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by

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Seasonal Changes in Total Lipid Contents of Chum and Pink Salmon in the North Pacific Ocean and Bering Sea during the Spring and Summer of 2005-2006

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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-July) of 2005, spring (April-June) and the summer (June-July) of 2006. TL extracted from white muscle of 1,105 chum and 725 pink salmon using chloroform and methanol was measured gravimetrically. TL of ocean age -.1 chum salmon caught in the Bering Sea did not increase from the spring to the summer in 2006. Ocean age -.1 chum salmon might take priority for growth over lipid storage during the summer. TL of chum white muscle increased from the spring to the summer for immature chum salmon (ocean age -.2-4) caught in the Bering Sea. It might reflect the environmental condition in the Bering Sea such as food availability, prey consumption rate, etc.. In annual variation in TL from 2000 to 2006, the TL of immature chum salmon showed similar fluctuation pattern among age groups; it was high in 2001 and decreased until 2004 gradually. TL was the lowest in 2004 and increased in recent years. 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. Thus long-term trophic monitoring of high-seas salmon may be valuable to understand the relationship between fish growth and mortality.

Introduction

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, Weatherly and Gill 1987). Although there have been a large number of lipid studies on cultured fish and artificial feed (Wilson 1991), few studies have determined lipid contents of high-seas salmon. Determination of total lipid content (TL) is an effective way to evaluate the trophic status and energy storage condition of high-seas salmonids. Nomura et al. (2000) found that the neutral lipid content in the muscle of chum (*Onchorhyncus keta*) and pink salmon (*O. gorbuscha*) in the winter was lower than other seasons. Nomura et al. (2005) also found that the neutral lipid content in the muscle of chum salmon during the summer and fall were higher than in the spring or winter. They interpreted their findings that salmon in the ocean consume prey heavily in the summer but had inadequate food in the winter. Storing the lipid in the summer would be necessary to survive through the following severe winter.

This study reports TL in the white muscle of pink and chum salmon by age group from fish caught in high-seas of the North Pacific Ocean and Bering Sea during the spring (April-June) and the summer (June-July) of 2006. In addition, this document reports a preliminary result of muscle lipid analysis using a portable fish fat meter.

Materials and Methods

Salmon were caught in the North Pacific Ocean and Bering Sea by a surface trawl during the spring cruise of the R/V *Kaiyo-maru*, April 24 to June 14, 2006 (Fig. 1) and by a drift gillnet during summer cruises of the R/V *Wakatake-maru*, June 18 to July 13, 2005, and June 14 to July, 2006 (Fig. 2). A total of 1,105 chum and 725 pink salmon was analyzed for TL in the white muscle (Tables 1, 2). Fish were measured for 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) on board ships (Tables 3, 4, 5, 6). From each fish, scales were collected for age determination. Fish bodies were preserved in a freezer (-30°C) for later examination. TL was estimated from electric resistance (E) using following formulae (Appendix Fig. 1):

$$TL = 0.23 \times E - 1.09 \quad (r^2 = 0.69, \text{ immature chum salmon}), \text{ and}$$
$$TL = 0.26 \times E - 1.73 \quad (r^2 = 0.64, \text{ pink salmon}).$$

In the laboratory, the white muscle tissue was carefully removed from fish body and homogenized in a food processor. Adequate amount of the homogenate was correctly weighed and kept frozen at -30ºC.

For determination of TL, thawed muscle sample was 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.

Results

The average TL in the white muscle of ocean age -.1 chum salmon caught in the North Pacific Ocean was 2.4% (n = 46) in the summer of 2005, 2.2% (n = 115) in the spring of 2006, and 2.7% (n = 18),in the summer of 2006 (Table 3). The average TL in the white muscle of ocean age -.1 chum salmon caught in the Bering Sea was 3.3% (n = 29) in the summer of 2005 and 3.8% (n = 54) in the summer of 2006 (Table 3).

The average TL in the white muscle of ocean age -.2 immature chum salmon caught in the North Pacific Ocean was 6.0% (n = 34) in the summer of 2005, 3.8% (n = 54) in the spring of 2006, and 3.7% (n = 37),in the summer of 2006 (Table 3). The average TL in the white muscle of ocean age -.2 immature chum salmon caught in the Bering Sea was 6.4% (n = 29) in the summer of 2005, 2.3% (n = 26) in the spring of 2006, and 4.1% (n = 34) in the summer of 2006 (Table 3).

In the Bering Sea, the average TL in the white muscle of ocean age -.2-4 immature chum salmon in the summer of 2006 was higher than the spring of 2006 (t-test; $P < 0.05$ age .-2 fish df = 17; $P < 0.001$ age .-3 fish df = 27; $P < 0.01$ age .-4 fish df = 18, Table 3). For ocean age -.2 immature chum salmon, the average TL in the summer of 2006 was lower than the same season of 2005 (t-test; $P < 0.01$ df = 28, Table 3).

The average TL in the white muscle of pink salmon caught in the North Pacific Ocean was 5.3% (n = 48) in the summer of 2005, 3.5% (n = 194) in the spring of 2006, and 3.3% (n = 9) in the summer of 2006 (Table 4). The average TL of pink salmon caught in the Bering Sea was 7.5% (n = 50) in the summer of 2005, 5.7% (n = 362) in the spring of 2006, and 7.6% (n = 61) in the summer of 2006 (Table 4).

In the Bering Sea, the average TL in the white muscle of pink salmon in the summer of 2006 was higher than the spring of 2006 (t-test; $P < 0.001$ df = 60, Table 4). In the North Pacific Ocean, the average TL of pink salmon in the summer of 2006 was lower than the summer of 2005 (t-test; $P < 0.01$ df = 8, Table 4).

Annual variation in total lipid content from 2000 to 2006 showed that TL of ocean age -.1 chum salmon did not fluctuate so much and it increased gradually from 2002 to 2006 (Fig. 3). The TL of ocean age -.2-4 immature chum salmon showed similar fluctuation pattern. TL was the highest in 2001 and decreased gradually until 2004. TL was the lowest in 2004 and increased in recent years. TL of ocean age -.3 immature chum salmon was larger that ocean age

-.4 immature chum salmon from 2003 to 2006.

From a large number of fish, TL was obtained using a fish fat meter (Table 7, Figs. 4-9). The average TLs estimated using the fish fat meter for ocean age -.2-4 immature chum salmon caught in the range from 165^{o}E to 175^{o}E in the North Pacific Ocean was higher than other areas.

Discussion

The effect of salmon age must be taken into consideration when examining lipid levels in samples collected in offshore waters because younger salmon had lower lipid levels than older salmon. (Nomura et al. 2000, 2001, 2002, 2004, 2005). Our results showed seasonal and annual differences in TLs of chum and pink salmon caught in the North Pacific Ocean and Bering Sea from 2005 to 2006 by age group. For ocean age -.1 chum salmon, TL in the Bering Sea did not increase from the spring to the summer in 2006. Nomura et al. (2002) hypothesize that the energy expenditure in ocean age -.1 chum salmon takes priority for growth over lipid storage during summer. However, Azuma et al. (1998) concluded that chum salmon slow their growth rate to maintain energy reserves prior to winter. During the fall, lipid storage can promote survival through winter (Nomura et al. 2002). 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 survive in the late fall and winter. We need to evaluate the trophic status of chum salmon, particularly young fish, in the fall just before overwintering. For ocean age -.2-4 immature chum salmon caught in the Bering Sea, TL increased from the spring to the summer in 2006. It might reflect the environmental condition in the Bering Sea such as food availability, prey consumption rate, etc..

When pink salmon abundance was high, chum salmon changed their prey composition (Shuntov et al. 1993; Tadokoro et al. 1996). The average TL of pink salmon caught in the North Pacific Ocean in the summer of 2006 was lower than 2005. In the Bering Sea and central North Pacific Ocean, pink salmon abundance fluctuates in two-year cycle (Nagasawa et al. 2006). Trophic status may relate with interspecific relationship among high-seas salmonids.

Using a fish fat meter, we can obtain the information on total lipid content with reducing cost and time from total lipid analysis. We need an extensive lipid content data for understanding the relationship between lipid content and environmental condition.

The present preliminary study as well as the past studies (Nomura et al. 2000, 2001, 2002, 2005; Kaga et al. 2006) 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.

Acknowledgements

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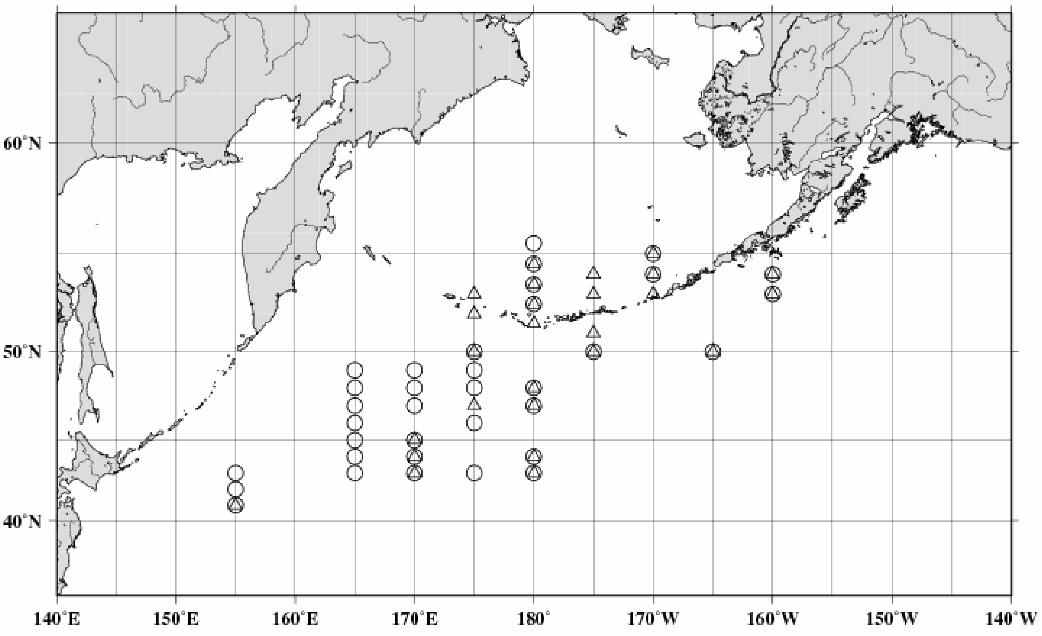

Fig. 1. Locations where chum salmon (open circle) and pink salmon (open triangle) were caught during the spring research cruise of R/V *Kaiyo-maru*, April-June 2006.

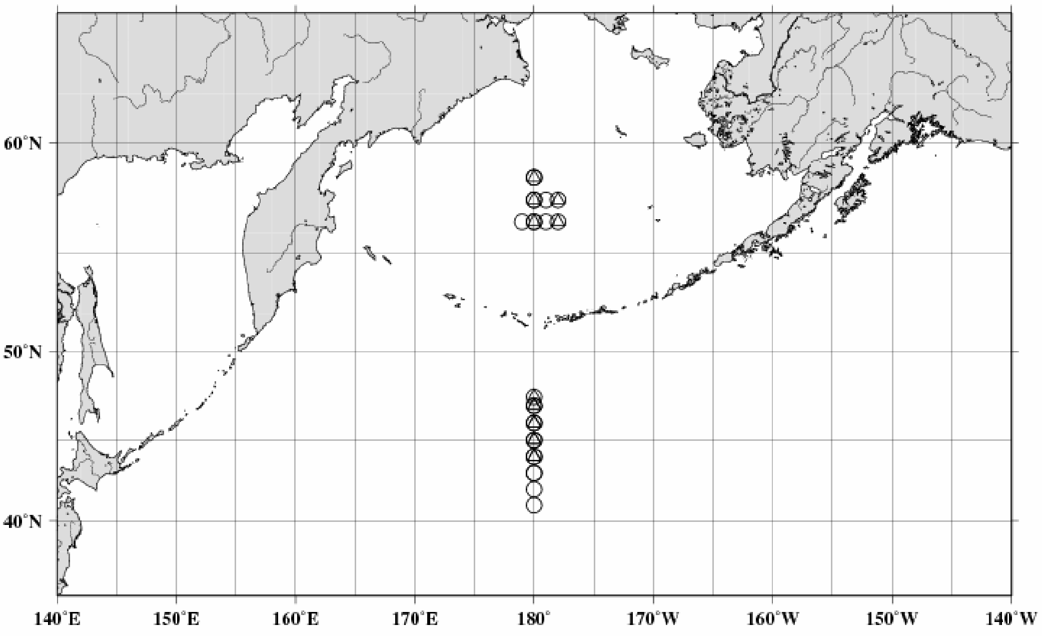

Fig. 2. Locations where chum salmon (open circle) and pink salmon (open triangle) were caught during the summer research cruises of R/V *Wakatake-maru*, June-July, 2005 and 2006.

Table 1. Locations, dates and numbers of chum salmon and pink salmon sampled in the North Pacific Ocean and the Bering Sea during the spring (April-June) of 2006.

Station	Longitude		Latitude	Date	Number of fish						
					Chum Salmon						Pink Salmon
					Ocean Age						
					1	2	3	4	5	Total	
1	155	E	41°N	Apr. 24	2	0	0	0	0	2	50
2	155	E	42°N	Apr. 24	11	1	0	1	0	13	0
3	155	E	43°N	Apr. 25	4	0	0	0	0	4	0
5	165	E	49°N	Apr. 28	0	0	0	5	0	5	0
6	165	E	48°N	Apr. 28	0	0	0	2	0	2	0
7	165	E	47°N	Apr. 29	0	0	2	13	0	15	0
8	165	E	46°N	Apr. 29	0	0	1	0	0	1	0
9	165	E	45°N	Apr. 30	0	2	17	4	0	23	0
10	165	E	44°N	Apr. 30	0	3	10	5	1	19	0
11	165	E	43°N	May 1	2	0	0	0	0	2	0
12	170	E	43°N	May 2	35	1	0	0	0	36	36
13	170	E	44°N	May 2	0	1	4	2	0	7	3
14	170	E	45°N	May 3	2	4	5	3	0	14	2
16	170	E	47°N	May 4	1	0	1	1	0	3	0
17	170	E	48°N	May 4	0	0	3	2	0	5	0
18	170	E	49°N	May 5	0	0	2	7	0	9	0
19	175	E	49°N	May 6	0	0	1	2	0	3	0
20	175	E	48°N	May 6	0	0	18	30	1	49	0
21	175	E	47°N	May 7	0	0	0	0	0	0	50
22	175	E	46°N	May 7	1	0	0	0	0	1	0
25	175	E	43°N	May 9	4	0	0	0	0	4	0
26	180		43°N	May 10	51	2	1	1	0	55	4
27	180		44°N	May 10	2	40	3	0	0	45	40
30	180		47°N	May 12	0	0	0	0	0	0	2
31	180		48°N	May 12	0	0	0	0	0	0	7
33	160	W	54°N	May 26	0	1	19	22	0	42	42
34	160	W	53°N	May 26	0	0	6	1	0	7	8
38	165	W	50°N	May 29	0	13	30	6	0	49	50
43	170	W	55°N	June 2	0	0	6	26	2	34	7
44	170	W	54°N	June 2	0	0	11	10	1	22	24
45	170	W	53°N	June 3	0	0	0	0	0	0	19
49	175	W	50°N	June 5	0	5	29	15	0	49	12
50	175	W	51°N	June 6	0	0	0	0	0	0	6
52	175	W	53°N	June 7	0	0	0	0	0	0	9
53	175	W	54°N	June 7	0	0	0	0	0	0	22
55	180		55.5°N	June 9	0	0	0	2	0	2	0
56	180		54.5°N	June 9	0	0	0	1	1	2	4
57	180		53.5°N	June 10	0	1	13	11	0	25	119
58	180		52.5°N	June 10	0	1	7	7	0	15	23
59	180		51.5°N	June 11	0	0	0	0	0	0	5
62	175	E	50°N	June 13	0	5	23	19	1	48	6
64	175	E	52°N	June 14	0	0	0	0	0	0	4
65	175	E	53°N	June 14	0	0	0	0	0	0	2
Total					115	80	212	198	7	612	556

Table 2. Locations, dates and numbers of chum and pink salmon which sampled in the North Pacific Ocean and the Bering Sea during the summer (June-July) of 2005 (upper) and 2006 (lower).

Station	Longitude		Latitude	Date	Number of Fish						
					Chum Salmon						Pink Salmon
					Ocean Age						
					1	2	3	4	5	Total	
5	180		43°N	June 18	0	12	3	0	0	15	0
6	180		44°N	June 19	2	3	3	0	0	8	1
7	180		45°N	June 20	7	1	0	0	0	8	5
8	180		46°N	June 21	3	9	6	1	0	19	9
9	180		47°N	June 22	34	9	4	1	0	48	34
19	180		56.5°N	July 2	0	4	49	12	2	67	0
20	180		57.5°N	July 3	0	0	1	0	0	1	0
21	180		58.5°N	July 8	0	1	16	1	0	18	0
22	179	W	57.5°N	July 9	0	3	6	3	0	12	0
23	178	W	57.5°N	July 10	1	2	8	2	0	13	22
24	178	W	56.5°N	July 11	3	8	13	3	0	27	28
25	179	W	56.5°N	July 12	7	8	22	1	2	40	0
26	179	E	56.5°N	July 13	18	3	0	0	0	21	0
Total					75	63	131	24	4	297	99

Station	Longitude	Latitude	Date	Number of Fish						
				Chum Salmon						Pink Salmon
				Ocean Age						
				1	2	3	4	5	Total	
3	180	41°N	June 14	0	3	0	0	0	3	0
4	180	42°N	June 16	0	5	0	0	0	5	0
5	180	43°N	June 17	0	8	0	0	0	8	0
6	180	44°N	June 18	8	4	0	0	0	12	0
7	180	45°N	June 19	5	4	0	0	0	9	1
8	180	46°N	June 20	3	1	2	1	0	7	3
9	180	47°N	June 21	2	3	1	0	0	6	4
10	180	47.5°N	June 22	0	9	1	0	1	11	1
18	180	55.5°N	July 13	7	3	4	6	0	20	14
19	180	56.5°N	July 12	20	7	2	0	0	29	11
20	180	57.5°N	July 11	15	15	7	6	0	43	15
21	180	58.5°N	July 10	3	8	7	5	0	23	16
26	180	56.5°N	July 14	9	1	8	2	0	20	5
Total				72	71	32	20	1	196	70

Table 3. Mean and standard deviation in parenthesis of fork length (FL), body weight (BW), total lipid (TL) content, and moisture in the white muscle of each ocean ages chum salmon caught in the North Pacific Ocean and the Bering Sea during the spring and the summer of 2005-2006.

Year Season	Area	Ocean Age	Number of Fish	FL (cm)		BW (g)		TL (%)		Moisture (%)	
2005											
Summer	North Pacific Ocean	1	46	332.5	(25.8)	375.2	(105.1)	2.4	(1.1)	77.1	(1.3)
		2	34	443.0	(29.6)	1034.7	(252.9)	6.0	(2.3)	73.9	(2.3)
		3	16	498.3	(25.9)	1356.3	(326.5)	5.2	(2.6)	74.5	(2.8)
		4	2	554.5	(13.4)	1860.0	(297.0)	9.0	(5.4)	70.2	(5.2)
		5	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
		Total	98	403.1	(74.7)	797.8	(471.3)	4.2	(2.7)	75.4	(2.6)
	Bering Sea	1	29	383.1	(23.0)	609.3	(107.9)	3.3	(1.5)	76.0	(1.7)
		2	29	469.0	(34.6)	1234.1	(311.8)	6.4	(3.7)	73.0	(3.4)
		3	115	531.7	(36.4)	1838.4	(468.9)	7.2	(3.6)	72.2	(3.3)
		4	22	572.9	(39.8)	2391.4	(605.4)	6.9	(3.2)	72.1	(2.9)
		5	4	657.0	(71.5)	3755.0	(1247.1)	8.7	(5.1)	71.1	(4.3)
		Total	199	508.2	(70.6)	1673.4	(746.7)	6.5	(3.6)	72.8	(3.4)
2006											
Spring	North Pacific Ocean	1	115	282.6	(24.9)	236.1	(73.3)	2.2	(1.1)	77.9	(1.1)
		2	54	414.5	(33.7)	795.3	(210.2)	3.8	(3.4)	76.7	(3.6)
		3	68	518.3	(32.0)	1762.9	(355.0)	8.1	(3.5)	72.3	(3.8)
		4	78	552.7	(32.8)	2053.3	(474.0)	6.8	(4.0)	73.4	(3.9)
		5	2	549.5	(3.5)	2175.0	(7.1)	7.4	(0.8)	73.5	(0.5)
		Total	317	453.1	(110.0)	1301.2	(807.7)	5.5	(4.0)	74.9	(4.0)
	Bering Sea	1	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
		2	26	480.4	(22.5)	1227.9	(208.9)	2.3	(2.0)	77.8	(2.3)
		3	144	530.4	(35.2)	1765.6	(414.1)	4.0	(2.4)	76.0	(2.3)
		4	120	571.9	(31.5)	2171.0	(393.7)	4.4	(3.2)	75.4	(3.2)
		5	5	589.7	(46.5)	2333.3	(312.1)	6.8	(5.1)	74.1	(4.0)
		Total	295	544.5	(43.2)	1898.0	(481.8)	4.0	(2.8)	75.9	(2.8)
2006											
Summer	North Pacific Ocean	1	18	324.8	(26.9)	395.0	(115.5)	2.7	(0.9)	76.2	(1.1)
		2	37	424.5	(23.4)	839.5	(166.4)	3.7	(3.1)	75.5	(2.8)
		3	4	485.8	(14.1)	1305.0	(143.9)	4.4	(3.5)	75.2	(2.9)
		4	1	561.0		2020.0		6.1		70.5	
		5	1	587.0		2330.0		2.9		75.2	
		Total	61	404.0	(64.0)	782.6	(390.0)	3.5	(2.6)	75.6	(2.4)
	Bering Sea	1	54	352.0	(25.2)	485.4	(95.9)	3.8	(1.3)	75.7	(1.2)
		2	34	446.0	(36.4)	986.8	(257.7)	4.1	(2.0)	75.2	(1.8)
		3	28	536.0	(52.3)	2024.3	(748.6)	8.3	(3.6)	71.1	(3.2)
		4	19	589.0	(58.8)	2767.4	(913.5)	7.4	(3.4)	71.3	(3.0)
		5	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
		Total	135	445.9	(98.1)	1237.4	(969.1)	5.3	(3.1)	74.1	(3.0)

Table 4. Mean and standard deviation in parenthesis of fork length (FL), body weight (BW), total lipid (TL) content, and moisture in the white muscle of pink salmon caught in the North Pacific Ocean and the Bering Sea during the spring and the summer o f 2005-2006.

Year Season	Area	Number of Fish	FL (cm)		BW (g)		TL (%)		Moisture (%)	
2005 Summer	North Pacific Ocean	48	484.8	(33.5)	1466.5	(534.7)	5.3	(1.3)	73.4	(1.2)
	Bering Sea	50	471.6	(38.3)	1350.0	(390.0)	7.5	(2.2)	71.7	(1.9)
	Total	98	478.1	(36.5)	1407.0	(467.8)	6.4	(2.2)	72.5	(1.8)
2006 Spring	North Pacific Ocean	194	384.1	(32.1)	629.4	(158.5)	3.5	(2.1)	76.8	(1.7)
	Bering Sea	362	437.5	(34.5)	1003.8	(276.2)	5.7	(2.9)	74.2	(2.8)
	Total	556	416.7	(42.5)	857.7	(299.4)	4.8	(2.8)	75.2	(2.8)
2006 Summer	North Pacific Ocean	9	448.0	(33.2)	1064.4	(213.6)	3.3	(1.4)	74.9	(2.2)
	Bering Sea	61	473.7	(43.5)	1414.3	(422.9)	7.6	(1.9)	71.9	(2.2)
	Total	70	470.4	(43.0)	1369.3	(418.0)	7.1	(2.3)	72.3	(2.4)

Table 5. Mean and standard deviation in parenthesis of total lipid content in the white muscle of chum salmon caught in the Bering Sea in the summer from 2000 to 2006.

	Ocean Age							
Year	1		2		3		4	
2000			6.2	(3.4)	8.1	(4.0)	9.9	(4.6)
2001	3.3	(1.4)	9.3	(4.6)	11.1	(4.1)	11.3	(5.2)
2002	1.8	(0.8)	5.1	(2.6)	6.9	(2.9)	9	(4.1)
2003	2.1	(1.6)	4.4	(2.7)	7.7	(3.4)	7.3	
2004	2.4	(0.9)	4.2	(2.1)	6.4	(2.9)	5.6	(1.5)
2005	3.3	(1.1)	6.4	(2.3)	7.2	(2.6)	6.9	(5.4)
2006	3.8	(1.3)	4.1	(2.0)	8.3	(3.6)	7.4	(3.4)

Table 6. Number of immature chum and pink salmon sampled in the North Pacific Ocean and the Bering Sea during the spring (Apr.-June) of 2006 for total lipid analysis using a fish fat meter

Number of Fish						
Chum Salmon						Pink Salmon
Ocean Age						
1	2	3	4	5	Total	
156	401	882	625	30	2079	1148

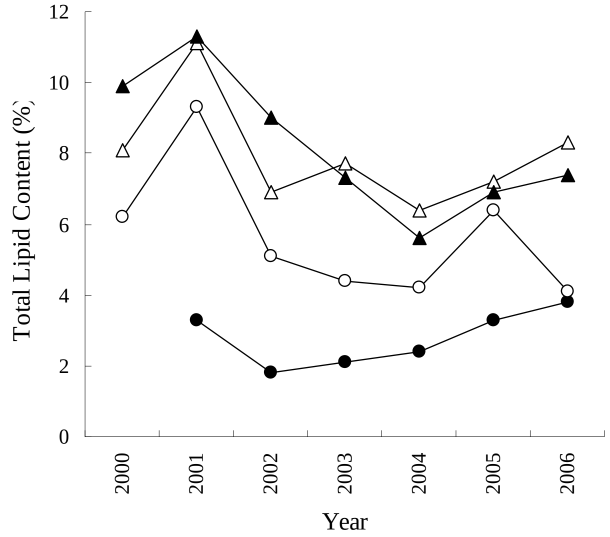

Fig. 3. Mean total lipid content in the white muscle of each ocean age of immature chum salmon caught in the Bering Sea during the summer of 2000-2006. Closed circle=ocean age -.2, open circle=ocean age -.3, open triangle=ocean age -.3, closed triangle=ocean age -.4. (2000-2004 data was cited from Nomura et al. 2001, 2005)

Table 7. Mean and standard deviation in parenthesis of total lipid content in the muscle estimated using a fish fat meter for chum and pink salmon caught in each station during the spring of 2006 .

Station	Total Lipid Content (%)											
	Chum Salmon										Pink Salmon	
	Ocean Age											
	1		2		3		4		5			
1	2.5	(0.9)									3.0	(1.2)
2	4.5	(1.6)	5.6								3.6	(1.9)
3	4.2	(1.7)									3.7	(1.5)
4											3.4	(0.9)
5					8.3		5.4	(3.0)				
6							4.9	(2.2)				
7					8.7	(2.6)	6.1	(3.0)				
8					7.3	(1.6)						
9			9.9	(0.2)	8.6	(2.1)	8.2	(1.5)				
10			6.9	(1.8)	8.1	(2.9)	8.5	(2.2)	7.7			
11			7.0	(3.0)	7.6	(2.4)	6.7	(2.9)	5.7	(0.6)	3.3	(3.5)
12	3.4	(1.7)	6.0	(2.2)							6.6	(1.5)
13			8.6		8.3	(1.1)	7.1	(2.0)			5.1	(1.9)
14	3.2	(0.6)	6.6	(0.0)	8.1	(0.4)	6.8	(3.2)			6.8	(1.9)
15					10.4		0.0				2.9	
16	1.2				8.5		6.8	(1.6)			3.1	
17					7.3	(0.2)	6.2	(2.8)	6.7			
18					7.9	(1.9)	6.4	(2.2)				
19					4.8		5.6	(4.1)				
20					7.1	(2.5)	6.3	(2.5)	7.5		4.3	(2.2)
21			3.4		7.4	(2.8)	6.6	(2.7)			3.2	(2.2)
22			7.9		5.1	(3.5)	2.2				1.9	(1.6)
23	4.9	(0.2)	4.1	(2.6)	4.8	(2.7)	4.2	(3.7)			2.8	(1.7)
24			4.0	(2.0)	5.3	(2.1)	4.9	(5.4)	7.7		4.6	(1.9)
25	3.8	(1.0)	4.8	(2.1)	7.1	(0.9)	10.2				4.1	(1.4)
26	2.5	(2.1)	2.8	(0.1)	4.2		3.4				3.8	(1.1)
27	1.9	(0.8)	2.9	(1.7)	5.5	(3.3)					3.2	(1.2)
28	2.1	(1.7)	2.6	(1.6)	5.3	(3.0)					3.8	(1.7)
29			3.2	(1.5)	5.0	(2.0)	5.3	(2.9)	0.8		3.5	(1.4)
30			3.4	(0.6)	4.9	(2.4)	5.2	(2.8)			4.6	(1.9)
31			2.3	(1.2)	2.7	(2.3)	2.2	(1.0)			2.1	(1.0)
32											1.8	(0.9)
33			1.4		4.3	(2.9)	4.2	(3.0)			4.4	(1.5)
34			2.0		3.1	(1.9)	4.9	(3.0)			4.0	(1.1)
35					2.9	(0.8)					4.0	(1.7)
36			1.5	(1.2)	1.9	(1.8)	1.5	(1.2)			2.6	(1.5)
37			1.2	(0.6)	0.9	(0.4)					3.9	(1.6)
38			1.8	(1.4)	2.5	(1.7)	2.3	(2.1)			4.4	(1.6)
39			1.1	(0.1)	3.0	(2.1)	2.2	(1.6)			4.1	(1.6)
40					5.8	(2.2)	5.1	(2.5)			5.5	(1.3)

Table 7. (Continued)

Station	Total Lipid Content (%)											
	Chum Salmon										Pink Salmon	
	Ocean Age											
	1		2		3		4		5			
41			0.9		3.5	(2.1)	4.1	(2.4)	1.8	(2.0)	4.1	
42					4.0	(2.4)	4.4	(2.2)			3.6	(0.2)
43					4.5	(2.9)	3.9	(2.2)	6.3	(4.7)	5.2	(1.6)
44					4.1	(2.4)	2.8	(1.9)	4.0		4.1	(1.6)
45					4.4	(2.3)	5.3	(2.6)			4.5	(1.5)
46			1.5	(0.1)	4.9	(1.8)	4.7	(2.6)	4.6		2.9	(0.7)
47			1.8	(0.6)	3.1	(1.8)	4.6	(2.3)			4.4	(2.5)
48			2.0	(1.3)	2.9	(2.1)	2.7	(2.1)			5.4	(1.6)
49			3.5	(1.9)	4.4	(2.5)	4.0	(2.7)			4.6	(1.9)
50			4.6		5.0	(2.0)	4.1	(2.6)			4.9	(2.2)
51					6.4	(3.2)	6.4	(2.5)				
52			4.4		4.7	(1.8)	5.4	(2.4)			3.7	(1.8)
53			5.4	(1.9)	5.6	(2.1)	4.7	(2.8)	4.6	(1.9)	5.9	(1.5)
54					5.2	(2.2)	6.3	(2.0)	4.0	(2.6)	5.4	
55							6.4	(0.9)				
56							7.0		3.2		5.1	(1.2)
57			2.2		4.0	(2.3)	3.0	(1.6)			4.8	(1.7)
58			3.6	(0.2)	4.0	(2.2)	5.0	(3.4)			4.2	(1.9)
59			4.1	(2.5)	4.2	(2.4)	5.1	(2.2)			5.0	(0.8)
60					6.1	(2.2)	6.2	(1.9)	2.8		6.5	(0.5)
61			4.3	(1.9)	5.2	(2.2)	5.7	(2.1)			5.5	(1.9)
62			4.3	(2.6)	4.9	(2.4)	5.2	(2.6)	7.4		7.0	(0.9)
63					2.7	(2.3)					1.5	
64			3.5		6.3	(1.9)	6.4	(2.2)	1.3		5.4	(2.1)
65					4.5	(1.7)	2.2				4.6	(2.3)
66			0.1		1.1						3.3	(1.2)
67			3.3		4.6	(2.3)	4.0	(2.7)			3.8	(1.5)
Average	2.8	(1.9)	3.5	(2.3)	4.9	(2.8)	4.9	(2.8)	4.7	(2.8)	4.1	(1.9)

Ocean Age -.1 Spring of 2006

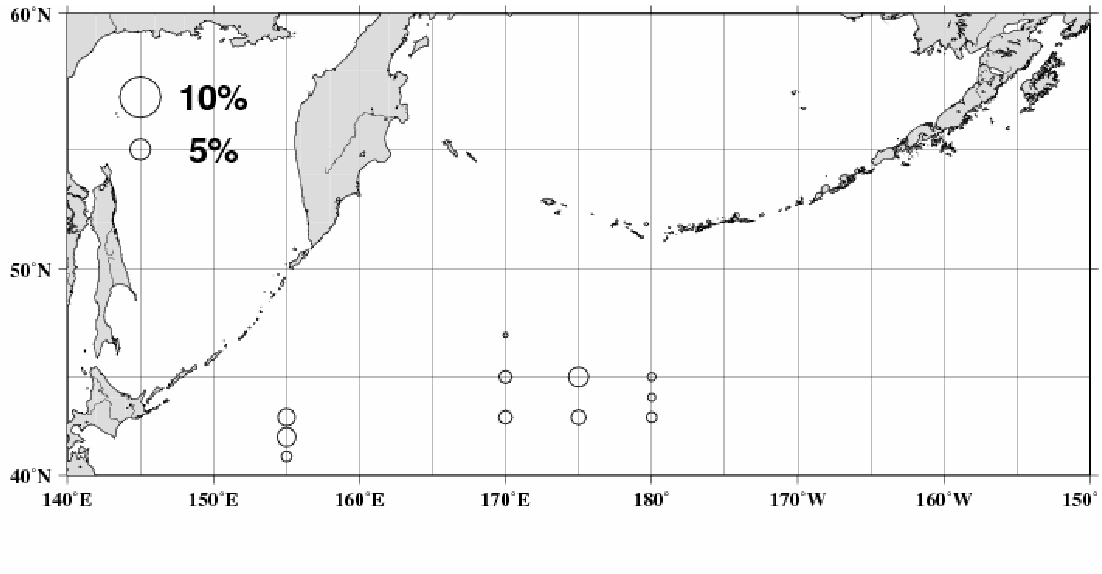

Fig. 4. Distribution of mean total lipid content in the muscle estimated using a fish fat meter for ocean age -.1 chum salmon caught in the North Pacific Ocean in Apr.-June of 2006.

Ocean Age -.2 Spring of 2006

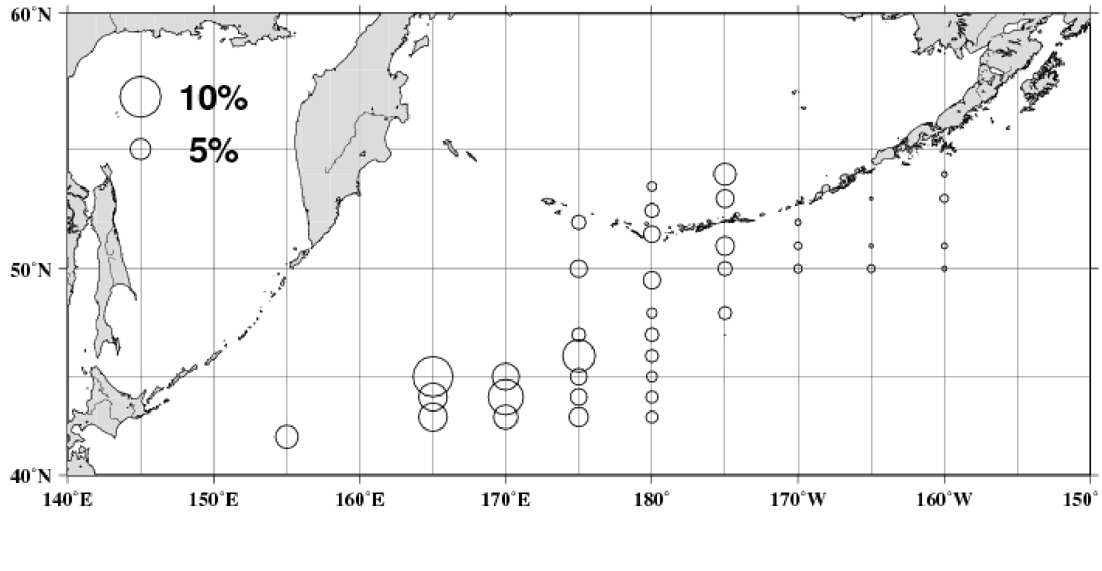

Fig. 5. Distribution of mean total lipid content in the muscle estimated using a fish fat meter for ocean age -.2 chum salmon caught in the North Pacific Ocean and the Bering Sea in Apr.-June of 2006.

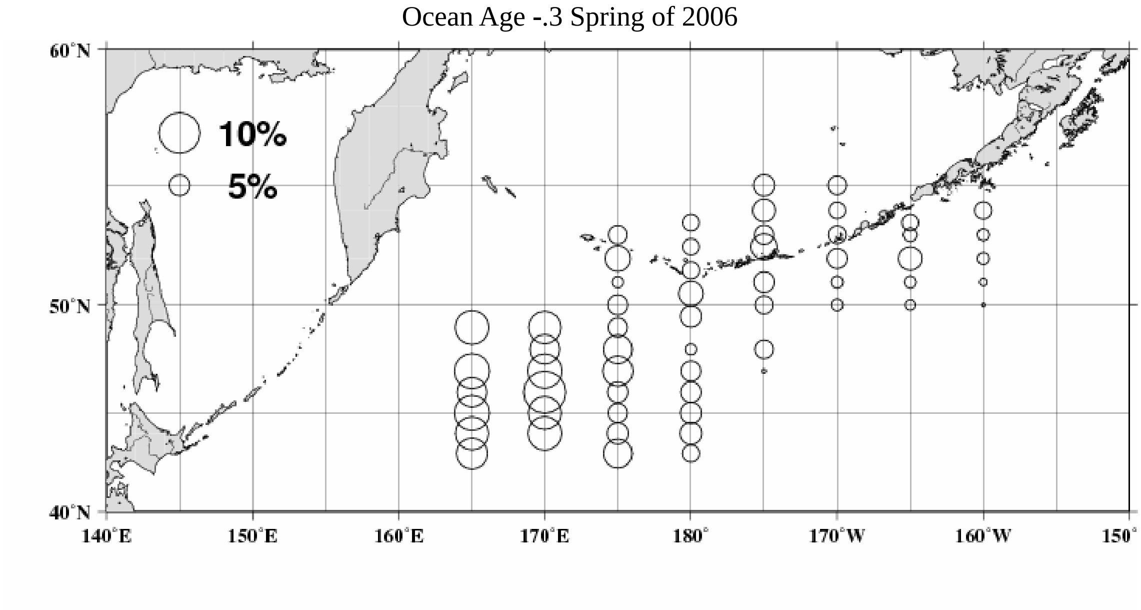

Fig. 6. Distribution of mean total lipid content in the muscle estimated using a fish fat meter for ocean age -.3 chum salmon caught in the North Pacific Ocean and the Bering Sea in Apr.-June of 2006.

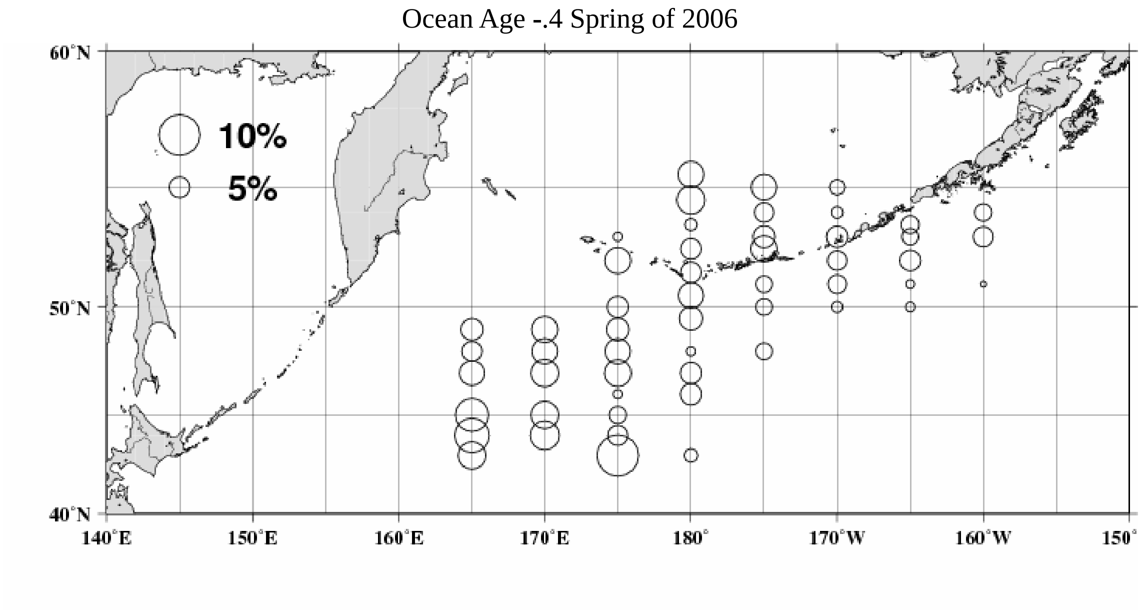

Fig. 7. Distribution of mean total lipid content in the muscle estimated using a fish fat meter for ocean age -.4 chum salmon caught in the North Pacific Ocean and the Bering Sea in Apr.-June of 2006.

Ocean Age -.5 Spring 0f 2006

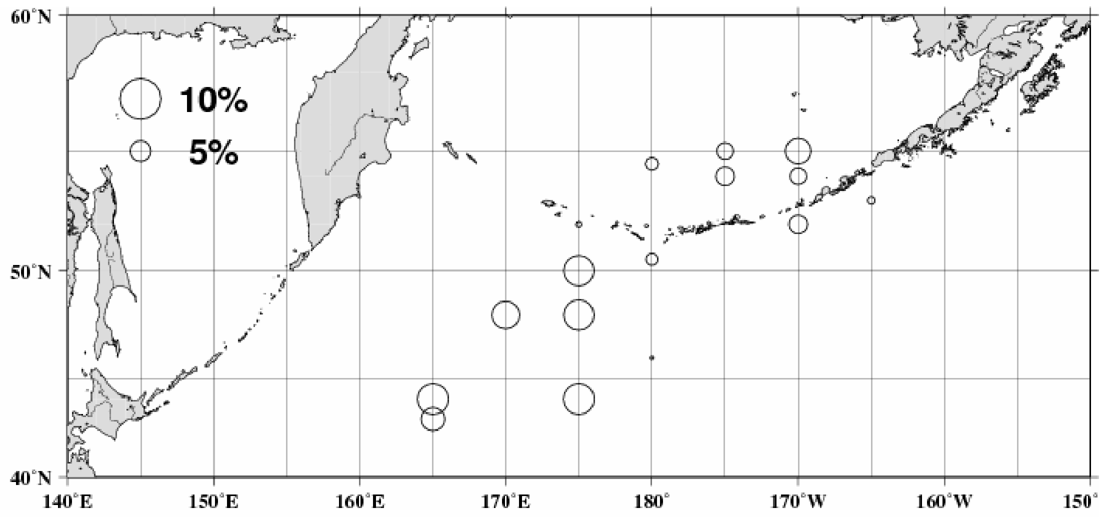

Fig. 8. Distribution of total lipid content in the muscle estimated using a fish fat meter for ocean age -.5 chum salmon caught in the North Pacific Ocean and the Bering Sea in April-June of 2006.

Pink Salmon Spring of 2006

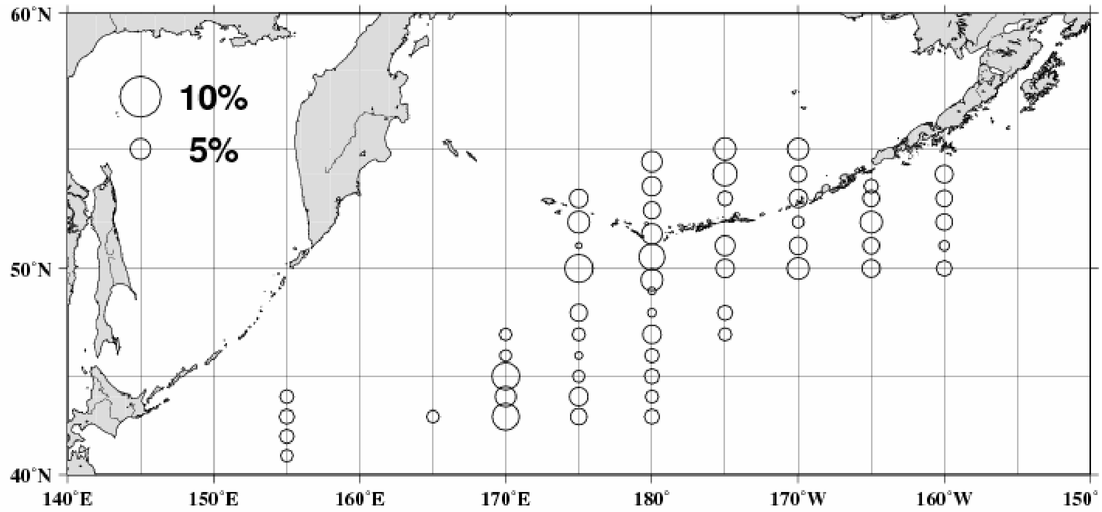

Fig. 9. Distribution of total lipid content in the muscle estimated using a fish fat meter for pink salmon caught in the North Pacific Ocean and the Bering Sea in April-June of 2006.

Appendix Fig. 1. Relationships between total lipid content and electric resistance measured using a fish fat meter for chum (upper) and pink (lower) salmon caught in the North Pacific Ocean and the Bering Sea in the spring of 2006.