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Abstract

This study reports the total lipid content of chum and pink salmon caught in the western North Pacific Ocean and the Gulf of Alaska in winter (January-March), 2006. The Total lipid content was extracted from the white muscle of 145 chum and 117 pink salmon using chloroform and methanol and then measured gravimetrically. The total lipid content of ocean age 1 chum salmon was much lower than that of older (ocean age 2-5) fish, averaging 2.4% in the western North Pacific Ocean and 1.2% in the Gulf of Alaska. The mean total lipid contents of chum and pink salmon were significantly higher in the western North Pacific Ocean than in the Gulf of Alaska. The present preliminary results as well as the past studies suggest that the trophic status of high-seas salmon is variable depending on the conditions of their ocean habitats, which may be related with climate changes. Thus long-term trophic monitoring of high-seas salmon is important to understand relationships between fish growth and mortalities.

Introduction

In winter, Pacific salmon may suffer from severe ocean condition linked natural mortality, because of low water temperature and low food availability. Beamish and Mahnken (2001) proposed the critical-size and critical-period hypothesis that Pacific salmon had to achieve a sufficient size by the end of the first marine summer to be able to survive the metabolic demands during a period of energy deficit in the late fall and winter.

The past winter surveys in 1996 and 1998 have indicated that Japanese ocean age 1 chum salmon (*Oncorhynchus keta*) are distributed in the western North Pacific Ocean in the first winter, while older chum salmon inhabit in the Gulf of Alaska during the following winters (Urawa 2000, Urawa et al. 2001). Why do they stay there? How is their trophic and survival status? It is an effective way to know their total

lipid content (TLC), because it can be used to estimate energy storage condition. Dietary lipids play an important role in providing energy in carnivorous fish due to their limited ability to utilize carbohydrates as an energy source (Watanabe 1982). Nomura et al. (2000) found that the lipid content in the muscle of chum and pink salmon (*Oncorhynchus gorbuscha*) in winter was low, and suggested that chum and pink salmon had inadequate food at that season.

In the winter and spring of 2006, we conducted trawl surveys to estimate the ocean distribution, trophic condition and possible mortalities of salmon (Fukuwaka et al. 2006; Morita et al. 2006). The present document reports a preliminary result of muscle lipid analysis for various ocean age chum salmon and pink salmon caught in the western North Pacific Ocean and Gulf of Alaska during the winter period.

Materials and Methods

Salmon were caught in the North Pacific Ocean by surface trawl net of the R/V Kaiyo-maru from late January to early March 2006 (Figs. 1-4, Fukuwaka et al. 2006). A total of 145 chum and 168 pink salmon was analyzed for total lipid contents (TLC) in the muscle (Table 1). Fork length and body weight were measured (Tables 2 and 3), and scales were collected from each fish for age determination. In the laboratory of National Salmon Resources Center, the white muscle tissue was carefully removed from fish sample and homogenized in a food processor. Adequate amount of the homogenate was correctly weighed and kept frozen at -30ºC.

For determination of TLC, the frozen sample was thawed and homogenized with 60 ml of methanol and 120 ml of chloroform (Folch et al. 1957). The homogenate was filtered through lipid-free paper into a glass vessel and the crude extract was mixed in a separator funnel with chloroform, methanol and water in the volumetric proportions 2:1:0.8. The lower phase was collected and the solvent was evaporated with a rotary evaporator. The remaining lipid was measured gravimetrically. The moisture content of the homogenized muscle was determined by weight loss after drying for 24 hours at 110ºC. There is a significant inverse correlation (r^2=0.651) between total lipid content and moisture in the white muscle of pink salmon (N=50, Fig. 5). Thus TLC is calculated by the following formula: TLC = -0.77×moisture + 62.20. For TLC, additional 49 pink salmon samples were estimated by using this formula.

Results

Average TLC in the white muscle of ocean age 1 chum salmon caught in the western North Pacific Ocean (WNPO) and Gulf of Alaska (GA) was 2.4% (N=53) and 1.2% (N=32), respectively (Table 2, Fig. 7). Average TLC in the white muscle of ocean age 2-5 chum salmon caught in WNPO and GA was 15.0% (N=7) and 3.9% (N=50), respectively (Table 2, Fig. 8). The average TLC in the same age groups of chum salmon was significantly higher in WNPO than in GA (t-test; $p < 0.01$). The average TLC of pink salmon was also significantly higher in WNPO (2.2%, n=99) than in GA (1.5%, n=18) (t-test, $p < 0.01$, Table 3, Fig. 9).

Discussion

Our preliminary analysis has showed geographical differences in the white muscle lipid contents of chum and pink salmon between the western North Pacific Ocean and the Gulf of Alaska. The total lipid content was significantly higher in the all age groups of chum salmon in the western North Pacific Ocean than those in the Gulf of Alaska, even though the number of fish samples was limited (Fig. 6). A similar geographical difference was observed in the total lipid contents of ocean age 1 pink salmon (2.2% in the western North Pacific and 1.5% in the Gulf of Alaska, Table 3). Nomura et al. (2000) reported that the average total lipid content was 1.1% in the white muscle of chum salmon (mostly ocean age 1) caught in the central North Pacific Ocean (45ºN, 179ºW) in the February of 1998. This low value is similar with the average total lipid content (1.2%) of ocean age 1 chum salmon caught in the Gulf of Alaska, but lower than that (2.4%) in the western North Pacific Ocean. Nomura et al. (2000) also showed that the average total lipid content of pink salmon was higher in the western North Pacific Ocean (3.3%) than in the eastern Gulf of Alaska (1.0%) during the winter of 1996. On the other hand, they observed annual variation in the total lipid contents of pink salmon in the western North Pacific among the winters of 1996 and 1998.

It is a fundamental question why chum and pink salmon overwintering in the western North Pacific have higher lipid contends than fish in the Gulf of Alaska. The CPUE (number of catches per 1-h trawl) of ocean age 1 chum and pink salmon was much higher in the western North Pacific than in the Gulf of Alaska (Figs. 2 and 4), while the CPUE of older chum salmon was much higher in the Gulf of Alaska than in the western North Pacific (Fig. 3). The average sea surface temperature (SST) in the western North Pacific and Gulf of Alaska was 4.7 and 6.3ºC for ocean age 1 chum salmon, 3.4 and 5.8ºC for older chum salmon, and 5.0 and 5.9ºC for pink salmon, respectively. Thus, it may be possible that the seawater temperature affects on the total lipid contends of overwinter salmon.

In addition, we should consider the biomass of available prey organisms in the winter habitats. Beamish et al. (2004) has suggested that size-related mortality in the first marine fall and winter may be an important determinant of brood year strength of some coho salmon stocks and stocks of other species of Pacific salmon. We need to evaluate the trophic status of chum and pink salmon in the fall season just before overwintering.

The present preliminary study as well as the past studies (Nomura et al. 2000, 2006) suggests that the trophic status of high-seas salmon is variable depending on the conditions of their ocean habitats, which may be related with climate and climate changes. Thus long-term trophic monitoring of high-seas salmon is important to understand relationships between fish growth and mortalities.

Acknowledgements

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Table 1. Sampling locations, dates and numbers of chum and pink salmon sampled in the North Pacific Ocean during winter 2006.

Station	Longitude	Latitude	Date	Number of Fish						
				Chum Salmon						Pink Salmon
				Ocean Age						
				1	2	3	4	5	Total	
2	42°02'N	154°50'E	Jan. 28	0	0	0	0	0	0	50
3	43°05'N	154°59'E	Jan. 29	3	0	0	0	0	3	0
5	48°00'N	165°03'E	Feb. 27	3	1	0	0	0	4	50
8.5	44°21'N	165°06'E	Feb. 28	11	0	0	1	0	12	0
9.5	43°21'N	165°04'E	Feb. 28	39	1	0	0	0	40	0
10	42°54'N	164°58'E	Feb. 1	0	0	0	0	0	0	7
10.5	42°30'N	164°56'E	Mar. 1	0	0	4	0	0	4	0
11	42°03'N	164°55'E	Jan. 31	0	0	0	0	0	0	37
12	41°07'N	165°00'E	Jan. 31	0	0	0	0	0	0	6
21	53°56'N	144°46'W	Feb. 15	0	1	6	4	0	11	2
22	53°01'N	145°00'W	Feb. 16	0	3	17	9	1	30	0
23	52°09'N	144°58'W	Feb. 16	0	3	4	2	0	9	0
24	50°52'N	144°52'W	Feb. 17	6	0	0	0	0	6	4
25	49°52'N	144°53'W	Feb. 17	7	0	0	0	0	7	3
26	48°53'N	144°49'W	Feb. 18	2	0	0	0	0	2	0
27	47°54'N	144°49'W	Feb. 18	17	0	0	0	0	17	9
Total				88	9	31	16	1	145	168

Table 2. Fork length (FL) and total lipid content (TLC) of ocean age 1 and older chum salmon caught in the western North Pacific and the Gulf of Alaska. Values of FL and TLC are mean (SD), and N is number of samples.

	Ocean Age 1					Ocean Age 2-5				
	FL (mm)		TLC (%)		N	FL (mm)		TLC (%)		N
Western North Pacific Ocean	244	(16)	*2.4	(1.0)	53	504.0	(42)	*15.0	(3.6)	7
Gulf of Alaska	269	(88)	*1.2	(0.3)	32	522.0	(40)	*3.9	(3.5)	50

* significant differences, t-test, $p < 0.01$

Table 3. Fork length (FL) and total lipid content (TLC) of pink salmon caught in the western North Pacific and the Gulf of Alaska. Values of FL and TLC are mean (SD), and N is number of samples.

	FL (mm)		TLC (%)		N
Western North Pacific Ocean	287	(17)	*2.2	(0.8)	99
Gulf of Alaska	277	(19)	*1.5	(0.4)	18

* significant differences, t-test, $p < 0.01$

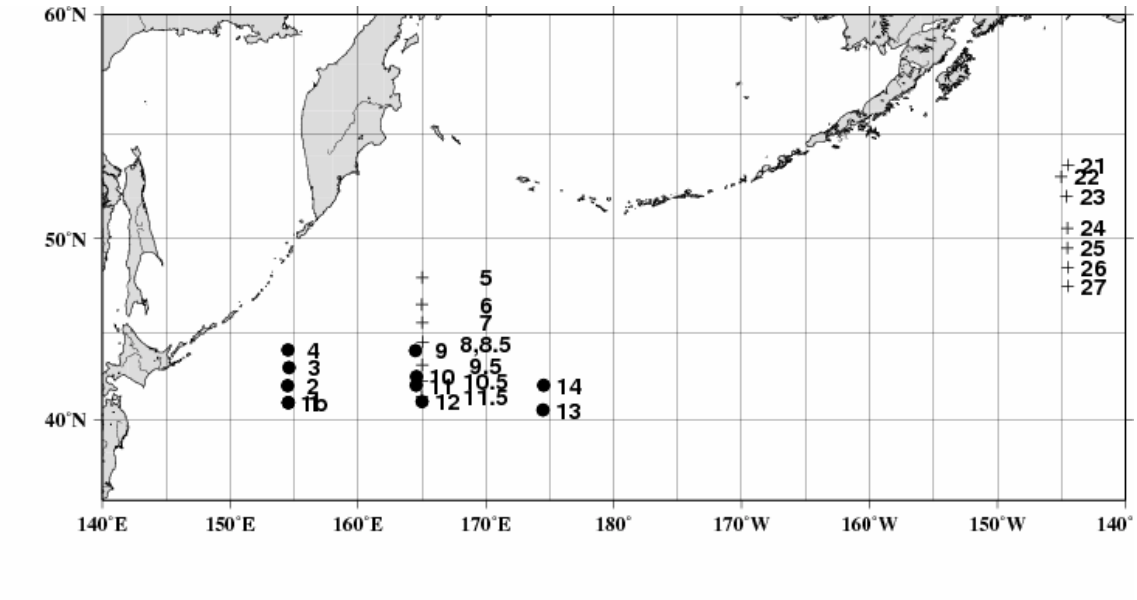

Fig. 1. A map showing the trawl sampling stations during the leg-1 (closed circles) and leg-2 (plus symbols) of 2006 winter research cruise of R/V Kaiyo-maru.

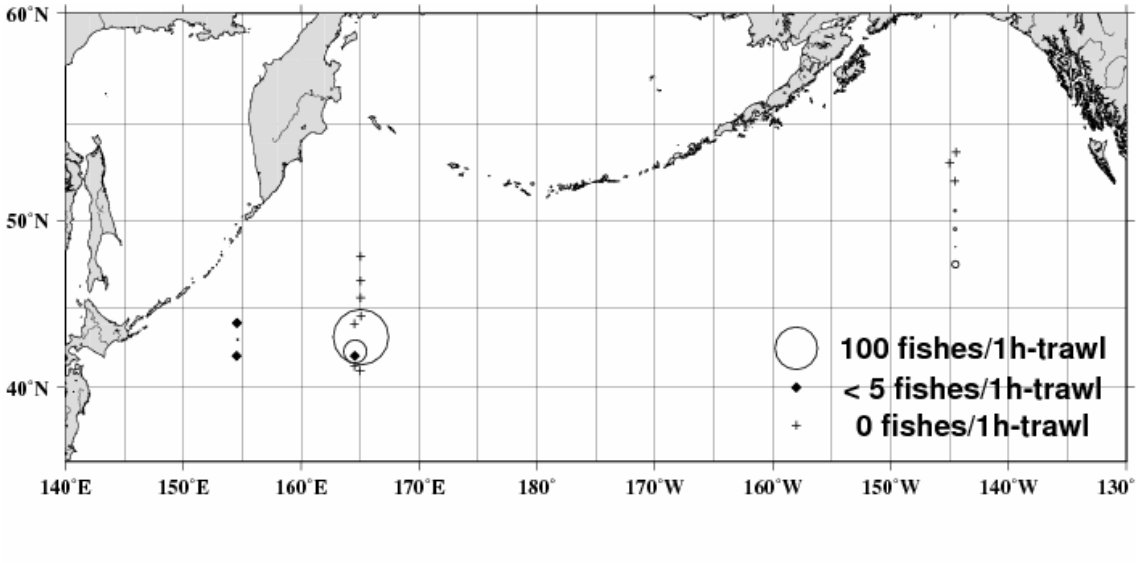

Fig. 2. CPUE of ocean age 1 chum salmon in the winter of 2006. CPUE means number of catches/1h-trawl.

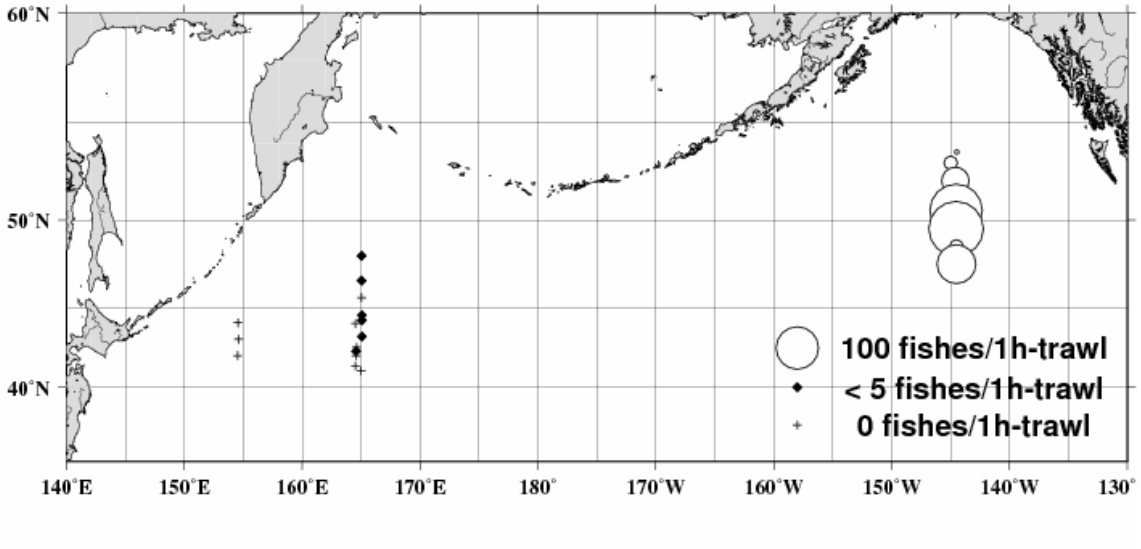

Fig. 3. CPUE of ocean age 2-5 chum salmon in the winter of 2006. CPUE means number of catches/1h-trawl.

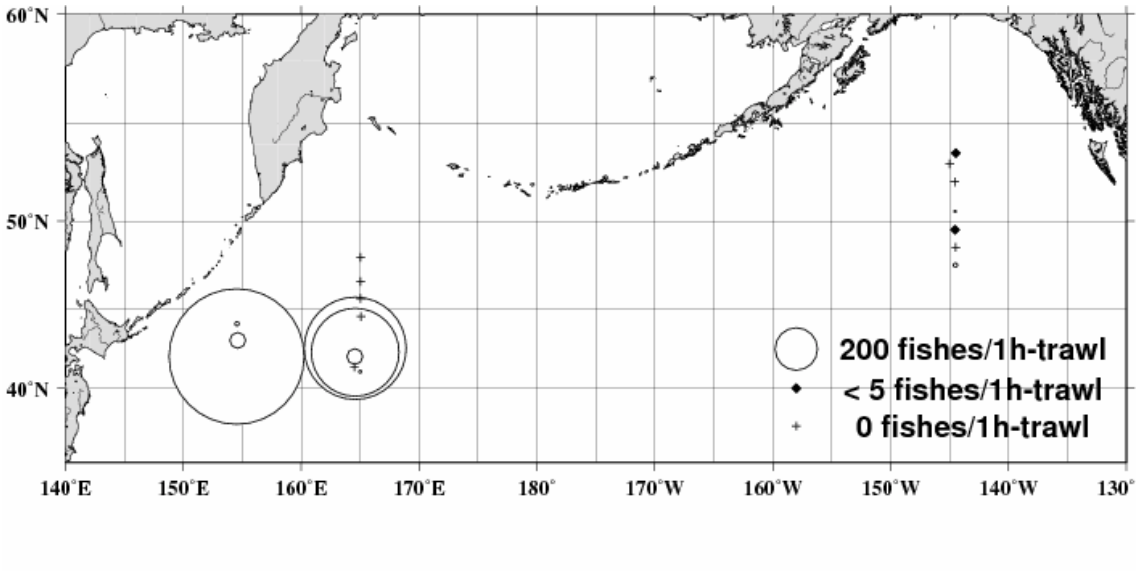

Fig. 4. CPUE of pink salmon in the winter of 2006. CPUE means number of catches/1h-trawl.

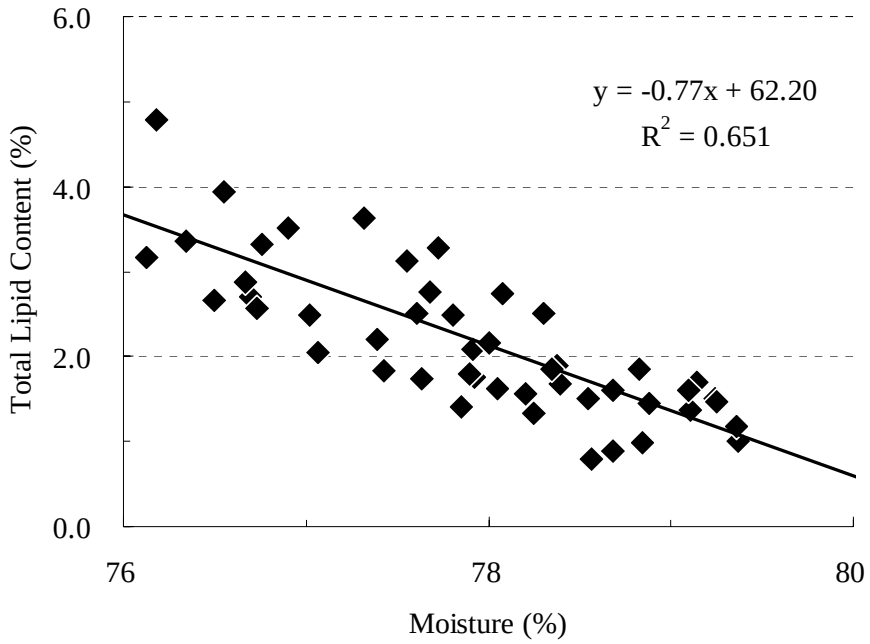

Fig. 5. Relationship between total lipid content (%) and moisture content (%) in the white muscle of pink salmon (N=50) caught in the North Pacific Ocean during the winter of 2006.

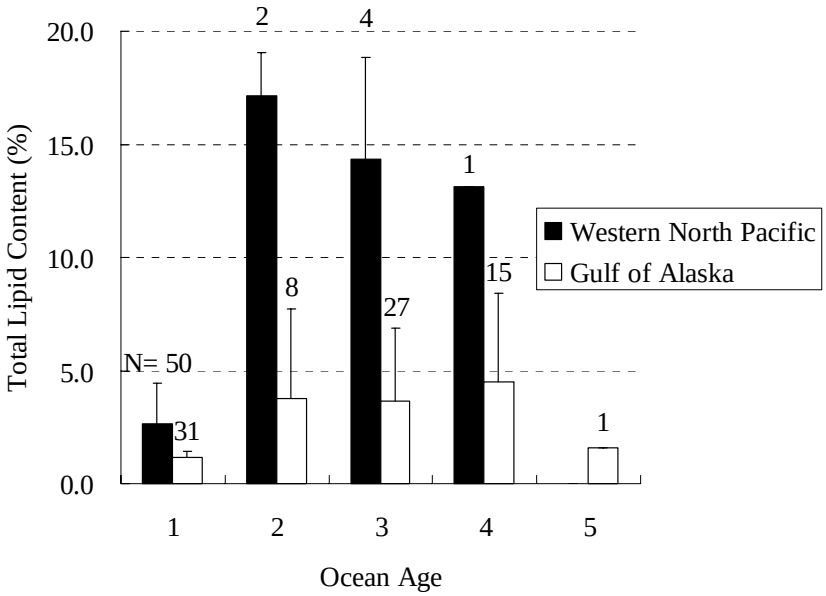

Fig. 6. Total lipid content (%) in the white muscle of chum salmon caught in the western North Pacific Ocean and Gulf of Alaska during the winter of 2006 by ocean age. Bar heights and line lengths show mean and one standard deviation (SD), respectively. Numerals indicate number of samples.

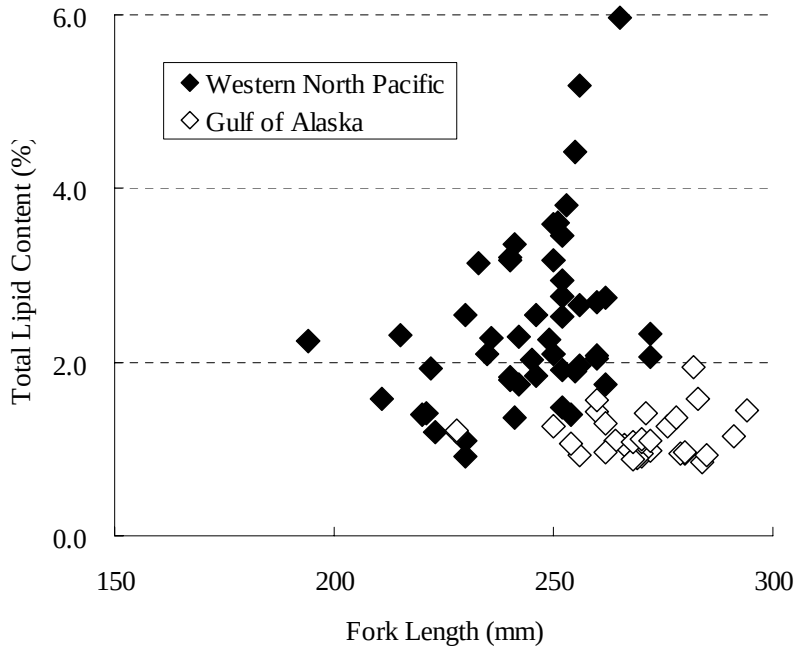

Fig. 7. Relationship between total muscle lipid content (%) and fork length (mm) of ocean age 1 chum salmon caught in the western North Pacific Ocean and Gulf of Alaska during the winter of 2006.

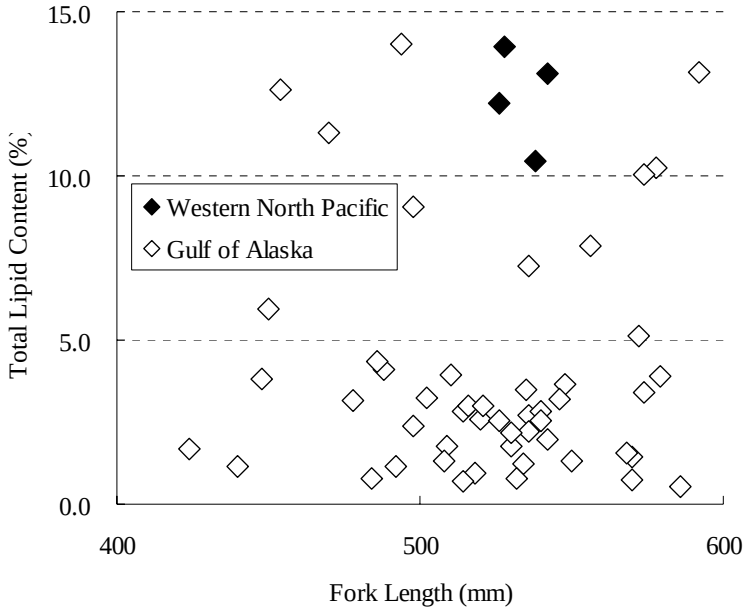

Fig. 8. Relationship between total muscle lipid content (%) and fork length (mm) of ocean age 2-5 chum salmon caught in the western North Pacific Ocean and the Gulf of Alaska during the winter of 2006.

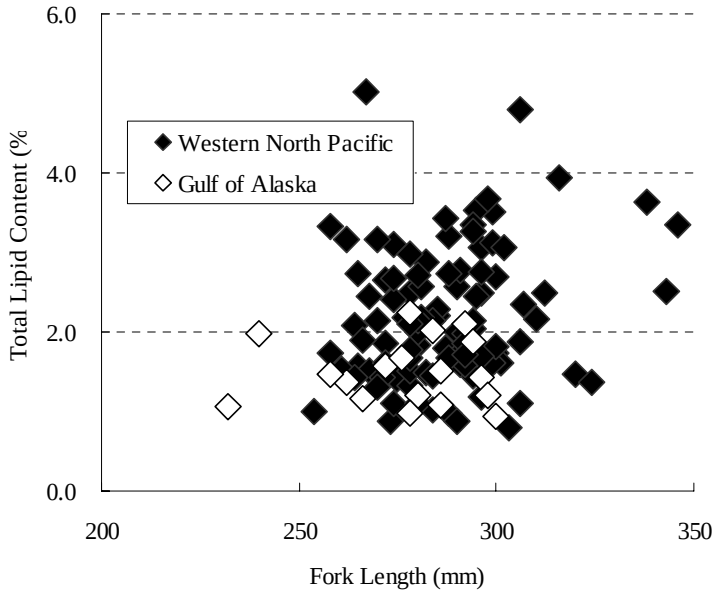

Fig. 9. Relationship between total muscle lipid content (%) and fork length (mm) of ocean age 1 pink salmon caught in the western North Pacific Ocean and Gulf of Alaska during the winter of 2006.