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Growth and nutritional aspects of juvenile chum and pink salmon migrating in the Okhotsk Sea and the Northwest Pacific Ocean

by

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Growth and nutritional aspects of juvenile chum and pink salmon migrating in the Okhotsk Sea and the Northwest Pacific Ocean

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Abstract

Growth and nutritional conditions of juvenile chum *Oncorhynchus keta* and pink salmon *O. gorbuscha* migrating in the Okhotsk Sea and the North Pacific Ocean were examined using biochemical indices: protein contents (%; percent wet weight of dorsal muscle), the RNA-DNA ratio, and triglyceride (%) along with their biological data: fork length, body weight, and condition factor. Both chum and pink salmon exhibited good growth, especially, in chum salmon captured in late August to early September, judging from the protein content and the RNA-DNA ratio. The relationships of RNA-DNA ratios and triglyceride contents suggest different strategies for survival between species. Chum salmon showed higher body growth rates and less energy storage in earlier stages but decreased growth rate and increased energy storage as growth progressed. Pink salmon had both low energy storage and low growth rates at first, but, gradually increased both of them during their growth.

Introduction

For juvenile chum, *Oncorhynchus keta*, and pink salmon, *O gorbuscha*, migrating to oceanic waters after leaving inshore areas, fall is an important season because during this period both metabolic rates and swimming abilities slow down due to the drop of water temperature, and growth and nutritional conditions influence survival processes during the following winter when food resources are reduced. Unfortunately, however, there is very little information regarding fish condition in the fall. Juvenile chum and pink salmon originating from the far east regions of Asia including Japan are known to distribute densely in the Okhotsk Sea and the northwest North Pacific Ocean during the fall (National Research Institute of Far Seas Fisheries 1994; Ueno 1994). The purpose of the present study is to clarify whether salmonids, especially chum salmon, remain in good condition, and to determine through comparative analysis whether there are species-specific strategies for survival of chum and pink salmon, which are the most abundant species in the Okhotsk Sea and the

North Pacific Ocean in the fall. Body conditions of chum and pink salmon captured in the Okhotsk Sea and the northwest North Pacific Ocean were analyzed using biochemical techniques.

Materials and Methods

The National Research Institute of Far Seas Fisheries, Fisheries Agency of Japan, conducted research cruises which focused on migration of juvenile chum salmon in the Okhotsk Sea and the northwest North Pacific Ocean using two research vessels, the *Wakashio maru* and the *Kaiyo maru* , in the fall of 1993 (FIG. 1, National Research Institute of Far Seas Fisheries 1994; Ueno 1994). Of the samples collected by the two research vessels, a total of 174 chum captured in the Okhotsk Sea and the northwest North Pacific Ocean between late August and late November, and 72 pink salmon caught in the Okhotsk Sea in October were used in the present study. The chum samples were divided into five groups, based on time periods (from late August to early September, in October, and in November), and on areas (the Okhotsk Sea and the North Pacific Ocean), while all pink samples were kept in one group because all samples were taken in the Okhotsk Sea in October (TABLE 1). As indices expressing growth and nutritional condition of fish, protein content (%, percent wet weight), the RNA-DNA ratio, and triglyceride content (%) of dorsal muscle of each fish were examined. Proteins are important structural components of body cells as well as physiologically-active components operating as enzymes. The RNA-DNA ratio indicates protein synthetic rates of the cells. Triglycerides constitute the majority of neutral fat in the body and are an energy reserve used for mechanical activities as well as for other functions such as buoyancy, protective covering, etc. Therefore, growth condition was judged by the protein content and the RNA-DNA ratio, while nutritional aspects were estimated by the triglyceride content. In the present study, I also calculated the protein-DNA ratio and examined the relationships of the RNA/DNA ratio and the triglyceride content in order to understand the growth processes. Protein and triglyceride were measured by the Lowry method (Lowry et al 1955) and the chlorophenol method (Wako Ltd.), respectively. The RNA-DNA ratio was estimated by the Schmidt-Thanhauser-Schneider method (Nakano 1988). As the second step of the analysis, i.e. considering the relationships of fork length or condition factor and the biochemical indices mentioned above, the chum groups captured in different areas in the same months were combined.

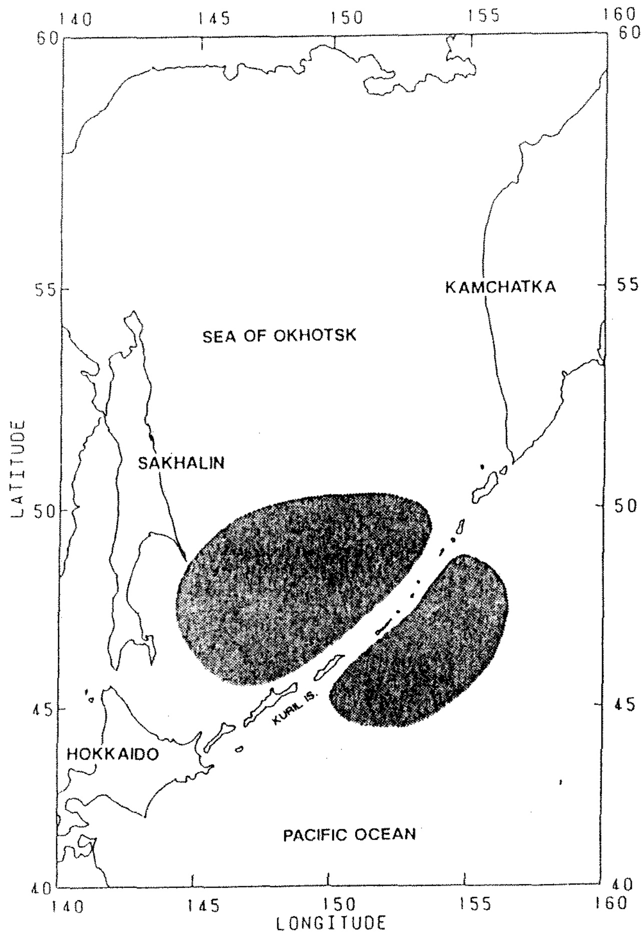

Figure 1. Location where juvenile chum and pink salmon were captured.

TABLE 1. Number of fish analyzed

Species	Time period	Area	Number of fish
Pink salmon	October	The Okhotsk Sea	72 (66)*
Chum salmon	Aug.-Sep.	The Okhotsk Sea	25
Chum salmon	October	The North Pacific	5
Chum salmon	October	The Okhotsk Sea	74
Chum salmon	November	The North Pacific	25
Chum salmon	November	The Okhotsk Sea	45

* The number in parentheses is for triglyceride measurement.

Results

Body sizes and condition factors

The mean fork length of all groups of both species ranged from 215 mm to 260 mm, and the mean body weights ranged from 119 g to 195 g. Both fork length (FL) and body weight (BW) of chum captured in the Okhotsk Sea from late August to early September were smallest while chum captured in the North Pacific in October were largest (FIG. 2). Chum salmon captured in November were significantly smaller than those caught in October in both the Okhotsk Sea and the North Pacific Ocean. There was no significant difference between the two areas in each month, although those in the Okhotsk Sea were smaller in both months. The body size of pink salmon was intermediate between that of chum captured in October and November.

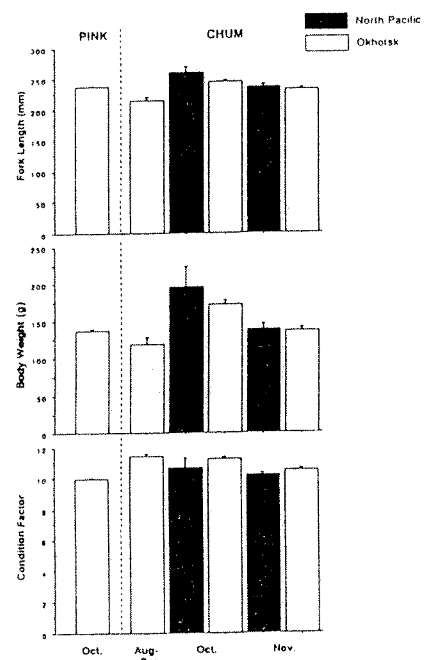

Figure 2. Fork length, body weight, and condition factor of the juvenile chum and pink salmon examined.

Mean condition factors (BW(g)·106·FL(mm)-3) ranged from 9.98 (pink salmon captured in the Okhotsk Sea in October) to 11.42 (chum salmon captured in Okhotsk Sea from the late August to early September, FIG. 2). Chum captured in the Okhotsk Sea from late August to early September had the highest condition factor although their body size was smallest. The condition factor, as well as the body size, of chum captured in October was higher than that in November in both areas, although the condition factor of Okhotsk chum was a little higher than that of North Pacific chum in contrast to body size differences.

Protein

The protein content (%) of pink salmon was about 12 %, and clearly less than that of chum salmon, which ranged from 14.9 % to 16.1 % ($P<0.0001$, FIG. 3). Although differences in protein content between groups were not related to body size, they are similar to those of the condition factor but not statistically significant ($P=0.1045$). Within groups in which the two areas were combined in respective months, only one group, chum in October, showed a significant positive correlation ($P<0.0001$) between protein content and fork length (FIG. 4). All groups showed no correlation between protein content and condition factor (FIG. 4).

The protein-DNA ratio

Okhotsk pink in October showed the lowest ratio, 124, while North Pacific chum in October showed the highest ratio, 231. The chum groups in October showed significantly higher ratios than those in November, while there were not statistical differences between the areas in either month (FIG. 5). All chum groups exhibited significant positive relationships between the protein-DNA ratio and fork length although no significant relationships were seen in pink salmon (FIG. 6). Only one chum group in October showed a positive relationship between the ratio and the condition factor ($P=0.0235$, FIG. 7).

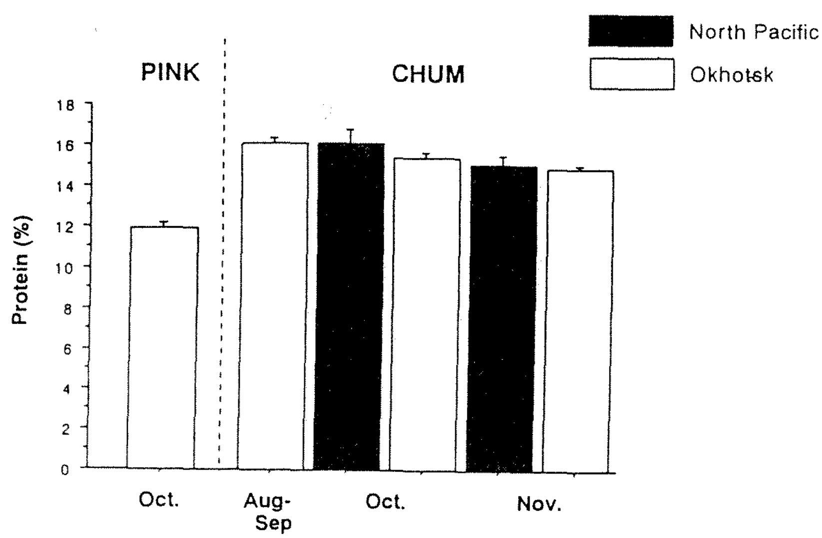

Figure 3. Protein contents (percent wet weight) in dorsal muscle of pink and chum salmon. Vertical bars indicate the standard error of the mean.

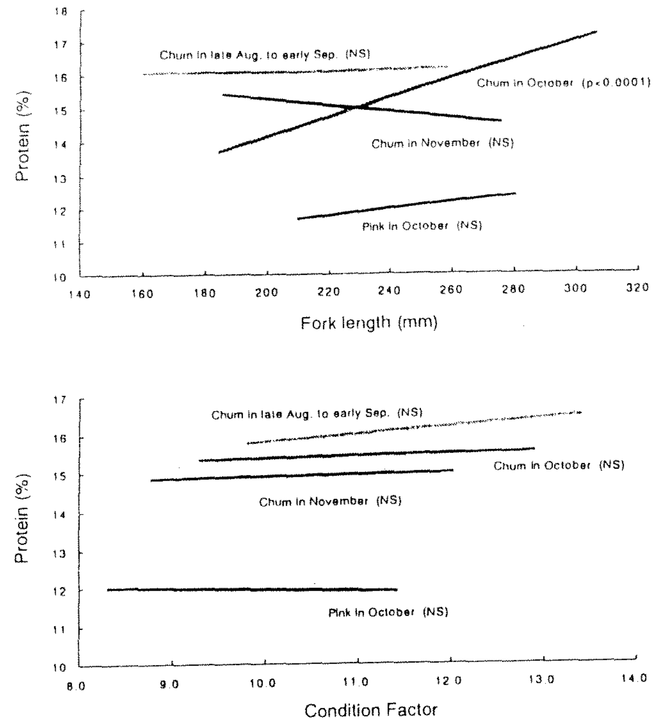

Figure 4. Regression lines showing relationships between protein content (%) and fork length (mm) (the upper figure) and between protein and condition factor (the lower figure). Lines are shown by species and by month. NS: not significant.

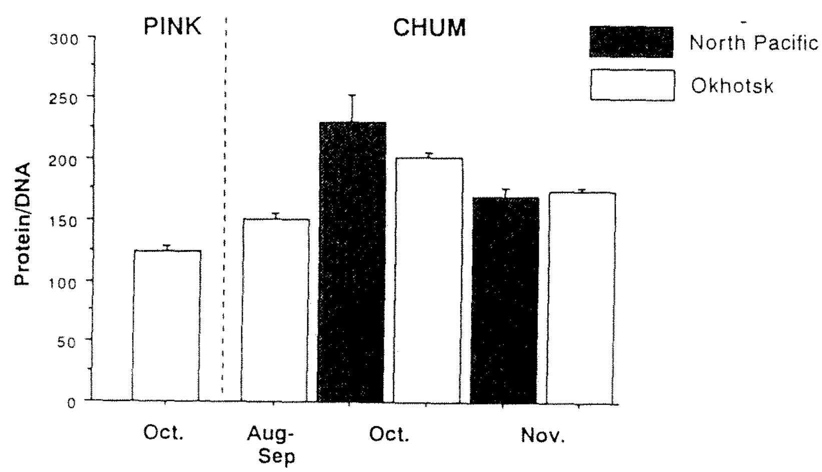

Figure 5. Protein-DNA ratio in dorsal muscle of pink and chum salmon. Vertical bars indicate the standard error of the mean.

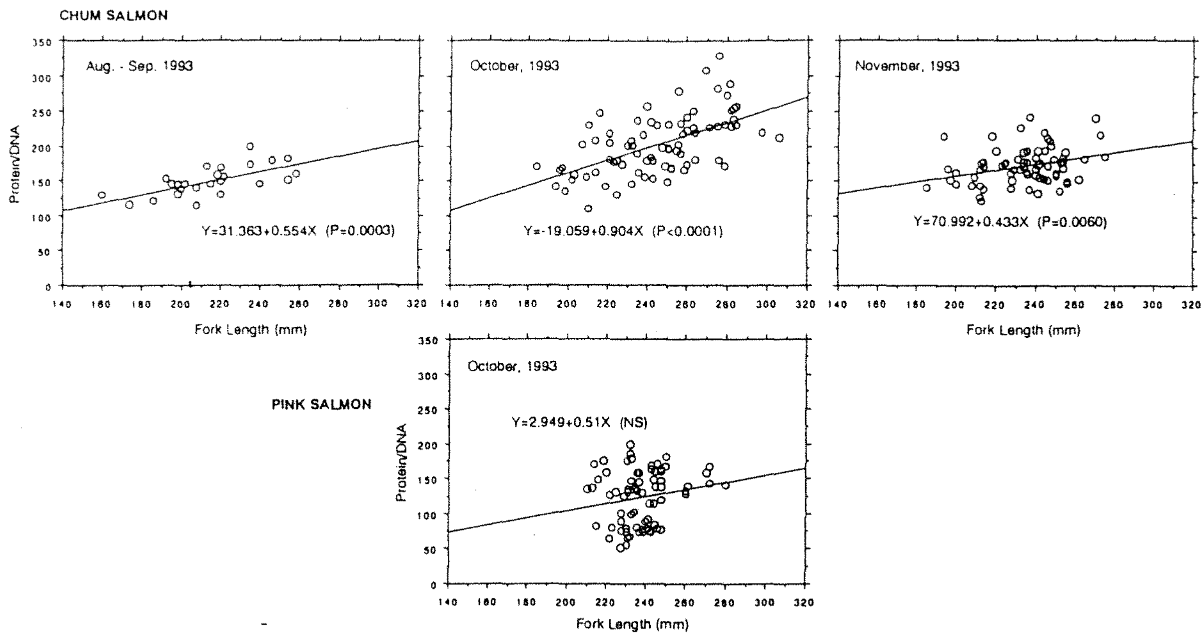

Figure 6. Relationship between protein-DNA ratio and fork length (mm) in juvenile chum (the upper figure) and pink salmon (the lower figure).

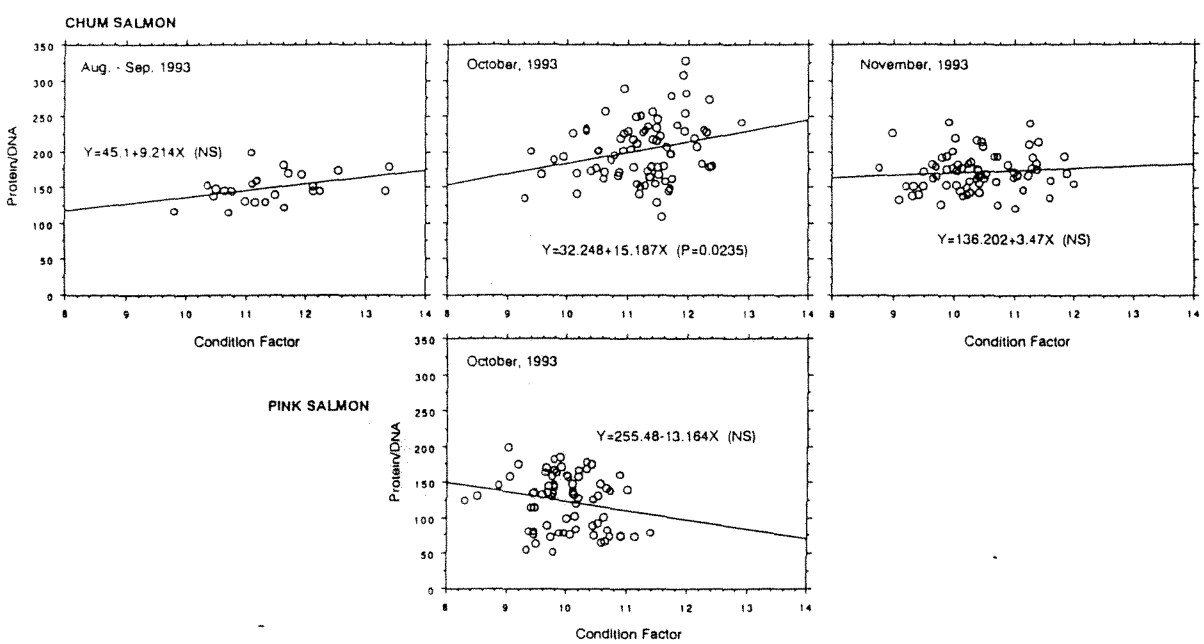

Figure 7. Relationship between protein-DNA ratio and condition factor in juvenile chum (the upper figure) and pink salmon (the lower figure).

The RNA-DNA ratio

Okhotsk chum captured from late August to early September showed a significantly higher ratio, 6.83, compared with the other groups ($p \leqq 0.0001$ to other chum groups, $p=0.0004$ to pink salmon, FIG. 8), while pink salmon also had a high value, 5.95. The lowest ratio, 4.98, was seen in the North Pacific chum in November. Although two chum groups in October and November showed negative correlations between DNA/RNA ratios and fork length ($p<0.0001$, FIG. 9), no chum group had a significant relation with condition factor (FIG. 10). The RNA-DNA ratio of pink salmon showed a positive correlation with the fork length ($p<0.0447$, FIG. 9), but a negative correlation with condition factor ($p<0.0077$, FIG. 10).

Triglyceride

Okhotsk chum in October showed the highest triglyceride content, 1.70, followed by the North Pacific chum in the same month, 1.21 (FIG. 11). The remaining groups had similar values ranging from 0.784 to 0.894. Triglyceride contents showed significant positive relationships with both fork length and condition factor in all groups except for the relation to condition factor in chum in late August to early September and in pink salmon (FIGS. 12 and 13). The relationships with fork length were stronger than those with condition factors.

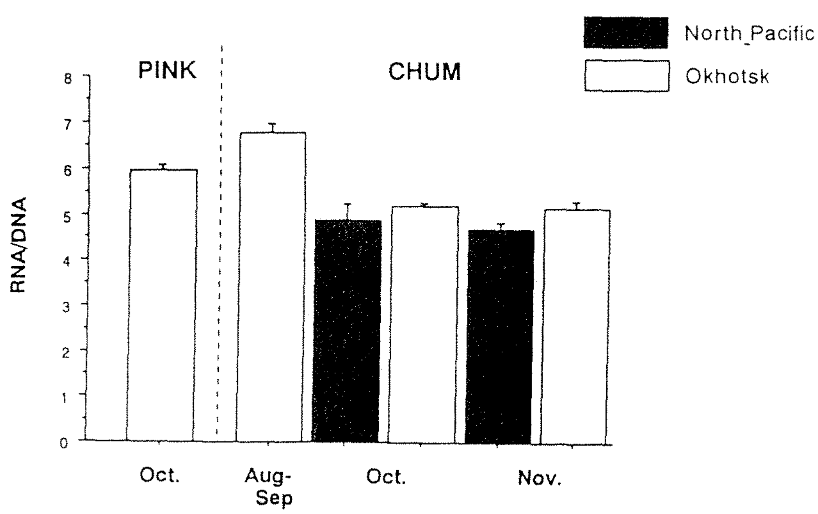

Figure 8. RNA-DNA ratio in dorsal muscle of pink and chum salmon. Vertical bars indicate the standard error of the mean.

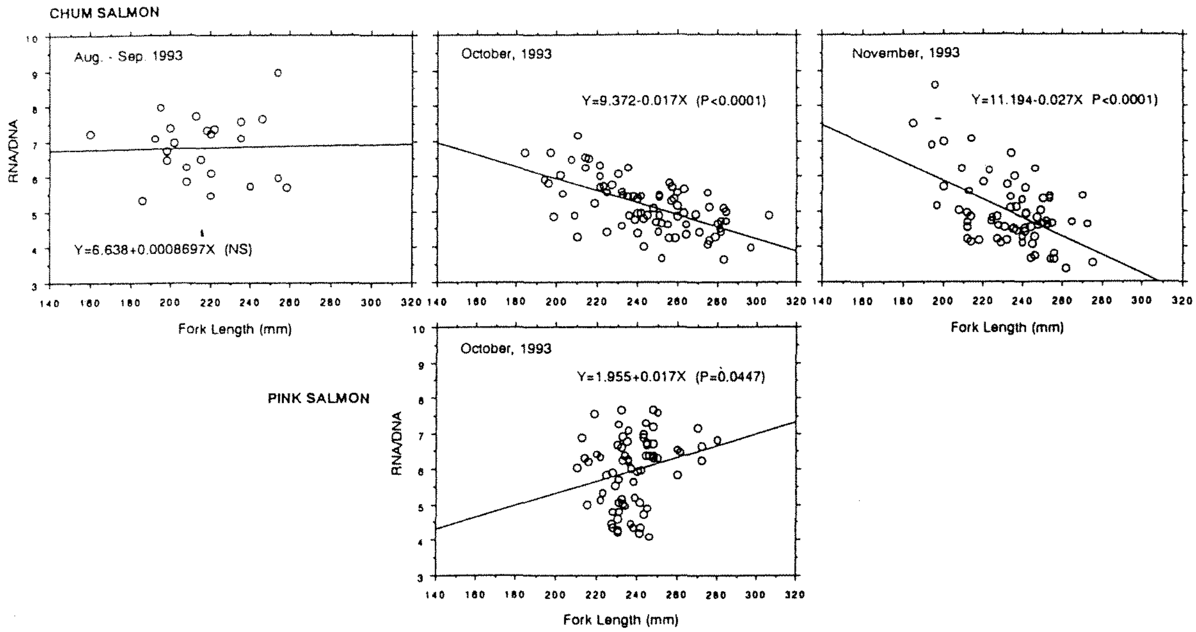

Figure 9. Relationship between RNA-DNA ratio and fork length (mm) in juvenile chum (the upper figure) and pink salmon (the lower figure).

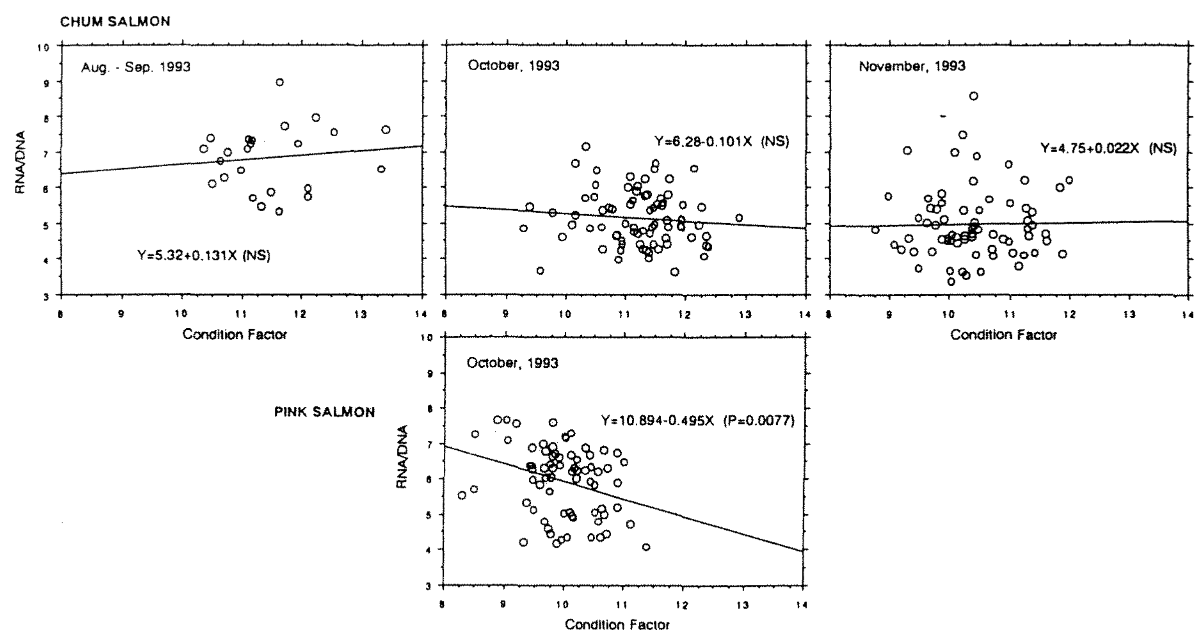

Figure 10. Relationship between RNA-DNA ratio and condition factor in juvenile chum (the upper figure) and pink salmon (the lower figure).

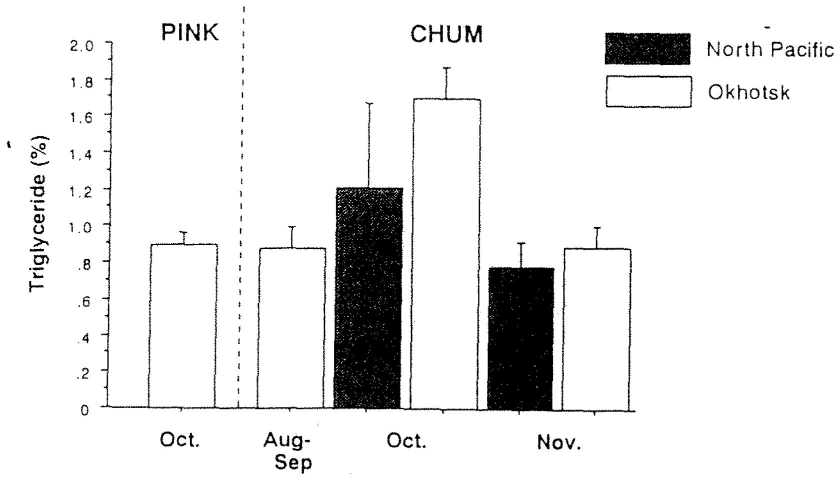

Figure 11. Triglyceride content (percent wet weight) in dorsal muscle of pink and chum salmon. Vertical bars indicate the standard error of the mean.

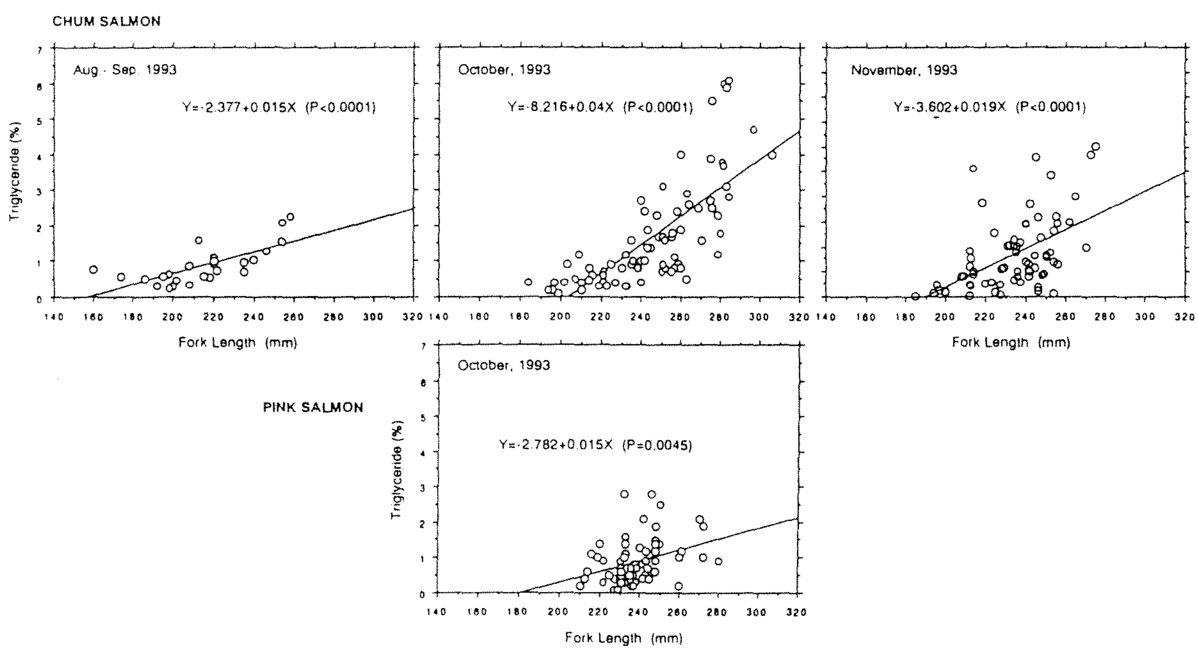

Figure 12. Relationship between triglyceride (%) and fork length (mm) in juvenile chum (the upper figure) and pink salmon (the lower figure).

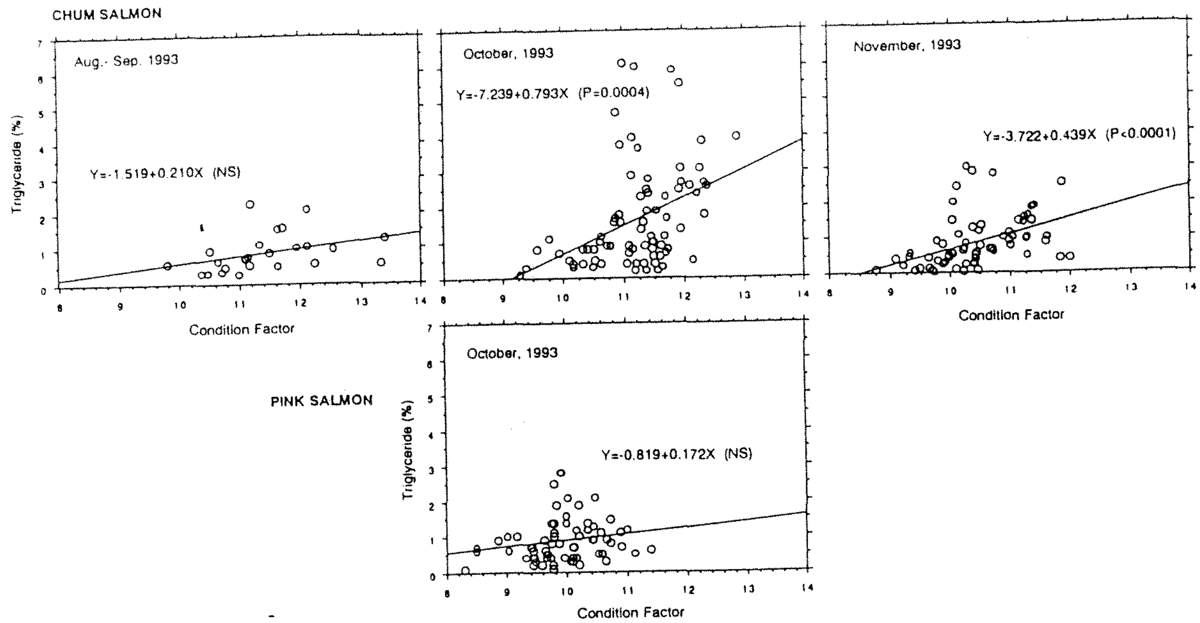

Figure 13. Relationship between triglyceride (%) and condition factor in juvenile chum (the upper figure) and pink salmon (the lower figure).

The relationship of RNA-DNA ratios and triglyceride contents

The direction of slopes were negative in chum groups while positive in pink salmon although the case of chum in late August to early September was not statistically significant (FIG. 14).

Discussion

Pink salmon captured in the Okhotsk Sea in October were thinner than chum salmon (FIG. 2). Although the condition factor and protein content were similar between groups, the change in protein content was not generally coupled with condition factor or fork length within groups pooled by month (FIGS. 3 and 4). Condition factor showed positive relationships with triglyceride content within groups (FIG. 13), but triglyceride was more strongly related to fork length (FIG. 12). Moreover, there was no correlation between the RNA-DNA ratio and condition factor in chum, while negative correlation in pink salmon (FIG. 10). Therefore it is not clear how to interpret condition factor, at least of juvenile chum and pink salmon, in judging growth and nutritional conditions.

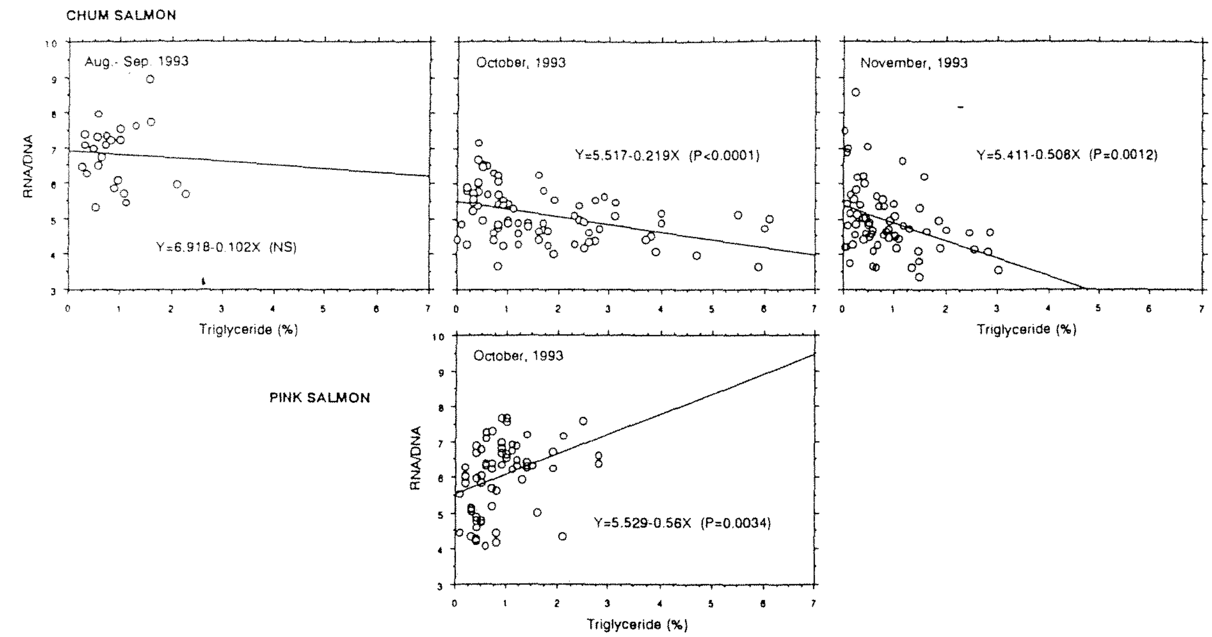

Figure 14. Relationship between RNA-DNA ratio and triglyceride (%) in juvenile chum (the upper figure) and pink salmon (the lower figure).

The protein content of pink salmon muscle was much lower than that of chum salmon (FIG 3). However, since it was not below the normal range of protein content of protoplasm of organisms, 7 to 10 % (Anonymous 1960), Okhotsk pink in October are not judged to be in an abnormally low growth condition.

The protein-DNA ratio has been employed as an index of relative cell mass (Bulow 1987). The changes in the protein-DNA ratio demonstrate that the relative cell mass of chum muscle is largest in October. Since it is known that the process of fish growth is associated with an increase in cell size and/or in number of cells (review of Bulow 1987), the increase of the ratio from late August to October (FIG. 5) is considered to indicate cell growth. This is consistent with an increase in body size during this period, and the fact that larger individuals have the larger ratios (FIGS. 2 and 6). However, in pink salmon the growth process may be a slightly different from that of chum, because the relationship between the protein-DNA ratio and fork length in pink salmon was not clear (NS) (FIG. 6). This suggests that increase of cell size does not contribute much to body growth in pink salmon. The decrease of the ratio seen in chum from October to November (FIG. 5) may be related to a depressed growth rate due to the reduction of metabolic rate with the drop in water temperature, which may also cause a decrease in feeding activity. Since the DNA contents of a cell are species specific values, the ratio could not be compared between species (Bulow 1987). However, on the supposition that there is not much difference in DNA content per cell between chum and pink salmon, pink salmon, with fork lengths similar to chum in October, are assumed to have smaller cell sizes than chum salmon.

Wilder and Stanley (1983) reported that significant correlations were found between the RNA-DNA ratio and growth rate in brook trout, *Salvelinus fontinalis*, and Atlantic salmon, *Salmo salar*, and that the RNA-DNA ratio was 3.14 for brook trout and ca. 1 for Atlantic salmon when the growth rate was zero. Wilder and Stanley (1983) demonstrated in another experiment that the RNA-DNA ratio was to 5.0 in brook trout receiving food of 1-2 % of their body weight· day-1 and showing a growth rate of 0.45 g· day-1. Nakano et al. (1985) showed the RNA-DNA ratio ranged from ca. 3 to 7 in juvenile chum salmon in healthy condition in early development stages, five to 20 weeks after hatching. Varnavskiy et al. (1992) also reported that a good correlation between RNA/DNA and growth rate was found in juvenile coho salmon, *Oncorhynchus kisutch*, under experimental conditions, and that the ratio ranged from 2.33 to 4.48 in well-fed coho underyearlings and from 1.18 to 1.90 in starved fish. In masu salmon, *Oncorhynchus masou*, Ohtsu (1992) reported that fish fed well and reared in water temperature of 13 °C showed a RNA-DNA ratio of 1.82. Judging from the above examples, the RNA-DNA ratios of 4.67 to 6.78 in chum and pink migrating in the Okhotsk Sea and the North Pacific Ocean are considered to indicate relatively good growth rates. Especially in chum in late August to early September and pink in October, it seems that cell multiplication is active. That pink showed a positive relationship between RNA/DNA and fork length while chum salmon have a negative relationship indicates that pink show rapid growth compared with chum in a comparable stage of life (FIG. 9). The fact that pink have low condition factors but a higher growth rate, while no such the relation was shown in chum salmon, makes interpretation of the condition factor complicated (FIG. 10).

The triglyceride contents of juvenile chum and pink in the present study were much lower compared with, for example, the values measured as fat content (%) in artificially well-fed Atlantic salmon. A value of ca. 3 to 6 % was reported by Shearer et al. (1994) for fish showing comparable body sizes with those in this study, 8 to 11 % by Aksnes et al. (1986) for immature fish ranging from 3 to 5.5 kg gutted weight, and ca. 3.5 to 12.5 % by Storebakken and Austreng (1987) for juvenile fish less than 30 g. For 0+ coho salmon, Griffioen and Narver (1974) reported lipid contents ranging from ca. 4.5 to 6.5 % for artificially well-fed juveniles, and ca. 1.5 to 5.5 % for starved fish.

However, Griffioen and Narver (1974) also noted that the lipid content of wild fish approximated that of starved cultured fish, so that triglyceride contents of 0.8 to 1.7 % obtained in juvenile chum and pink migrating in the Okhotsk Sean and the North Pacific Ocean do not seem to be lethally low. The seasonal change of this value in chum salmon may be explained in the same way as in the protein-DNA ratio. The triglyceride contents showed higher values in individuals with larger body sizes in both juvenile chum and pink salmon (FIG. 12). However, as mentioned before, condition factor was not always a suitable index for assessing the energy reserves of individuals, although significant correlations between triglyceride and condition factor were shown in chum in October and November (FIG. 13).

The relationships between the RNA-DNA ratio and triglyceride content suggest a difference in survival strategy between the two species (FIG. 14). Chum salmon may change the way they divide their energy budget as they grow. When body size is small, they tend to invest in a higher body growth rate rather than storing energy, as indicated by a high value of the RNA-DNA ratio and a low value of triglycerides. As they grow, they deposit more energy in the form of triglycerides rather than maintaining a growth rate. This may be an reasonable strategy for chum to survive in the following winter when feeding efficiency decreases with colder temperatures. On the other hand, pink salmon invest in both growth rate and energy storage as they grow, although the initial stage of the juvenile was much severe and may be critical. Therefore, if pink salmon survive their early life stage, they can grow more easily and more rapidly. This strategy appeared to underlie the rapid growth characteristic of pink salmon.

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