observation period, fish were captured and then anesthetised in 0.04% 2-phenoxyethanol. At least 200 ml of blood were collected from the caudal blood vessels of each fish by syringe with hypodermic needle. Blood samples were centrifuged; then the plasma was stored at -80°C until assayed. Plasma samples were assayed for T_4 by RIA following the procedures of Tagawa and Hirano (1989). Plasma T_4 levels and nipping frequencies of each group were compared using Tukey's HSD multiple pairwise comparison test in the Systat software package. Data are presented as means \pm SEM.

Results

Nipping behavior showed a tendency to decrease with the progression of smoltification, and to increase again in desmoltified fish (Fig. 9). The highest frequency of nipping was recorded in stage IV of parr in December; desmolts in the summer also showed high nipping frequency. Slightly smoltified fish (stage III) in winter showed a decrease in nipping frequencies from those of stage IV parr. Nipping frequencies of stage II and stage I fish were consistently low during pre- and peak migratory periods. The frequency of nipping tended to increase soon after the peak of the migration season, and it increased significantly in demoltified fish.

Levels of plasma T_4 showed the opposite tendency to those of the nipping behavior. The levels increased gradually with the progression of smoltification, then decreased after the peak migration period. Plasma T_4 level of fully-smoltified fish (stage I) in June reached the highest value (13 ± 2.7 ng/ml, $P < 0.05$); it decreased in the post-smolt and desmoltified fish, at the end of June and August, respectively.

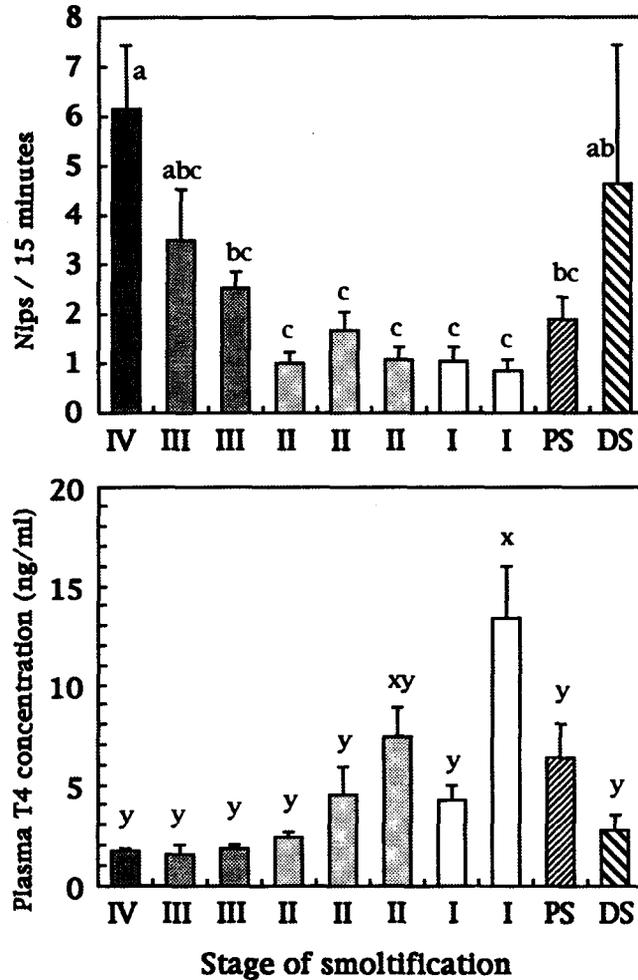


Fig. 9. Nipping frequencies and plasma thyroxine concentrations of masu salmon during the parr-smolt transformation. Data are represented as mean + SEM. Groups not sharing a letter in common are significantly different by Tukey's multiple pairwise comparisons test, $p < 0.05$, $n = 8$.

Discussion

Clearly, aggressive behavior is reduced significantly during the parr-smolt transformation by the time fish are in stage II. Transformation from parr to smolt develops prior to the obtainment of hypoosmoregulatory ability and of behaviors relating to downstream migration. At the same period, the lowest level of nipping behavior appears in stages II and I of smolting fish. However fish which do not migrate return to an aggressive phase, the same strategy as adopted by parr for life in running waters.

Levels of plasma T_4 show a tendency to be higher in stage II fish than in either stage III

or IV fish, and are significantly elevated in fully-smoltified fish at the peak migration period. Nipping behavior is reduced concurrently. Thyroid hormones, together with growth hormone and cortisol, play an important role in smolting and various behavioral changes which for downstream migration (Iwata, 1995). Godin et al. (1974) observed a reduction in aggressive behavior in yearling Atlantic salmon following intraperitoneal injection of thyroxine. However, this experiment was conducted during July and August and not during the parr-smolt transformation period. The negative relationship between plasma thyroxine levels and nipping behavior observed during this experiment suggests that T_4 may play a role in reducing aggressive behavior during smolting. Loss of aggressive behavior is a necessary component in the transformation of salmon from territorial stream fish to shoaling lake or oceanic fish. Reduction of aggression may induce other behavioral changes which are necessary for the formation of social relationship among individuals in a school.

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VII. LIFE HISTORY STRATEGY AND MIGRATION PATTERN OF JUVENILE SOCKEYE AND CHUM SALMON

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Abstract

Life histories of juvenile sockeye and chum salmon show a conditional strategy which has two tactics of residence and migration. They usually remain in lake and river if they can obtain sufficient resources such as food and habitat, whereas salmon migrate seaward when they do not have enough of those resources to satisfy their energy metabolism. Their migration pattern, controlled by effects of "prior residence" and "precedent migration", is determined as a trade-off between the profitability of resource acquisition and risks such as osmoregulation, energetic demands of swimming, exposure to predators, and movement to a non-adaptable habitat by water current.