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RESEARCH NOTE

Variation in Lipid Content in the Muscle of Chum and Pink Salmon in the Gulf of Alaska in May 1999

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Abstract. — We report on a study of the total lipid content (TL) of chum and pink salmon in the Gulf of Alaska in May 1999. Chum and pink salmon were caught by surface trawl net in the Gulf of Alaska during a spring cruise of the F/V *Great Pacific*. TL was extracted from the muscle of 99 chum and 50 pink salmon by Folch's method using chloroform/methanol and measured gravimetrically. A significant difference in the total lipid content by ocean age was observed in chum salmon. Younger chum salmon (ocean age-.1 and .2) had lower lipid content than older fish (ocean age-.3 and .4). Mean TL in pink salmon was 2.6% in females and 2.7% in males. Our results suggest that low lipid content, previously observed in hig-seas salmon during the winter season, is prolonged into the spring in young chum and pink salmon.

Key words: total lipid content, muscle, chum salmon, pink salmon, spring, Gulf of Alaska

Introduction

The quantity of lipid has been used as a biochemical index of trophic condition in a variety of contexts for both freshwater and marine fish (Novotony and Beeman 1990). Dietary lipids play an important role in providing energy in carnivorous fish like salmonids due to their limited ability to utilize carbohydrates as an energy source (Watanabe 1982).

Although there have been a large number of lipid studies on cultured fish and artificial food (Wilson 1991), little is known about high-seas salmonid lipid content. Azuma et al. (1998) reported on the growth characteristics of Pacific salmon through examination of triglycerol and protein content, and nucleic acid ratios. In our previous paper, lipid content and fatty acids were examined to investigate trophic condition of chum (*Oncorhynchus keta*) and pink salmon (*O. gorbuscha*) in the North Pacific Ocean in winter (Nomura et al. 2000). A low lipid content in the muscle and a high percentage of docosahexaenoic acid in fatty acid composition of neutral lipid were observed in chum and pink salmon in winter.

Information on the lipid content of salmonids during high-seas migrations is useful to estimate their trophic condition, growth, and survival. In general, it is supposed that salmonids resume feeding in spring, and lipid content level in the muscle of these fish may be higher than in winter. But there is no previous report of lipid content in high-seas salmonids in spring. In this report, we studied lipid content in the white muscle of chum and pink salmon caught in the Gulf of Alaska in the spring of 1999.

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Materials and Methods

Chum and pink salmon were caught by surface

Table 1. Sampling station, date, location, number of fish sampled by ocean age, and seawater temperature (ST) in the Gulf of Alaska in the spring of 1999.

Station	Date	Longitude (W)	Latitude (N)	Chum Ocean age					Pink Ocean age	ST* (℃)
				1	2	3	4	5	1	
1	May 4	166°38′	54°06′	0	0	0	1	0	0	3.1-3.2
2	May 5	166°43′	53°26′	0	0	0	3	0	0	3.2-3.4
3	May 5	166°23′	53°09′	0	0	0	1	0	0	3.3
4	May 5	166°07′	52°51′	0	0	0	2	1	0	4.0-4.1
5	May 6	165°00′	50°58′	0	0	1	4	1	0	3.3
6	May 6	165°00′	49°59′	0	0	0	2	1	0	3.4-3.5
7	May 6	164°59′	49°02′	0	0	1	5	1	0	3.9
8	May 7	165°00′	47°59′	0	0	0	3	0	1	4.7-4.8
9	May 7	165°00′	47°00′	0	0	0	1	0	4	4.9
10	May 7	165°01′	46°54′	0	0	2	2	1	4	5.0
11	May 7	165°00′	46°23′	0	0	0	0	0	12	5.1-5.5
12	May 8	164°59′	45°00′	0	0	1	1	0	4	6.5-6.6
13	May 8	164°59′	43°58′	3	7	2	1	0	0	6.5-6.7
14	May 16	144°59′	42°34′	0	0	0	0	0	7	8.1-8.2
15	May 16	144°58′	43°00′	10	2	0	0	0	2	8.2-8.3
16	May 16	145°00′	43°51′	0	2	0	0	0	2	7.8-7.9
17	May 17	145°00′	45°01′	3	3	0	0	0	12	7.1-7.2
18	May 17	145°00′	46°00′	0	0	0	0	0	2	6.7
19	May 19	145°00′	50°57′	0	0	1	1	0	0	5.1-5.3
20	May 19	145°00′	52°54′	0	0	3	0	0	0	4.6-4.9
21	May 20	144°58′	54°31′	0	0	2	0	0	0	4.8-4.9
22	May 20	144°59′	55°00′	0	1	11	2	0	0	4.7-4.8
23	May 20	144°59′	55°31′	0	0	2	0	0	0	5.0-5.2
24	May 21	144°59′	56°00′	0	0	7	1	0	0	5.3-5.7
Total				16	15	33	30	5	50	

*ST, Seawater temperature at head rope of trawl net.

trawl net in the Gulf of Alaska during a spring cruise of the F/V *Great Pacific* (Table 1) (Carlson et al. 1999). Salmon ages were determined by examination of scale patterns. Ocean age was designated by the European method, whereby a dot followed by a number indicates the number of winters in the ocean, for example, an age-.1 salmon spent one winter in the ocean. The fork lengths (FL in cm) and weights (BW in g) of the salmon were measured and used to calculate the condition factor $(((BW)/(FL)^3) \times 1{,}000)$. The white muscle was sampled from the dorsal muscle directly behind the head, and muscle samples were frozen at -30℃ until analyzed.

Total lipids (TL) in the white muscle were extracted with chloroform/methanol by the method of Folch et al. (1957) and measured gravimetrically. Lipids were extracted by homogenizing the white muscle (10 g) with 50 ml of methanol and 120 ml of chloroform. The homogenate was filtered through a lipid free paper into glass vessel. The crude extract and water were mixed in a separatory funnel in the proportions 8:4:3 by volume. The lower phase was collected, and solvent was evaporated with rotary evaporator.

The resulting values were tested for significant differences using analysis of variance (ANOVA) followed by Turkey' multiple comparisons test ($p<0.05$).

Table 2. Biological parameter and total lipid content of chum and pink salmon caught in the Gulf of Alaska in May 1999 by ocean age.

Species	Ocean age	Sex	No. of fish	Fork length (cm)	Body weight (g)	Condition factor	Total lipid content (%)	
Chum	1	Female	7	30.0 (1.63)*1	340 (60)	12.31 (0.58)	1.4 (0.47)	0.9-2.3*2
		Male	9	30.4 (2.12)	320 (51)	11.43 (0.96)	1.2 (0.96)	0.9-1.4
	2	Female	10	38.9 (1.59)	640 (110)	10.80 (0.80)	1.9 (0.91)	1.0-4.1
		Male	5	39.6 (1.69)	650 (54)	10.41 (0.56)	1.6 (0.35)	1.3-2.2
	3	Female	22	54.9 (4.53)	2,062 (505)	12.15 (1.06)	4.0 (2.08)	1.2-10.9
		Male	11	58.8 (3.34)	2,452 (490)	11.90 (1.29)	3.9 (2.10)	0.9-7.4
	4	Female	16	57.5 (2.18)	2,290 (271)	11.97 (1.10)	4.9 (3.33)	1.4-15.6
		Male	14	60.0 (3.53)	2,605 (727)	11.75 (1.42)	3.1 (1.80)	1.0-6.4
	5	Female	3	58.2 (3.71)	2,120 (380)	10.68 (0.67)	3.6 (0.76)	2.7-4.2
		Male	2	61.6 (4.95)	2,950 (1,060)	12.31 (1.55)	5.1 (5.57)	1.1-9.0
Pink	1	Female	15	35.9 (3.04)	480 (110)	10.22 (0.94)	2.6 (1.29)	0.8-6.5
		Male	35	36.5 (3.33)	509 (128)	10.36 (1.03)	2.7 (1.34)	1.1-6.2

*1 mean (SD)

*2 range

Results

Chum salmon

TL in female and male age-.1 fish was low and increased with increasing ocean age (Table 2, Fig. 1). There was a significant difference in TL between ocean age-.1 and .4 female chum salmon. In female chum salmon, a significant difference in TL was also observed between ocean age-.2 and .4 fish. TL in ocean age-.1 male chum salmon was significantly lower than in ocean age-.3 male fish.

A positive relationship between body weight and TL was observed in ocean age-.4 male fish (Fig. 2). There was no significant relationship between body weight and TL in other ages and sexes of fish. A positive relationship between condition factor and TL was observed in ocean age-.2 female, age-.3 male, and age-.4 male fish. There was no significant relationship between condition factor and TL in other ages and sexes fish.

Pink salmon

All pink salmon in the samples were ocean age-.1. TL was 2.6% in female and 2.7% in male (Table 2). There was no significant difference in the average of TL between female and male pink salmon ($p>0.05$). There was a negative correlation (R^2=0.176) between body weight and TL in the male fish, and a positive correlation (R^2=0.162) between condition factor and TL in male pink salmon (Fig. 3).

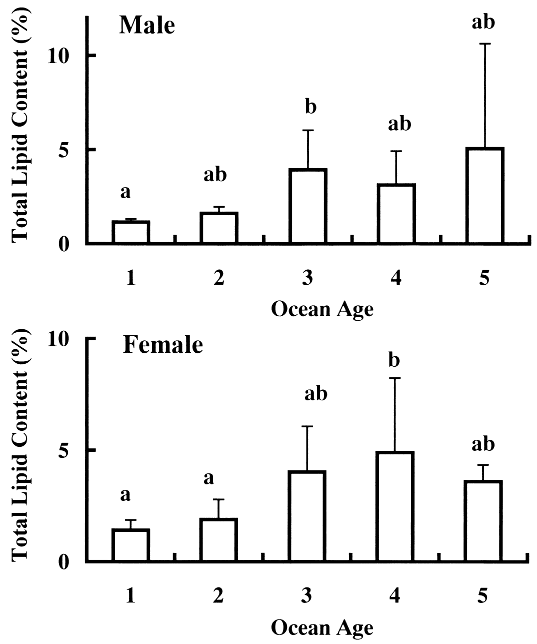

Fig. 1. Total lipid content in the white muscle in chum salmon caught in the Gulf of Alaska in May 1999 by ocean age. Sample sizes are shown in Table 2. Bars are means, and lines are SD. Letters at the top of each bar summarize the result of Turkey's multiple comparison (ANOVA). Data points sharing the same letter are not significantly different ($p>0.05$).

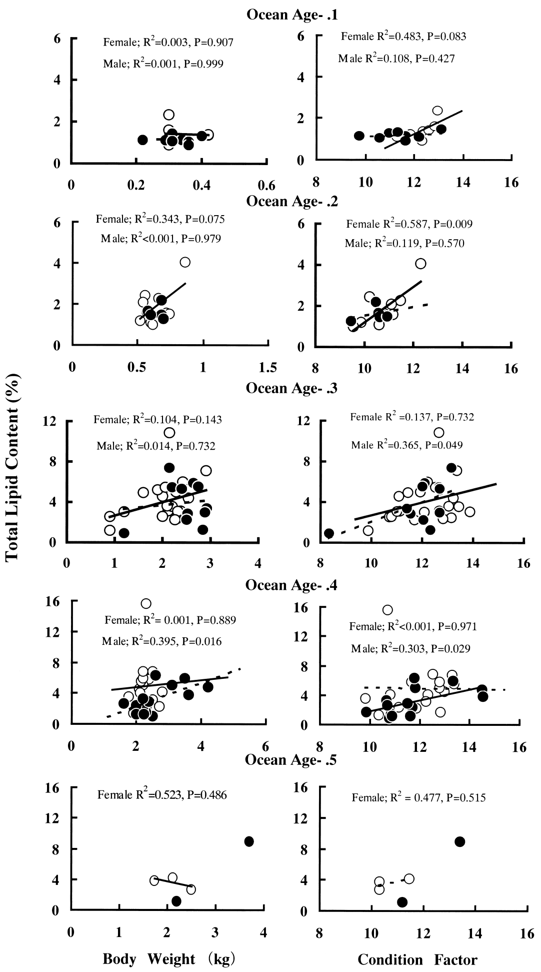

Fig. 2. Relationships between total lipid content in the white muscle of chum salmon and body weight (left) or condition factor (right) by ocean age. Open and close circles indicate female (n=58) and male (n=41) fish, respectively. The regression lines were drawn with a solid line for female and broken line for male.

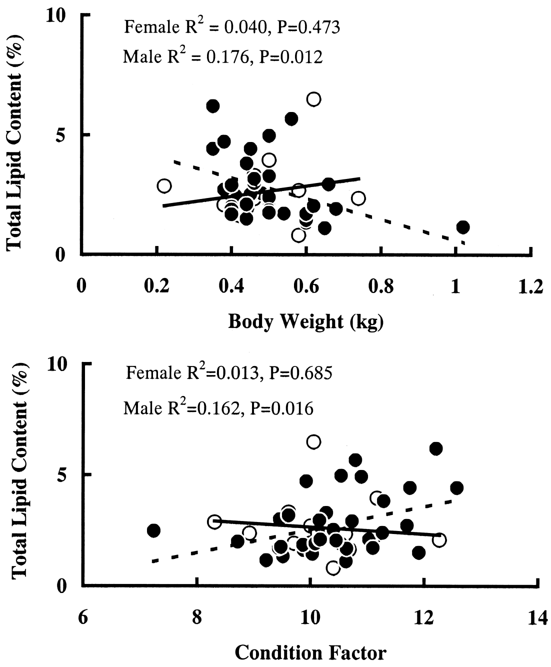

Fig. 3. Relationship between total lipid content in the white muscle of pink salmon and body weight (upper) or condition factor (lower). Open and close circles indicate female (n=15) and male (n= 35) fish, respectively. The regression lines were drawn with a solid line for female and broken line for male.

Discussion

In this study, we found a significant difference by ocean age in total lipid content in the white muscle of chum salmon caught in the Gulf of Alaska in spring. We conclude that the effect of age must be taken into consideration when examining lipid levels in salmon in offshore waters. The average TL content in winter was 1.1% in chum salmon and 1.7% in pink salmon (Nomura et al. 2000). Present results for TL content of ocean age-.1 and .2 chum salmon, and pink salmon in spring were similar to those in winter, indicating that lipid levels had not increased in early spring. Younger chum and pink salmon still had lower lipid levels than older salmon in spring, and the starved condition observed by Nomura et al. (2000) in winter seemed to be continued even in spring in the Gulf of Alaska.

Ocean environmental conditions, especially water temperatures, play an important role in the regulation of metabolism in marine fish. Bioenergetic models show that high-seas salmon expend more energy for metabolism at high temperatures than at low temperatures (Davis et al. 1998; Walker et al. 2000). Sea surface temperature (SST) was lower than 4°C at many stations where chum salmon were caught in our study, but the ocean age-.1 and .2 fish were primarily caught at SSTs between 6.5-8.3°C (Table 1). The surface water layers along the survey transects were well-mixed to a depth of a least 100 m (Carlson et al. 1999), so that young salmon would have had to migrate substantial horizontal or vertical distances to find cooler water temperatures. More studies are needed to reveal effects of annual and seasonal variation in ocean conditions on lipid content in young chum and pink salmon.

Our results cannot explain the reason for the observed low lipid content of young chum salmon in spring 1999. At the time of capture, most young chum salmon appeared to be actively feeding on a wide variety of zooplankton prey, and percentages of fish with empty stomachs were lower and stomach contents weight as a percentage of body weight were higher than in chum salmon samples collected from the same region in July 1999 (Carlson et al. 1999; Myers et al. 2000). During their ocean migrations salmon use much energy for movement and control of metabolism. Lipid is an important energy source for fish, and thus low lipid content in young chum salmon indicates that there was not enough intake of dietary lipid, or that they expended much lipid on growth. A negative correlation between triacylglycerol content and RNA:DNA ratio demonstrates that juvenile chum salmon slow down their growth rate to maintain their energy reserve (Azuma et al. 1998). Low lipid content in young chum and pink salmon in spring may have a significant effect on their ocean growth and survival.

There are many papers discussing the association of lipid levels with maturation (Kiessling et al. 1991; Thorpe et al. 1991; Kadri et al. 1996; Shearer and Swanson 2000). We did not evaluate the relationship between maturation and lipid levels in chum salmon, because we judged maturation only by visual examination of gonads. Pooled-years analyses of historical high- seas salmon data (1956-1971) have shown that older, maturing chum salmon tend to be distributed farther to the north than younger, immature chum salmon in the spring North Pacific Ocean (Neave et al. 1976). We observed little overlap in the distribution of immature and maturing chum salmon during our May 1999 survey, and maturing chum salmon, caught in northern areas along the transect, had higher stomach content weights as a percentage of body weight than immature chum salmon, caught in southern areas (Carlson et al. 1999). The lack of overlap in spring high seas distribution of immature and maturing chum salmon may serve to maximize the growth potential of maturing fish and minimize intra specific competitive feeding interactions, perhaps at the expense of reduced growth rates of younger age groups. Further investigation of seasonal changes and annual variation in lipid content of each age and maturity group of chum salmon will be important for understanding their ocean survival, growth, and fecundity.

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1999年5月にアラスカ湾で採集されたサケとカラフトマスの筋肉脂質含量

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1999年5月にアラスカ湾でトロール網で採集されたサケ99尾とカラフトマス50尾の筋肉脂質含量について検討した．サケでは海洋年齢1年および2年魚の筋肉脂質含量は3年魚および4年魚より有意に低い値を示した．カラフトマスでもサケと同様の低い脂質含量であった．海洋年齢1年および2年魚の平均脂質含量は，越冬期のサケやカラフトマスの含量とほぼ同様の値であり，越冬期に観察された飢餓状態が若齢魚では春季にも継続していることが示唆された．海洋生活期のサケやカラフトマスの脂質含量を検討する際は年齢の影響を十分考慮する必要がある．