

Total Lipid Contents of Chum and Pink Salmon in the North Pacific Ocean and the Bering Sea during the Summer of 2007

by

Toshiki Kaga¹, Shunpei Sato¹, Kentaro Morita², Masa-aki Fukuwaka²

¹ *National Salmon Resources Center, Fisheries Research Agency,
2-2 Nakanoshima, Toyohira-ku, Sapporo 062-0922, Japan*

² *Hokkaido National Fisheries Research Institute, Fisheries Research Agency,
116 Katsurakoi, Kushiro, Hokkaido 085-0802, Japan*

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¹ National Salmon Resources Center, Fisheries Research Agency,
2-2 Nakanoshima, Toyohira-ku, Sapporo 062-0922, Japan

² Hokkaido National Fisheries Research Institute, Fisheries Research Agency,
116 Katsurakoi, Kushiro, Hokkaido 085-0802, Japan

Abstract

This document reports total lipid content (TL) of chum and pink salmon caught in the North Pacific Ocean and the Bering Sea in the summer (June-August) of 2007. TL of 1,077 chum and 162 pink salmon was measured. We classified salmons into several categories according to their fork length and compared the lipid content within the same size category. The mean TL showed significant variability with years. The mean TLs of B, C class increased in 2001 and decreased in 2004. The fluctuation pattern of TL might be different between fish size. The mean TL in 2007 seemed as same as that of 2006. Using a fish fat meter, we can obtain much information on total lipid content with reducing cost and time from total lipid analysis. From those results the TL in the southern part of central Bering Sea was shown to be higher than in the southern part of western Bering Sea. The present and past studies suggested that the trophic status of high-seas salmon should be variable depending on the conditions of their ocean habitats related with ocean climate changes. We should continue long-term trophic monitoring of high-seas salmon to understand the relationship between fish growth and environmental condition.

Introduction

Dietary lipids play an important role in providing energy in most fish including salmon because of their limited ability to utilize carbohydrates as an energy source (Watanabe 1982, Weatherly and Gill 1995). Although there have been a large number of lipid studies on cultured fish and artificial feed (Wilson 1991 etc.), few studies have determined lipid contents of high-seas salmon. Lipid content is useful to evaluate the trophic status and energy storage condition of high-seas salmonids. But strong correlation between fish size and lipid content had been observed (Lovern 1938, Arevalo 1948), we classified salmons into several categories according to their fork length and compared the lipid content within the same size category. Nomura et al. (2005) found that the neutral lipid content in the muscle of chum salmon (*Oncorhynchus keta*) during the summer and fall were higher than in the spring or winter. It was also found that zooplankton biomass in the subarctic water is poor in winter (Nagasawa 2000; Parsons, Lalli 1988; Brodeur et al. 1996; Sugimoto, Tadokoro 1998) and the lipid content of chum salmon was quite low in winter (Nomura et al. 2000, Kaga et al. 2006). Storing lipid in summer is necessary for them to survive through the following severe winter.

This study reports total lipid in the white muscle of pink (*Oncorhynchus gorbuscha*) and chum salmon which were caught in high-seas of the North Pacific Ocean and Bering Sea during the summer (June-August) of 2007.

Materials and Methods

Salmon were caught in the North Pacific Ocean and Bering Sea by a drift gillnet during summer cruises of the R/V *Wakatake-maru*, June 15 to July 12, 2007 and by a surface trawl net

during the summer cruise of the R/V Hokko-maru, July 22 to Aug. 2, 2007 (Fig. 1). A total of 1,077 chum and 162 pink salmon was analyzed for crude lipid in the white muscle (Tables 1, 2, 3). Fork length, body weight and electric resistance (dB) of the body using a fish fat meter (Model 692 manufactured by Distell Inc., West Lothian, Scotland) were measured on board ships. Total lipid (TL) was estimated from the electric resistance (E) using following formulae (Appendix Fig. 1):

$$TL = 0.237 \times E - 2.026 \quad (r = 0.802, \text{immature chum salmon})$$

Semi dress sample were preserved in a freezer (-30°C) for later examination. In the laboratory, the fillet, excluding skin, was homogenized in a food processor. Total lipids were determined from freshly minced samples from individual fish which was homogenized using a modified Folch method (Folch et al., 1957). Total lipids were extracted with chloroform: methanol (2:1 v/v). Extracted total lipid was collected and the solvent was evaporated with a rotary evaporator and the remaining lipid was measured gravimetrically.

Results

The mean TL in the white muscle of chum salmon caught in the Bering Sea was measured. The amount of TL data with 0 (FL 200-300 mm) and D class (FL 600-700 mm) was short, then we did not apply these data for analysis. The mean TL of A class (FL 300-400 mm) chum salmon was 3.8% (± 0.3 , n=131), 5.6% (± 0.5 , n=121) for B class (FL 400-500 mm), 8.1% (± 1.2 , n=47) for C class (FL 500-600 mm) (Table 4). In the same way that of pink salmon was 8.4% (± 0.4 , n=95) for B class, and 7.0% (± 0.6 , n=44) for C class. The mean TL became larger with the increase of body size. Contrary the mean TL of small size pink salmon was higher than large one. Comparing the TL within the same size fish, pink salmon had significantly higher TL than chum salmon for B class (t-test, $p < 0.001$ df=191), and chum salmon had higher TL than pink salmon for C class, but it was not significant (t-test).

Annual variation in the mean TL from 1998 to 2007 is shown in Fig. 2. Each size salmon's TL fluctuated with year (ANOVA $p < 0.05$). A similar fluctuation pattern was observed in B, C classes. The TL of B, C class became high in 2001 and low in 2004. Fluctuation pattern of A class was different from that of B, C class. In 2007 TL of each class was not different from that of 2006.

Distribution of the mean TL along longitude 180° is shown in Fig. 3. The mean TL of both chum and pink salmon did not change significantly according to the difference of latitude (Kruskal Wallis test). The mean TL in the North Pacific Ocean (south of 52°) and the Bering Sea (north of 52°) was compared in two species. The B class pink salmon's TL in the Bering Sea was significantly higher than the North Pacific Ocean (Wilcoxon Rank Sum test, $p < 0.001$). The mean TL of both classes chum and C class pink salmon was not different between the Bering Sea and the North Pacific Ocean.

TL of chum salmon which were caught in wide area of the Bering Sea was estimated utilizing fish fat meter (Fig. 4-6). Comparing the mean TL between stations, TL for A class showed no difference, however and TL for B, C class showed significantly difference (ANOVA, Kruskal Wallis test $p < 0.001$). From the result of the post hoc test, the mean TL of B class at the stations which were located in the range from 52° to 56°N along 180° was higher than the station in the 53, 54°N 170°W. In the same way the mean TL of C class at the station in the 52°N 180° was higher than 53, 54° N 170°W.

Discussion

Lipid displays wide variability during the certain period of the annual cycle and changed with living conditions, and hence owns considerable potential as condition marker (Shulman, Love 1999). The importance of clarifying the specie's specific growth and physiological condition is indicated by Azuma et al. 1998. Thus we studied about the condition of chum and pink salmon in the Pacific Ocean

using the total lipid content as condition marker.

The annual fluctuation of the mean TL of chum salmon from 1998 to 2007 is shown in Fig. 2. The mean TL showed significant variability with years. The mean TLs of B, C class increased in 2001 and decreased in 2004. That of A class in 2001 similarly increased, but increased in 2004. The fluctuation pattern of TL might be different between fish size. Different species of Pacific salmon are known to frequently occupy common feeding areas (Mishima et al. 1966; Mishima, Shimazaki 1969; Takagi 1971; Brodeur 1989; Azuma 1991; Perry et al. 1996) and increase in age of maturation and decrease in size at age, especially for chum salmon originating from Japan and Russia is indicated by Ishida et al. 1993 and Ida, Hayashizaki 1994. Thus the population density of Pacific salmon might affect on the chum salmon's biochemical condition like total lipid. Abundance of pink salmon in the Bering Sea fluctuates in two-year cycle (Nagasawa et al. 2007), however TL of chum salmon did not show the notable differences with the fluctuation of pink salmon's abundance. Comparing the TL of chum salmon with the same size pink salmon, B class chum salmon's TL was lower than that of pink salmon. It is known that chum salmon shifts major components of its diet in response to competition with pink salmon (Tadokoro et al. 1996). We should continue to obtain data about both chum and pink salmon's trophic condition to understand their interspecifics relationship.

Using a fish fat meter, we can obtain much information on total lipid content with reducing cost and time from total lipid analysis. From those results the TL in the southern part of central Bering Sea was shown to be higher than in the southern part of western Bering Sea. We should continue to acquire data in order to consider the relationship between lipid content and environmental condition.

The present preliminary study as well as the past studies (Nomura et al. 2000, 2001, 2002, 2004, and 2005; Kaga et al. 2006 and 2007) suggested that the trophic status of high-seas salmon could be variable depending on the conditions of their ocean habitats related with climate changes. Thus long-term trophic monitoring of high-seas salmon can be valuable to understand relationships between fish growth and mortality.

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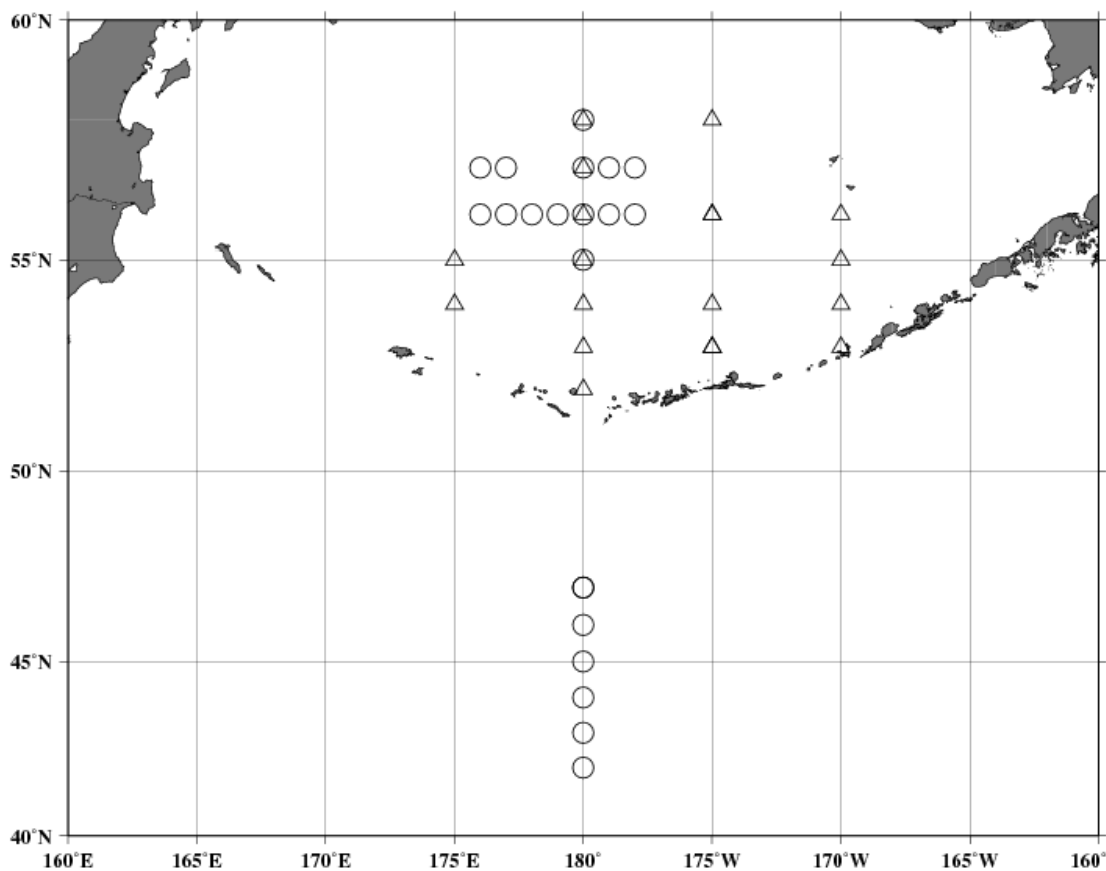


Fig. 1. Locations where chum and pink salmon were caught during the summer research cruises of R/V *Wakatake-maru* (open circle), June-July 2007 and *Hokko-maru* (open triangle), July-August 2007.

Table 1. Date, location, mean (standard error) of fork length, body weight, total lipid, and gonad somatic index of chum salmon which were sampled during the summer (June-July) cruise of *Wakatake-maru* 2007. Salmons were classified into four categories: A (300-400 mm), B (400-500 mm), C (500-600 mm), or D (600-700 mm) according to their fork length.

Station	Date	Latitude	Longitude	Hem	A class (300-400 mm)				N
					FL (mm)	BW (g)	Total lipid (%)	GSI (%)	
4	20070615	42	180		326 (32)	430 (148)	2.2 (1.1)	5.8 (2.6)	3
5	20070616	43	180		306 (32)	357 (137)	2.7 (1.6)	4.6 (3.8)	4
6	20070617	44	180		315 (11)	353 (45)	2.2 (1.0)	3.4 (1.2)	6
7	20070618	45	180		320 (14)	365 (33)	2.3 (0.7)	2.8 (0.2)	6
8	20070619	46	180		336 (25)	406 (88)	2.3 (0.8)	3.1 (1.0)	5
9	20070620	47	180		333 (25)	423 (89)	2.4 (1.1)	3.2 (1.7)	4
10	20070621	47	180		311 (7)	330 (36)	1.3 (0.6)	3.6 (1.0)	5
18	20070629	55	180						
19	20070630	56	180		366 (28)	543 (123)	2.0 (0.8)	4.8 (2.2)	4
20	20070701	57	180						
21	20070702	58	180						
22	20070703	57	179	W	373 (10)	573 (45)	3.5 (1.0)	2.6 (0.9)	4
23	20070704	57	178	W	363 (22)	540 (113)	2.8 (1.1)	2.7 (1.9)	3
24	20070705	56	178	W					
25	20070706	56	179	W					
26	20070707	56	179	E	377 (11)	585 (88)	2.1 (0.4)	1.7 (0.3)	2
27	20070708	56	178	E	347 (11)	464 (46)	2.2 (0.6)	3.0 (1.7)	5
28	20070709	56	177	E	351 (9)	465 (49)	2.1 (0.8)	2.2 (0.2)	2
29	20070710	57	177	E	357 (8)	493 (29)	2.9 (1.6)	2.6 (1.2)	4
30	20070711	57	176	E					
31	20070712	56	176	E					

Station	Date	Latitude	Longitude	Hem	B class (400-500 mm)				N
					FL (mm)	BW (g)	Total lipid (%)	GSI (%)	
4	20070615	42	180		422 (15)	920 (152)	3.0 (0.7)	3.2 (2.2)	4
5	20070616	43	180		435 (16)	962 (108)	4.4 (1.0)	3.1 (2.0)	6
6	20070617	44	180		467 (27)	1183 (137)	3.5 (3.1)	4.4 (3.3)	4
7	20070618	45	180		433 (9)	932 (85)	2.1 (1.9)	1.5 (0.8)	5
8	20070619	46	180		451 (25)	1083 (126)	4.7 (3.4)	3.4 (3.4)	3
9	20070620	47	180		438 (29)	1007 (285)	3.5 (1.6)	1.7 (0.5)	3
10	20070621	47	180		424	840	6.5	1.2	1
18	20070629	55	180		433	940	4.1	1.1	1
19	20070630	56	180		448 (45)	1027 (317)	2.1 (0.3)	3.5 (4.6)	3
20	20070701	57	180		407	900	6.2	2.2	1
21	20070702	58	180						
22	20070703	57	179	W					
23	20070704	57	178	W	435 (4)	940 (78)	5.8 (2.9)	5.4 (2.5)	2
24	20070705	56	178	W	460 (13)	1150 (118)	4.5 (2.4)	3.4 (4.8)	2
25	20070706	56	179	W	447 (13)	1012 (89)	4.8 (1.9)	3.9 (2.4)	5
26	20070707	56	179	E	432 (12)	910 (111)	3.6 (1.4)	3.5 (2.6)	5
27	20070708	56	178	E	439 (11)	1060 (82)	3.8 (2.0)	2.3 (2.7)	3
28	20070709	56	177	E	433 (8)	1007 (78)	5.9 (2.1)	1.7 (1.3)	7
29	20070710	57	177	E	441	1070	6.7	0.9	1
30	20070711	57	176	E	437 (9)	1003 (58)	4.4 (1.0)	3.2 (2.2)	7
31	20070712	56	176	E	431 (15)	1000 (92)	5.9 (1.6)	3.9 (2.1)	7

Table 1. Continued.

Station	Date	Latitude	Longitude	Hem	C class (500-600 mm)				
					FL (mm)	BW (g)	Total lipid (%)	GSI (%)	N
4	20070615	42	180		473	1290	6.1	7.0	1
5	20070616	43	180		467 (30)	1200 (283)	5.1 (1.6)	3.5 (5.3)	3
6	20070617	44	180						
7	20070618	45	180		410	780	1.6	1.3	1
8	20070619	46	180		508 (62)	1620 (541)	5.2 (3.8)	4.0 (5.1)	3
9	20070620	47	180		495	1540	7.1	1.3	1
10	20070621	47	180		461	1300	7.6	6.9	1
18	20070629	55	180		510 (13)	1563 (119)	5.2 (1.4)	4.4 (3.0)	7
19	20070630	56	180		479 (23)	1385 (10)	6.7 (3.4)	6.9 (3.5)	2
20	20070701	57	180						
21	20070702	58	180						
22	20070703	57	179	W	515	1590	4.2	15.1	1
23	20070704	57	178	W	541	1870	3.2	1.6	1
24	20070705	56	178	W	497 (15)	1501 (120)	7.0 (1.7)	4.4 (2.8)	8
25	20070706	56	179	W					
26	20070707	56	179	E					
27	20070708	56	178	E	452	1190	2.4	0.8	1
28	20070709	56	177	E					
29	20070710	57	177	E	522	1530	8.3	13.1	1
30	20070711	57	176	E	500	1520	4.6	0.7	1
31	20070712	56	176	E	508	1490	3.3	0.7	1

Station	Date	Latitude	Longitude	Hem	D class (600-700 mm)				
					FL (mm)	BW (g)	Total lipid (%)	GSI (%)	N
4	20070615	42	180						
5	20070616	43	180						
6	20070617	44	180						
7	20070618	45	180						
8	20070619	46	180						
9	20070620	47	180						
10	20070621	47	180		529 (11)	1830 (196)	4.6 (3.6)	6.1 (3.9)	2
18	20070629	55	180						
19	20070630	56	180						
20	20070701	57	180		543	2030	13.4	8.4	1
21	20070702	58	180						
22	20070703	57	179	W					
23	20070704	57	178	W					
24	20070705	56	178	W					
25	20070706	56	179	W					
26	20070707	56	179	E					
27	20070708	56	178	E					
28	20070709	56	177	E	607	2790	10.7	0.4	1
29	20070710	57	177	E	592	2440	7.6	5.7	1
30	20070711	57	176	E					
31	20070712	56	176	E					

Table 2. Date, location, mean (standard error) of fork length, body weight, total lipid, and gonad somatic index of pink salmon which were caught during the summer (June-July) cruise of *Wakatake-maru* 2007. Salmons were classified into two categories: B (upper: 400-500 mm) or C (lower: 500-600 mm) according to their fork length.

Station	Date	Latitude	Longitude	Hem	B class (400-500 mm)				N
					FL (mm)	BW (g)	Total lipid (%)	GSI (%)	
4	20070615	42	180						
5	20070616	43	180						
6	20070617	44	180		464	1230	6.5	5.5	1
7	20070618	45	180		450 (38)	1030 (250)	4.0 (1.5)	2.8 (20.4)	4
8	20070619	46	180		473 (17)	1202 (138)	4.5 (1.0)	4.9 (15.9)	5
9	20070620	47	180		458 (16)	1156 (178)	5.6 (1.5)	4.2 (27.5)	5
10	20070621	47	180		443 (20)	1003 (150)	6.0 (1.6)	3.1 (23.1)	4
18	20070629	55	180		450 (14)	1220 (176)	9.7 (1.3)	6.5 (13.2)	7
19	20070630	56	180		442 (22)	1224 (279)	8.7 (1.6)	6.5 (10.1)	9
20	20070701	57	180		457 (15)	1317 (151)	9.8 (1.1)	6.8 (8.7)	9
21	20070702	58	180		458 (12)	1276 (92)	8.0 (1.0)	6.9 (10.8)	10
22	20070703	57	179	W	464 (15)	1292 (166)	8.6 (1.6)	8.7 (4.6)	5
23	20070704	57	178	W	456 (18)	1217 (147)	8.2 (0.9)	7.5 (12.3)	10
24	20070705	56	178	W	432 (7)	980 (45)	8.2 (1.6)	8.0 (8.7)	6
25	20070706	56	179	W	426 (20)	964 (178)	7.3 (2.2)	7.9 (9.4)	5
26	20070707	56	179	E	473 (8)	1443 (102)	9.2 (2.3)	7.7 (8.5)	4
27	20070708	56	178	E	468 (18)	1465 (320)	9.0 (1.2)	7.0 (15.2)	4
28	20070709	56	177	E	459 (16)	1278 (241)	8.0 (2.1)	8.1 (6.8)	6
29	20070710	57	177	E	454 (25)	1288 (259)	8.1 (2.0)	10.2 (5.7)	4
30	20070711	57	176	E	446 (12)	1146 (118)	7.1 (1.1)	8.8 (19.9)	10
31	20070712	56	176	E	458 (15)	1280 (171)	7.9 (1.5)	9.1 (16.7)	6

Station	Date	Latitude	Longitude	Hem	C class (500-600 mm)				N
					FL (mm)	BW (g)	Total lipid (%)	GSI (%)	
4	20070615	42	180						
5	20070616	43	180						
6	20070617	44	180		515	1580	1.3	0.1	1
7	20070618	45	180						
8	20070619	46	180						
9	20070620	47	180						
10	20070621	47	180		504	1780	7.4	5.8	1
18	20070629	55	180		523 (6)	2115 (323)	6.5 (1.1)	7.7 (1.0)	2
19	20070630	56	180		575	2670	4.2	6.7	1
20	20070701	57	180		562	2900	7.3	5.8	1
21	20070702	58	180						
22	20070703	57	179	W	540 (15)	2314 (98)	5.6 (1.0)	6.0 (1.3)	5
23	20070704	57	178	W					
24	20070705	56	178	W	528 (15)	2018 (225)	8.5 (1.8)	5.0 (0.3)	4
25	20070706	56	179	W	551 (34)	2394 (478)	6.8 (2.4)	6.5 (1.3)	5
26	20070707	56	179	E	532 (17)	2068 (246)	7.6 (2.5)	6.4 (1.1)	6
27	20070708	56	178	E	525 (14)	2007 (191)	6.9 (1.7)	7.5 (2.2)	6
28	20070709	56	177	E	535 (21)	2263 (337)	7.2 (1.4)	6.1 (1.0)	4
29	20070710	57	177	E	529 (20)	2150 (334)	6.8 (1.6)	6.9 (2.2)	6
30	20070711	57	176	E					
31	20070712	56	176	E	521 (12)	1993 (101)	8.0 (2.3)	6.5 (0.6)	4

Table 3. Date, location, mean (standard error) of fork length, body weight, total lipid, and gonad somatic index of chum salmon which were sampled during the summer (July-August) cruise of *Hokko-maru* 2007. Salmons were classified into four categories: A (300-400 mm) , B (400-500 mm), C (500-600 mm), or D (600-700 mm) according to their fork length.

Station	Date	Latitude	Longitude	Hem	A class (300-400 mm)				N
					FL (mm)	BW (g)	Total Lipid(%)	GSI (%)	
H03	20070722	53	170	W	342 (5)	453 (23)	4.1 (0.5)	1.4 (0.3)	37
H04	20070722	54	170	W	346 (9)	470 (38)	3.5 (1.1)	1.3 (0.6)	12
H05	20070723	55	170	W	342 (6)	462 (27)	4.2 (0.5)	2.0 (1.0)	38
H06	20070723	56	170	W	358 (13)	542 (51)	3.5 (0.9)	1.6 (0.7)	12
H07	20070724	58	174	W	345 (6)	467 (28)	2.9 (0.6)	2.2 (0.4)	33
H08	20070725	56	174	W	344 (6)	457 (23)	4.5 (0.7)	2.1 (1.2)	35
H09	20070725	56	175	W	343 (7)	467 (28)	5.3 (2.8)	2.1 (0.5)	32
H10	20070726	54	175	W	341 (8)	478 (38)	3.6 (0.5)	2.1 (0.5)	26
H11	20070726	53	174	W	335 (7)	453 (32)	3.6 (0.6)	1.3 (0.5)	22
H12	20070727	53	175	W	352 (30)	500 (113)	3.0 (1.4)	3.6 (2.7)	5
H13									
H14									
H15	20070728	52	179	E	351 (15)	490 (39)	4.8 (1.3)	2.3 (1.0)	2
H16	20070728	53	179	E	339 (7)	456 (31)	4.0 (0.6)	1.8 (0.4)	27
H17	20070729	54	179	E	341 (7)	484 (34)	4.0 (0.6)	2.3 (1.8)	25
H18	20070729	55	179	E	348 (11)	544 (68)	4.7 (1.4)	1.2 (0.6)	13
H19	20070730	56	179	E	346 (10)	505 (48)	4.1 (0.9)	2.0 (0.6)	20
H20	20070730	57	179	W	333 (4)	446 (21)	2.9 (0.5)	1.8 (0.4)	49
H21	20070731	58	180		344 (7)	490 (27)	3.4 (0.4)	1.5 (0.4)	42
H22	20070801	55	175	E	350 (6)	546 (32)	5.1 (0.6)	1.5 (0.5)	20
H23									
H24	20070802	54	174	E	355 (7)	553 (36)	5.5 (0.7)	1.4 (0.5)	16

Station	Date	Latitude	Longitude	Hem	B class (400-500 mm)				N
					FL (mm)	BW (g)	Total Lipid(%)	GSI (%)	
H03	20070722	53	170	W	461 (10)	1193 (92)	5.2 (1.3)	2.6 (1.2)	18
H04	20070722	54	170	W	457 (7)	1100 (61)	5.1 (0.9)	3.4 (1.2)	36
H05	20070723	55	170	W	460 (10)	1092 (41)	6.6 (1.2)	4.0 (1.8)	13
H06	20070723	56	170	W	455 (7)	1114 (53)	5.9 (0.8)	4.8 (1.1)	33
H07	20070724	58	174	W	467 (9)	1141 (76)	4.2 (1.0)	3.2 (1.5)	23
H08	20070725	56	174	W	452 (10)	1052 (67)	6.1 (1.0)	4.2 (1.4)	22
H09	20070725	56	175	W	453 (12)	1094 (86)	6.0 (1.2)	3.3 (1.5)	18
H10	20070726	54	175	W	468 (11)	1271 (95)	7.4 (0.7)	4.9 (1.6)	19
H11	20070726	53	174	W	456 (19)	1124 (186)	8.2 (1.2)	3.8 (3.2)	5
H12	20070727	53	175	W	454 (14)	1232 (129)	6.5 (1.4)	2.9 (1.6)	16
H13									
H14									
H15	20070728	52	179	E	453 (13)	1253 (170)	8.5 (1.5)	4.8 (1.8)	13
H16	20070728	53	179	E	440 (12)	1101 (100)	7.8 (0.9)	3.7 (1.4)	13
H17	20070729	54	179	E	461 (13)	1304 (111)	8.4 (1.1)	3.3 (1.5)	14
H18	20070729	55	179	E	456 (20)	1211 (276)	7.1 (2.6)	4.4 (2.2)	7
H19	20070730	56	179	E	455 (13)	1191 (118)	8.0 (0.7)	3.1 (1.6)	14
H20	20070730	57	179	W	450 (17)	1094 (139)	4.9 (1.9)	3.3 (2.8)	8
H21	20070731	58	180		459 (17)	1185 (121)	6.7 (1.3)	3.2 (2.0)	12
H22	20070801	55	175	E					
H23									
H24	20070802	54	174	E	435 (23)	1093 (165)	7.4 (0.5)	4.4 (2.6)	4

Table 3. Continued.

										C class (500-600 mm)				
Station	Date	Latitude	Longitude	Hem	FL (mm)	BW (g)	Total Lipid(%)	GSI (%)	N					
H03	20070722	53	170	W	514 (8)	1428 (68)	4.2 (1.3)	5.8 (4.2)	5					
H04	20070722	54	170	W	506 (8)	1540 (112)	4.0 (1.2)	3.0 (3.5)	5					
H05	20070723	55	170	W	510 (5)	1540 (64)	6.8 (1.6)	4.8 (3.9)	6					
H06	20070723	56	170	W	529 (11)	1758 (137)	7.2 (1.6)	4.6 (2.3)	14					
H07	20070724	58	174	W	505 (7)	1458 (144)	3.8 (2.2)	3.1 (4.7)	4					
H08	20070725	56	174	W	549 (43)	1990 (532)	6.6 (3.5)	2.8 (4.2)	3					
H09	20070725	56	175	W	549 (27)	1968 (323)	7.4 (2.4)	3.0 (4.4)	6					
H10	20070726	54	175	W	521 (6)	1725 (85)	7.5 (1.3)	5.9 (2.3)	13					
H11	20070726	53	174	W	509 (8)	1606 (132)	8.2 (1.5)	2.6 (2.7)	7					
H12	20070727	53	175	W	535 (14)	1947 (208)	9.6 (2.3)	2.5 (1.4)	14					
H13														
H14														
H15	20070728	52	179	E	541 (11)	2173 (156)	9.1 (1.0)	4.1 (1.7)	22					
H16	20070728	53	179	E	513 (8)	1955 (127)	10.0 (0.7)	4.5 (7.4)	2					
H17	20070729	54	179	E	540 (12)	2049 (122)	8.5 (1.6)	3.0 (1.7)	14					
H18	20070729	55	179	E	536 (14)	1979 (172)	9.1 (0.8)	4.4 (2.6)	7					
H19	20070730	56	179	E	528 (11)	1858 (139)	8.8 (1.5)	4.1 (1.7)	19					
H20	20070730	57	179	W	557	2510	9.9	0.4	1					
H21	20070731	58	180		529 (22)	1890 (413)	8.1 (1.6)	3.9 (4.0)	5					
H22	20070801	55	175	E										
H23														
H24	20070802	54	174	E										

										D class (600-700 mm)				
Station	Date	Latitude	Longitude	Hem	FL (mm)	BW (g)	Total Lipid(%)	GSI (%)	N					
H03	20070722	53	170	W										
H04	20070722	54	170	W										
H05	20070723	55	170	W										
H06	20070723	56	170	W										
H07	20070724	58	174	W										
H08	20070725	56	174	W										
H09	20070725	56	175	W										
H10	20070726	54	175	W	609	2560	10.2	6.4	1					
H11	20070726	53	174	W										
H12	20070727	53	175	W										
H13														
H14														
H15	20070728	52	179	E	607	2870	11.0	0.8	1					
H16	20070728	53	179	E										
H17	20070729	54	179	E	601	2850	10.0	0.7	1					
H18	20070729	55	179	E	606	2920	11.8	4.6	1					
H19	20070730	56	179	E										
H20	20070730	57	179	W										
H21	20070731	58	180											
H22	20070801	55	175	E										
H23														
H24	20070802	54	174	E										

Table 4. Mean (standard error) total lipid, and sample number of chum salmon which were caught in the Bering Sea in the summer from 1999 to 2007. Salmon were classified into five categories according to their fork length.

	0 class (200-300)		A class (300-400)		B class (400-500)		C class (500-600)		D class (600-700)						
	N		N		N		N		N						
1999					8.5	(2.0)	11	6.4	(3.5)	4					
2000					6.7	(0.8)	64	9.2	(1.3)	58	4.5				
2001	3.7	(1.4)	3	4.3	(0.5)	51	8.6	(1.3)	41	12.1	(1.2)	40	14.9	1	
2002	1.9		1	2.1	(0.5)	17	5.4	(0.7)	48	7.6	(1.7)	15	12.3	1	
2003				1.9	(0.2)	70	4.3	(0.7)	77	8.1	(1.4)	20	7.3	1	
2004	6.1		1	3.2	(0.3)	115	3.9	(0.4)	96	4.9	(1.4)	13			
2005				3.2	(0.6)	22	5.5	(0.8)	44	7.0	(0.8)	72	7.8	(2.5)	3
2006	1.5		1	3.7	(0.4)	53	5.0	(0.8)	41	8.8	(2.0)	16			
2007	2.7	(0.0)	2	3.8	(0.3)	131	5.6	(0.5)	121	8.1	(1.2)	47	10.9	(0.3)	2

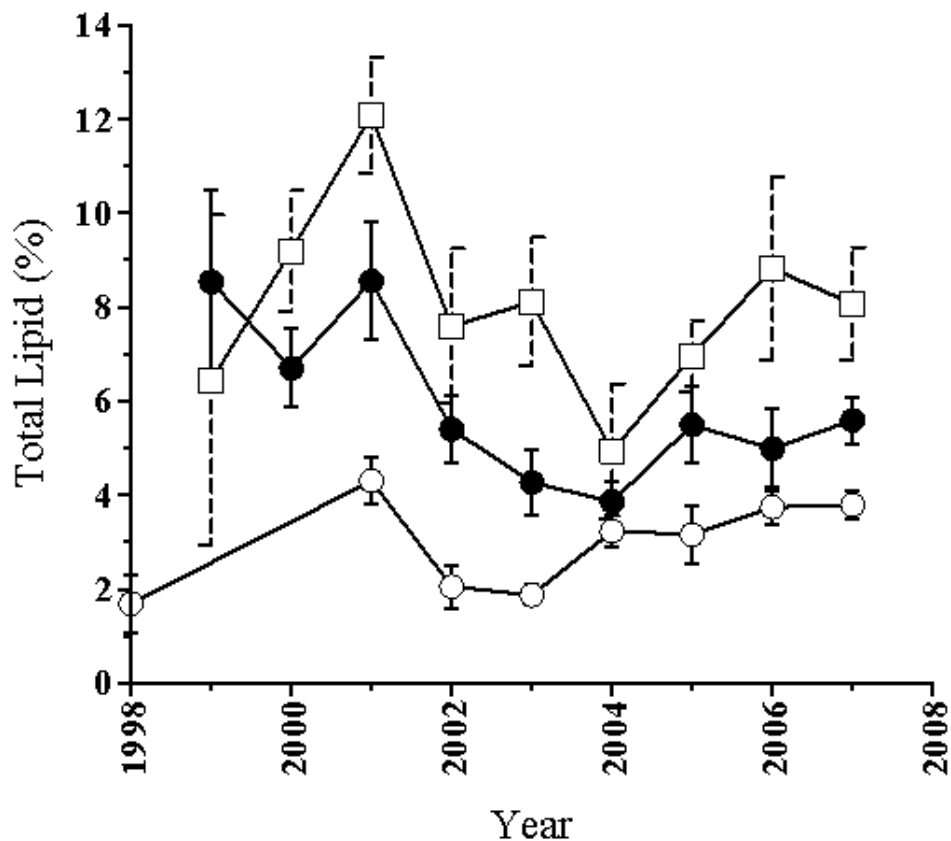


Fig. 2. Mean total lipid in the white muscle of immature chum salmon which were caught in the Bering Sea during the summer of 1998-2007. Chum Salmons were classified into 3 categories: open circle=A class (FL 300-400 mm), closed circle=B class (FL 400-500 mm), open square=C class (FL 500-600 mm). The error bars represent the standard error for the means. (1998-2004 data was cited from Nomura et al. 2001, 2005)

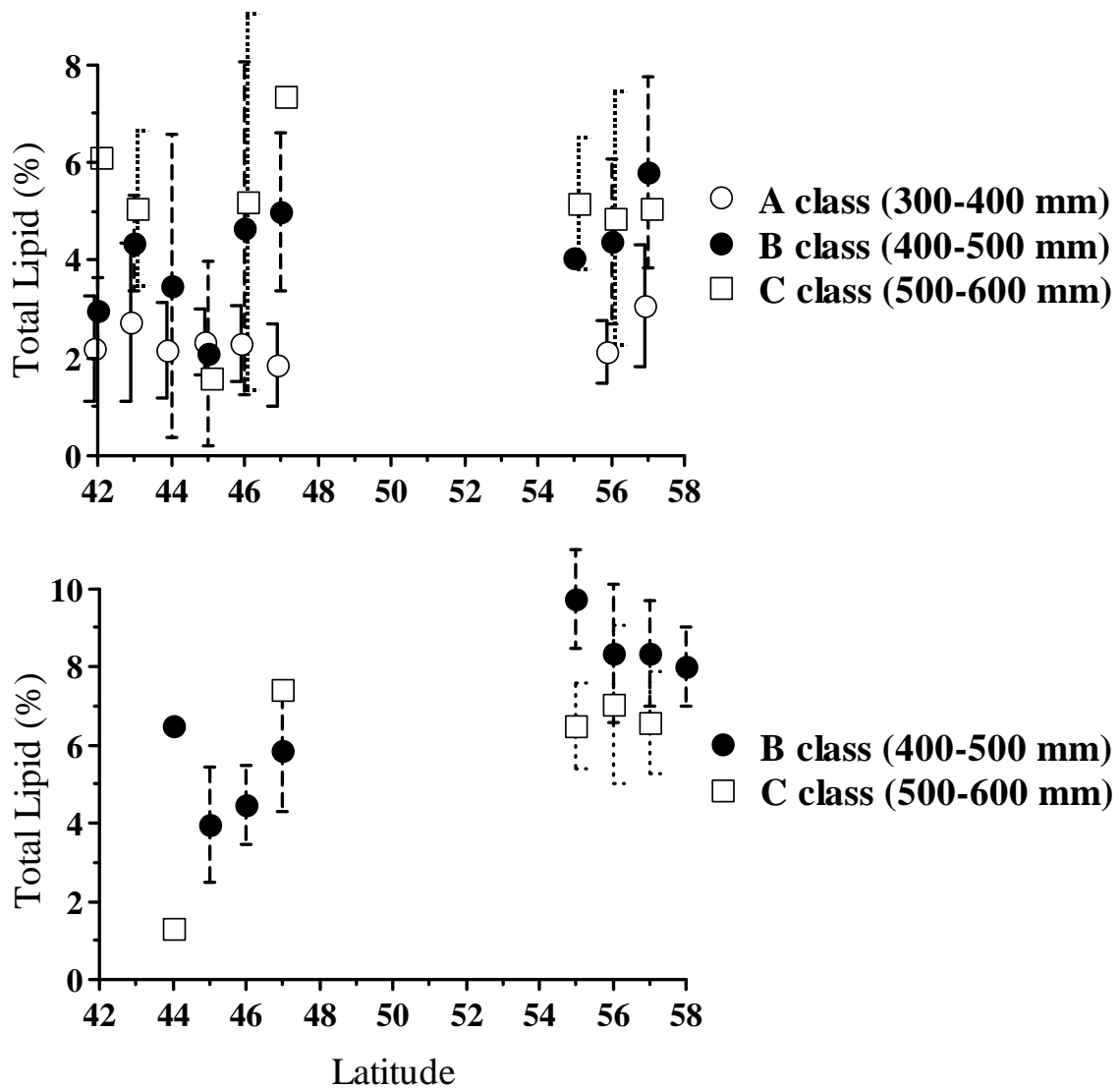


Fig. 3. Distribution of total lipid in the white muscle of chum (upper) and pink salmon (lower) which were caught in the North Pacific Ocean and the Bering sea along the longitude 180°. The error bars represent the standard error for the means.

A class (FL 300-400 mm)- Summer of 2007

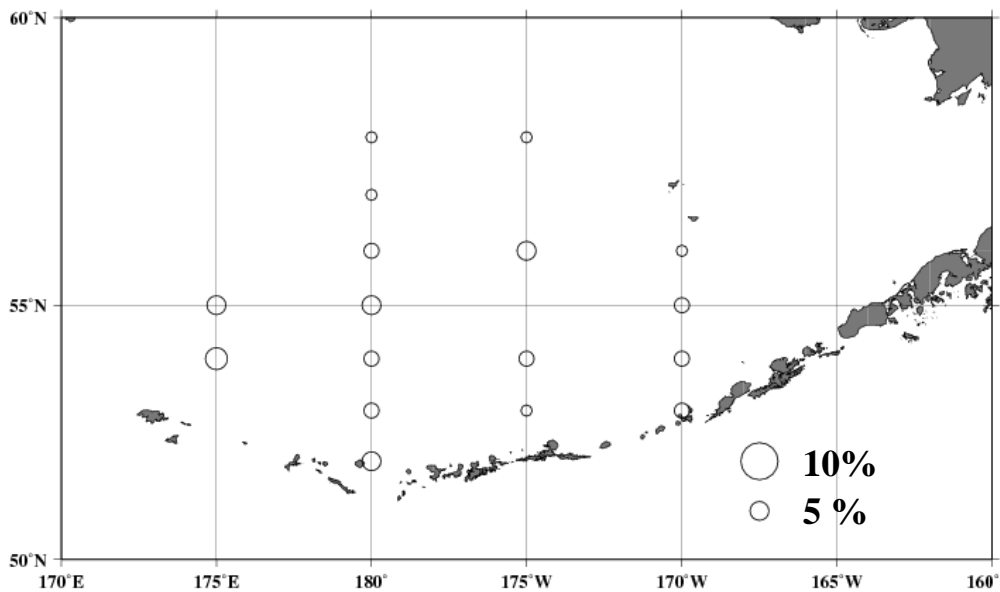


Fig. 4. Distribution of mean total lipid in the white muscle estimated using a fish fat meter for A class chum salmon (FL 300-400 mm) caught in the North Pacific Ocean in July-August of 2007.

B class (FL 400-500 mm) Summer of 2007

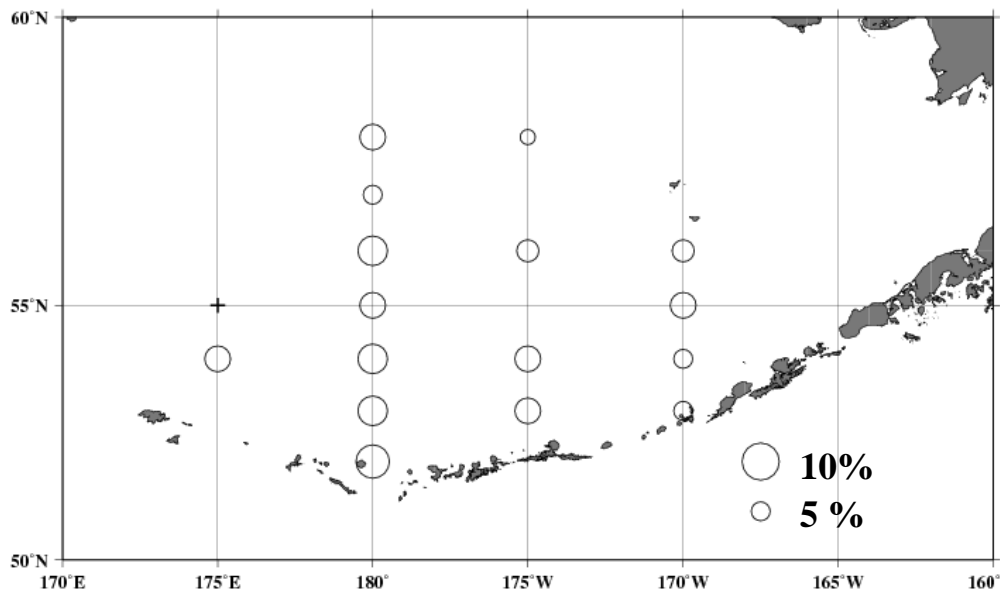


Fig. 5. Distribution of mean total lipid in the white muscle estimated using a fish fat meter for A class chum salmon (FL 300-400 mm) caught in the North Pacific Ocean in July-August of 2007. Plus figure means no data.

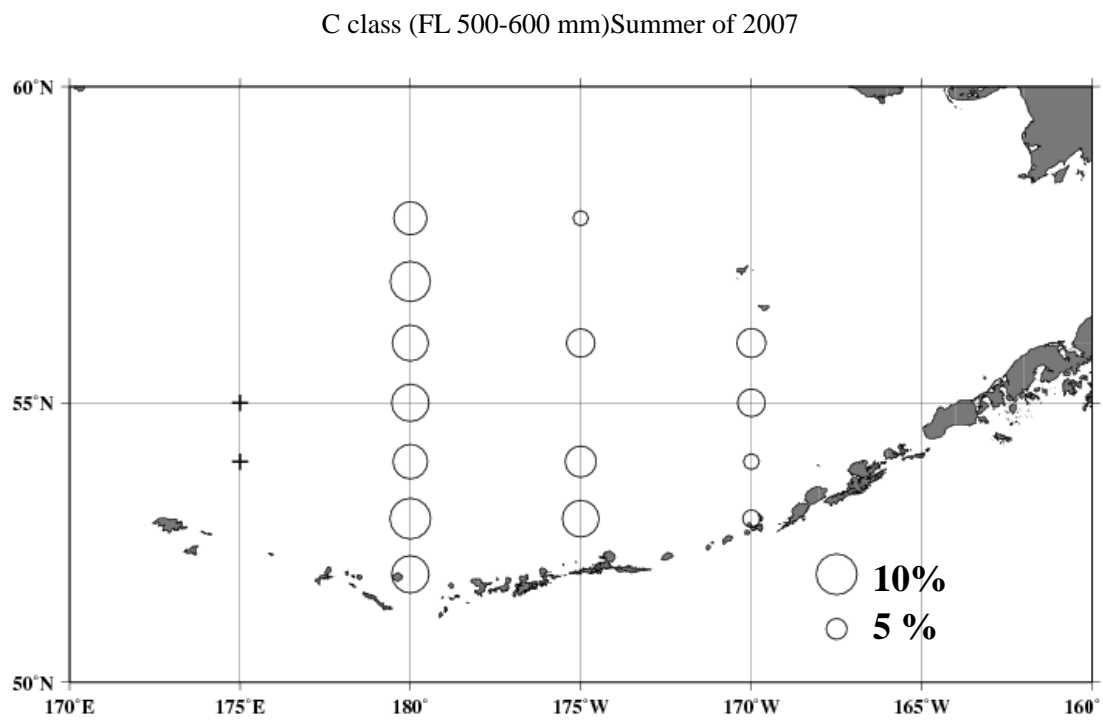


Fig. 6. Distribution of mean total lipid in the white muscle estimated using a fish fat meter for C class chum salmon (FL 500-600 mm) caught in the Bering sea in July-August of 2007. Plus figure means no data.

Appendix Fig. 1. Relationships between total lipid and electric resistance measured using a fish fat meter for chum salmon which were caught in the Bering Sea during the summer cruise in 2007 of *Hokko-maru*.

