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the Bering Sea during the
Summer and Fall of 2002-2004**

By

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Seasonal Changes in the Total lipid Content of Immature Chum Salmon in the Bering Sea during the Summer and Fall of 2002-2004

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Abstract

This study reports the total lipid (TL) content in the white muscle of chum salmon by age group from fish caught in the Bering Sea in summer (June-July) and fall (September) 2002-2004. The TL was extracted from the muscle of 1,282 immature chum salmon using chloroform and methanol and then measured gravimetrically. The TL content of young fish (ocean age-.1) caught in summer was significantly lower than fish caught in the fall. The mean TL content of ocean age-.1 fish caught in summer 2002, 2003, and 2004 was 1.8 % (n=48), 2.1% (n=89) and 2.4% (n=58), respectively. The mean TL content of ocean age-.1 chum salmon caught in fall 2002 and 2003 was 7.3% (n=180) and 5.2% (n=198), respectively. The low lipid content in young (ocean age-.1) chum salmon caught during summer suggested this is a period when young fish grow at the expense of lipid storage. Higher lipid content in the fall suggests this is a period when lipid is stored at the expense of growth, in order to promote survival through the winter. There was a significant inverse correlation between TL content and moisture, and TL content and moisture together totaled about 80% of the body weight. We recommend continuing the study of chum salmon TL content by age group with an emphasis on monitoring seasonal changes, particularly those that occur in ocean age-.1 and -.2 fish.

Introduction

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, Weatherly and Gill 1987, Novotny and Beeman 1990). Although a large number of lipid studies have focused on cultured fish and artificial food (Wilson 1991), few studies have determined lipid content of high-seas salmon (Nomura et al. 2000, 2001, 2002, 2004).

Examination of triacylglycerol and protein content, and nucleic acid ratios have been used to characterize Pacific salmon growth (Azuma et al. 1998). The low level of neutral lipid and the high proportion of docosahexaenoic acid (DHA) in the muscle of chum and pink salmon in the North Pacific Ocean collected during winter and spring demonstrated these fish were in a starving condition (Nomura et al. 2000, 2001).

Determination of lipid content of salmonids conducted during their high-seas migrations can be used to estimate their energy storage condition and potential for growth (Nomura et al. 2000, 2001). In general, it is assumed that salmonids consume prey heavily during the summer and fall, and the lipid content in the muscle would be higher during these periods than in spring and winter.

Nomura et al. (2004) reported the total lipid content in white muscle of immature chum salmon caught in the Bering Sea in 2002. This study updates the earlier report by summarizing the results of lipid analysis of Bering Sea chum salmon caught in the summer and fall 2002-2004, stratified by age group.

Materials and Methods

Chum salmon were caught by surface trawl net during the summer (June-July) and fall (September) 2002-2004 cruises of the R/V Kaiyo-maru in the Bering Sea (Tables 1-5; Figs. 1-3). Fork length (FL, cm) and body weight (BW, g) of some chum salmon were measured onboard. After measuring, these fish were kept as round samples, and frozen at -30 °C. Other chum salmon were frozen (-30°C) as round samples prior to measurement of length and weight. In this case, fork length and body weight were measured at the National Salmon Resources Center (NASREC) laboratory after thawing. In the laboratory, scales were collected for age determination, and a fillet was carefully removed from the fish. The white muscle was removed from the fillet and homogenized in a food processor. An approximate 10 g sample of the homogenized white muscle was removed, weighed, and kept frozen at -30°C until analyzed.

For determination of TL content, 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 8:4:3. 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 110°C

Results

A total of 660 chum salmon muscle samples were analyzed from immature fish caught during the summer and 622 samples were analyzed from fish caught during the fall. Average fork length (FL), body weight (BW) and condition factor ($CF: BW/FL^3 \times 1,000$) of salmon used in our study are shown in and Tables 6-9 and Figs. 4-6.

Average TL content in the white muscle of immature ocean age -.1 chum salmon caught during summer (June -July) was 1.8% (n=48), 2.1% (n=89), and 2.4% (n=118) in 2002, 2003 and 2004 respectively (Table 6, Fig. 7). Average TL content in the white muscle of immature ocean age -.1 chum salmon caught during fall (September) was 7.3% (n=180), and 5.2% (n=198) in 2002 and 2003, respectively.

Average TL content in the white muscle of ocean age-.2 chum salmon caught in summer (June-July) was 5.1% (n=69), 4.4% (n=103), and 4.2% (n=125) in 2002, 2003 and 2004, respectively (Table 7, Fig. 7). The TL in ocean age -.2 chum salmon caught in fall was 11.7% (n=122) and 8.5% (n=83) in 2002 and 2003. In September the average TL observed in chum salmon of each age was significantly higher than the value observed in fish of the same age collected in June-July (T-test; $P < 0.001$ age-.1 fish $df=633$; $P < 0.001$ age -.2 fish $df=502$; $P < 0.001$ age -.3 fish $df=131$; and $P=0.018$ age -.4 $df=16$; Figs. 8-15).

There was no significant difference in TL content of female and male fish among age groups (T-test, $p > 0.05$), and no significant relationship between TL content and condition factor in ocean age-.1 and -.2 fish (ANOVA, $P > 0.05$; Tables 6-9, Figs. 16-19).

There was a significant inverse correlation ($r^2=0.94$) between total lipid content and moisture (Fig. 20). The sum of total lipid content and moisture composed approximately 80% of the chum salmon's body weight.

Discussion

The effect of salmon age must be taken into consideration when examining lipid levels in samples collected in offshore waters (Nomura et al. 2000, 2001, 2002, 2004). Our results clearly demonstrate that TL content of chum salmon white muscle increases from summer to fall for ocean age -.1 to -.4 caught in the Bering Sea. Young (ocean age-.1) chum salmon had lower lipid levels than older salmon, but the starved condition observed in winter and spring (winter TL=1.1% and spring TL=1.4% in female and 1.2% in male chum salmon; Nomura et al. 2000, 2001) does not occur in this age-group during summer and fall.

It is unclear why young chum salmon have lower lipid content than older fish during the summer. During their ocean migrations, salmon use energy for movement, metabolism, and growth (Higgs et al. 1995). Low lipid content in young chum salmon indicates either inadequate intake of dietary lipid, utilization of their lipid for growth, or a combination of these

conditions. Azuma et al. (1998) concluded that immediately prior to winter, chum salmon slow their growth rate to maintain energy reserves. We hypothesize that expenditure of energy for growth in ocean age .1 chum salmon takes priority over lipid storage during summer. During the fall the reverse occurs, and lipid storage occurs at the expense of growth, promoting survival through the winter. If our hypothesis is true, then growth to avoid size-selective predation (Ricker 1964, 1976, Weatherly and Gill 1995) may not occur at all times of the year, even when consumption rates are high, as may occur in the fall. Food availability and high prey consumption rates in the late summer and fall, particularly for young fish, may be critical to survival through the following winter.

The close inverse correlation between lipid and moisture content enables us to accurately estimate lipid levels from moisture in salmon muscle tissue. Moisture determinations require less time, lower cost, and can improve our estimates of salmon condition by permitting a greater number of samples to be examined.

We recommend continuing the study of chum salmon TL content by age group with an emphasis on monitoring seasonal changes.

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Table 1. Sampling locations, dates, and numbers of chum salmon sampled in the Bering Sea during summer (June-July), 2002.

Station	Latitude	Longitude	Date	Number of Fish				
				Ocean Age				
				1	2	3	4	Total
26	52°31'N	179°58'W	Jun 29	1	6	1	1	9
24	53°30'N	179°59'W	Jun 30	30	0	0	0	30
18	58°50'N	179°43'E	July 2	0	1	0	0	1
19	57°29'N	179°46'E	July 2	0	0	3	2	5
3	55°58'N	174°44'E	July 4	3	11	9	0	23
4	54°59'N	174°43'E	July 4	3	14	2	0	19
39	52°59'N	175°17'W	July 9	7	0	0	1	8
38	54°09'N	174°19'W	July 9	1	26	6	0	33
52	55°00'N	170°27'W	July 12	1	7	1	1	10
53	54°06'N	170°24'W	July 13	2	4	2	0	8
Total				48	69	26	5	146

Table 2. Sampling locations, dates, and numbers of chum salmon sampled in the Bering Sea during fall (September), 2002

Station	Latitude	Longitude	Date	Number of Fish				
				Ocean Age				Total
				1	2	3	4	
46	53°51'N	172°21'W	Sept. 3	9	36	5	0	50
18	58°30'N	180°00'	Sept. 3	45	1	1	0	47
21	55°50'N	180°00'	Sept. 10	22	18	1	0	41
24	53°33'N	179°42'E	Sept. 11	11	3	0	0	14
26	52°28'N	179°43'E	Sept. 12	9	8	2	0	19
27	51°43'N	179°46'W	Sept. 12	0	14	4	3	21
4	54°59'N	175°02'W	Sept. 15	18	36	5	0	59
3	56°10'N	175°00'E	Sept. 16	30	0	0	0	30
9	56°27'N	177°25'E	Sept. 16	19	0	0	0	19
1	54°10'N	172°30'E	Sept. 18	17	6	0	0	23
Total				180	122	18	4	323

Table 3. Sampling locations, dates, and numbers of chum salmon sampled in the Bering Sea during summer (June-July), 2003

Station	Latitude	Longitude	Date	Number of Fish				
				Ocean Age				Total
				1	2	3	4	
3	53°50'N	174°59'E	June 30	2	2	2	0	6
4	53°05'N	174°44'E	June 30	5	11	3	0	19
8	58°24'N	179°44'E	July 2	0	0	7	1	8
9	57°23'N	179°42'E	July 3	0	2	3	0	5
10	57°23'N	179°42'E	July 3	3	13	3	0	19
11	55°40'N	179°58'W	July 4	8	6	0	0	14
12	55°40'N	179°58'W	July 4	6	6	1	0	13
13	53°25'N	179°42'W	July 5	7	10	0	0	17
14	52°35'N	179°44'E	July 5	24	2	2	0	28
15	51°34'N	179°44'W	July 6	8	7	7	0	22
18	57°03'N	175°20'W	July 11	1	8	0	0	9
19	55°49'N	175°00'W	July 10	5	4	0	0	9
20	54°49'N	175°09'W	July 10	0	4	6	0	10
21	53°49'N	174°59'W	July 9	0	4	1	0	5
30	52°09'N	169°56'W	July 14	0	5	2	0	7
31	50°50'N	169°48'W	July 15	10	4	0	0	14
32	49°52'N	170°14'W	July 15	4	4	0	0	8
35	51°55'N	164°46'W	July 17	3	7	2	0	12
36	51°06'N	165°12'W	July 17	0	3	1	0	4
37	50°03'N	165°14'W	July 16	3	1	0	0	4
Total				89	103	40	1	233

Table 4. Sampling locations, dates, and numbers of chum salmon sampled in the Bering Sea during fall (September), 2003.

Station	Latitude	Longitude	Date	Number of Fish				
				Ocean Age				Total
				1	2	3	4	
1	56°01'N	174°59'E	Sept. 16	39	11	0	0	50
10	56°34'N	179°49'W	Sept. 14	39	10	1	0	50
12	54°31'N	179°59'W	Sept. 13	14	4	2	0	20
13	53°28'N	179°43'W	Sept. 12	26	4	0	0	30
14	52°30'N	179°49'W	Sept. 12	9	14	3	0	26
15	51°23'N	179°56'W	Sept. 11	2	20	2	0	24
18	56°55'N	174°44'W	Sept. 6	14	7	7	1	29
19	55°59'N	175°00'W	Sept. 7	8	11	1	0	20
37	50°10'N	165°05'W	Sept. 1	47	2	1	0	50
Total				198	83	17	1	299

Table 5. Sampling locations, dates, and numbers of chum salmon sampled in the Bering Sea during summer (June-July), 2004.

Station	Latitude	Longitude	Date	Number of Fish				
				Ocean Age				Total
				1	2	3	4	
8	57°08'N	175°12'W	June 29	1	19	0	0	20
10	55°11'N	175°00'W	June 30	0	1	7	1	9
11	54°10'N	175°02'W	July 1	6	13	2	0	21
12	53°11'N	175°00'W	July 1	2	1	0	0	3
13	51°40'N	175°06'W	July 2	38	10	1	0	49
16	52°38'N	179°51'E	July 4	0	3	5	5	13
17	53°22'N	179°49'W	July 4	30	19	2	0	51
20	56°21'N	179°52'W	July 6	0	28	6	0	34
21	57°20'N	179°53'W	July 6	0	13	3	0	16
23	55°05'N	175°14'E	July 7	31	16	3	0	50
25	52°58'N	175°16'E	July 8	10	2	3	0	15
Total				118	125	32	6	281

Table 6. Mean (and standard deviation) fork length (FL), body weight (BW), total lipid (TL) content, and moisture in the white muscle of ocean age -1 immature chum salmon caught in the Bering Sea during summer and fall, 2002-2004. F = female and M = male.

Year Season	Sex	No. of Fish	FL (cm)	BW (g)	TL (%)	Moisture %
2002						
Summer	F	21	337.0 (23.1)	420.5 (79.7)	1.8 (0.6)	77.8(0.7)
	M	27	338.9 (28.7)	420.5 (114.4)	1.8 (0.9)	78.1(0.9)
	Total	48	338.1 (26.1)	420.5 (99.7)	1.8 (0.8)	77.9(0.8)
Fall	F	92	342.0 (26.6)	486.0 (129.7)	7.5 (2.7)	72.9(2.6)
	M	88	340.4 (26.3)	479.8 (121.9)	7.1 (2.7)	73.5(2.4)
	Total	180	341.2 (26.4)	483.0 (125.6)	7.3 (2.7)	73.2(2.6)
2003						
Summer	F	42	338.5 (22.8)	448.4 (97.6)	2.2 (1.8)	76.9(1.6)
	M	47	339.1 (21.2)	458.7 (87.2)	2.0 (1.4)	77.3(1.3)
	Total	89	338.8 (21.9)	453.8 (91.9)	2.1 (1.6)	77.1(1.5)
Fall	F	92	353.7 (21.1)	530.0 (103.6)	5.1 (2.5)	74.3(2.2)
	M	106	358.9 (240.1)	559.6 (106.8)	5.2 (2.3)	74.3(2.0)
	Total	198	356.5 (22.9)	545.8(106.1)	5.2 (2.4)	74.3(2.1)
2004						
Summer	F	58	337.5 (20.2)	451.9 (86.2)	2.3 (0.9)	77.5(0.8)
	M	60	344.1 (18.9)	479.4 (79.1)	2.5 (1.0)	77.7(0.9)
	Total	118	340.9 (19.8)	465.9 (83.4)	2.4 (0.9)	77.6(0.9)

Table 7. Mean (and standard deviation) fork length (FL), body weight (BW), total lipid (TL) content, and moisture in the white muscle of ocean age -.2 immature chum salmon caught in the Bering Sea during summer and fall, 2002-2004. F = female and M = male.

Year	Sex	No. of	FL	BW	TL	Moisture
Season		Fish	(cm)	(g)	(%)	(%)
2002						
Summer	F	31	438.7 (25.3)	1035.7(198.1)	5.4 (2.7)	74.8 (2.5)
	M	38	443.7 (29.8)	1073.0(245.0)	4.7 (2.6)	75.6 (2.5)
	Total	69	441.4 (27.8)	1056.2 (224.4)	5.1 (2.6)	75.2 (2.5)
Fall	F	68	439.9 (30.8)	1071.4(212.6)	11.7 (3.1)	68.9 (3.0)
	M	54	440.2 (32.7)	1057.4(220.7)	11.8 (3.5)	69.0 (3.1)
	Total	122	438.4 (34.3)	1065.2(215.4)	11.7 (3.3)	68.9 (3.0)
2003						
Summer	F	56	434.2 (31.9)	998.6(222.0)	4.2 (2.5)	75.0 (2.4)
	M	47	437.5 (27.1)	1028.6(229.6)	4.7 (3.0)	74.5 (2.9)
	Total	103	435.7 (29.7)	1012.3(224.9)	4.4 (2.7)	74.8 (2.6)
Fall	F	47	438.1 (38.5)	1017.9(235.0)	9.3 (4.2)	70.9 (3.7)
	M	36	453.3 (34.7)	1076.3(239.7)	7.5 (3.1)	72.3 (3.0)
	Total	83	444.7 (37.4)	1043. 2(237.4)	8.5 (3.9)	71.5 (3.5)
2004						
Summer	F	61	428.9 (32.4)	958.0(266.1)	4.3 (1.9)	75.9 (1.8)
	M	64	437.6 (29.8)	1018.5(214.5)	4.2 (2.2)	76.2 (1.9)
	Total	125	433.4 (31.3)	989.0(242.0)	4.2 (2.1)	76.0 (1.9)

Table 8. Mean (and standard deviation) fork length (FL), body weight (BW), total lipid (TL) content, and moisture in the white muscle of ocean age -3 immature chum salmon caught in the Bering Sea during summer and fall, 2002-2004. F = female and M = male.

Year Season	Sex	No. of Fish	FL (cm)	BW (g)	TL (%)	Moisture (%)
2002						
Summer	F	13	510.1 (39.0)	1594.3 (373.2)	6.4 (2.6)	73.9 (2.8)
	M	11	515.2 (38.6)	1703.1 (445.8)	7.6 (3.3)	72.8 (3.0)
	Total	24	510.6 (38.0)	1644.2(402.7)6.9	(2.9) 73.4	(2.9)
Fall	F	10	520.5 (44.0)	1777.5 (468.2)	12.2 (2.9)	68.2 (2.2)
	Male	8	505.5 (50.6)	1563.5 (594.3)	11.2 (5.3)	68.7 (5.3)
	Total	18	513.8 (46.3)	1682.4 (522.9)	11.7 (4.0)	68.4 (3.8)
2003						
Summer	F	20	493.4 (46.9)	1541.6 (407.8)	8.0 (3.5)	71.9 (3.1)
	M	20	513.4 (34.9)	1744.0 (344.8)	7.3 (3.3)	72.3 (2.8)
	Total	40	490.7 (81.4)	1642.8 (386.6)	7.7 (3.4)	72.1 (2.9)
Fall	F	12	511.4 (34.1)	1610.9 (341.2)	10.8 (3.7)	69.5 (3.1)
	M	5	474.2 (50.7)	1305.2 (375.0)	9.0 (3.9)	71.3 (3.4)
	Total	17	500.5 (41.8)	1521.0 (368.6)	10.3 (3.8)	70.0 (3.2)
2004						
Summer	F	18	508.0 (37.6)	1614.4 (379.8)	6.5 (2.6)	73.8 (2.3)
	M	14	513.7 (28.1)	1679.6 (297.3)	6.3 (3.4)	73.8 (3.5)
	Total	32	510.5 (33.4)	1642.9 (342.4)	6.4 (2.9)	73.8 (2.8)

Table 9. Mean (and standard deviation) fork length (FL), body weight (BW), total lipid (TL) content, and moisture in the white muscle of ocean age -.4 immature chum salmon caught in the Bering Sea during summer and fall, 2002-2004. F = female and M = male.

Year	Sex	No. of	FL	BW	TL	Moisture
Season		Fish	(cm)	(g)	(%)	(%)
2002						
Summer	F	3	573.3 (48.1)	2505.7 (826.8)	10.8 (4.5)	69.6 (4.7)
	M	2	567.0 (15.6)	2210.5 (212.8)	6.2 (1.7)	74.1 (0.9)
	Total	5	570.8 (35.0)	2387.0 (615.9)	9.0 (4.1)	71.4 (4.2)
Fall	F	3	582.7 (29.3)	2445.0 (483.5)	15.0 (2.1)	66.1 (2.0)
	Total	3	582.7 (29.3)	2445. 2(483.5)	15.0 (2.1)	66.1 (2.0)
2003						
Summer	M	1	646.0	3056.0	7.3	71.4
	Total	1	646.0	3056.0	7.3	71.4
Fall	M	1	556.0	2191.0	16.6	66.4
	Total	1	556.0	2191. 0	16.6	66.4
2004						
Summer	F	4	598.3 (60.8)	2664.0 (900.8)	6.2 (1.3)	73.0 (1.8)
	M	2	597.5 (38.9)	2822.5 (822.4)	4.3 (1.2)	74.4 (0.6)
	Total	6	598.0 (50.2)	2716.8 (793.0)	5.6 (1.5)	73.5 (1.6)

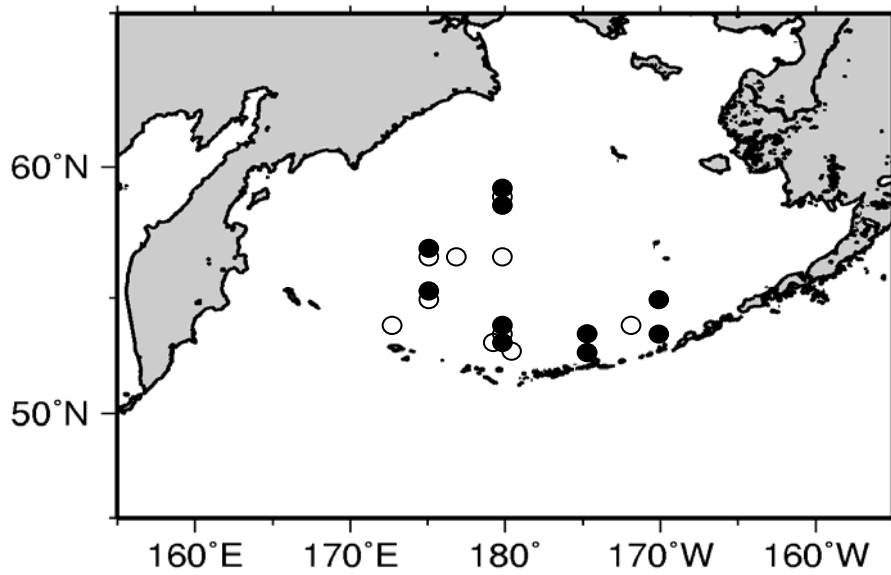


Fig. 1. Station locations where immature chum salmon were caught during the summer (June-July, open circle) and fall (September, solid circle) 2002 cruise of the R/V Kaiyou-maru.

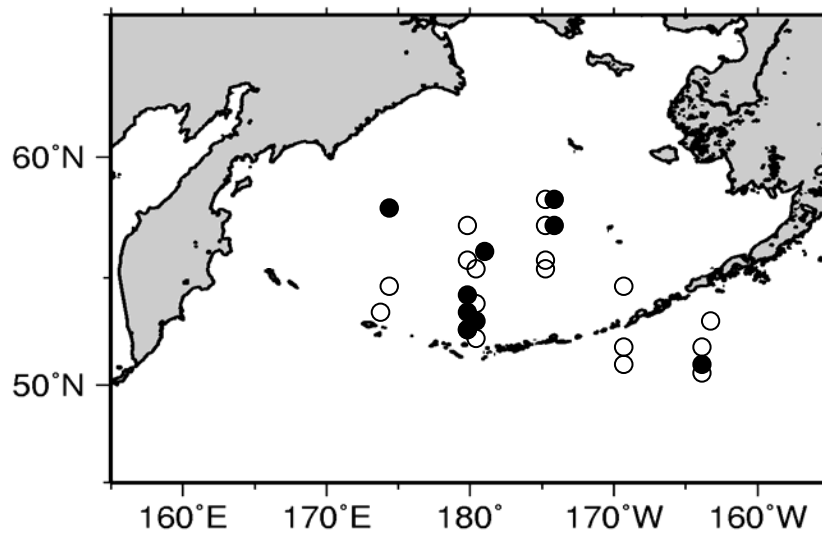


Fig. 2. Station locations where immature chum salmon were caught during the summer (June-July, open circle) and fall (September, solid circle) 2003 cruise of the R/V Kaiyou-maru.

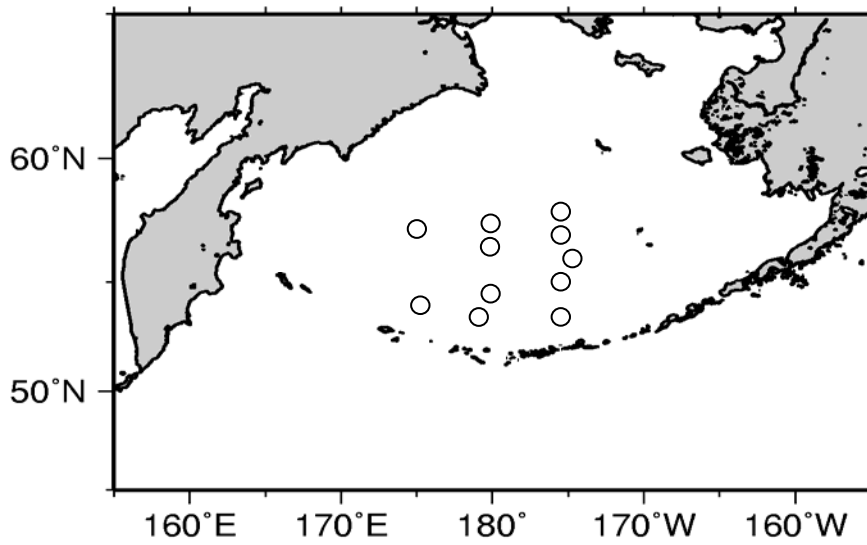


Fig. 3. Station locations where immature chum salmon were caught during the summer (June-July) 2004 cruise of the R/V Kaiyo-maru.

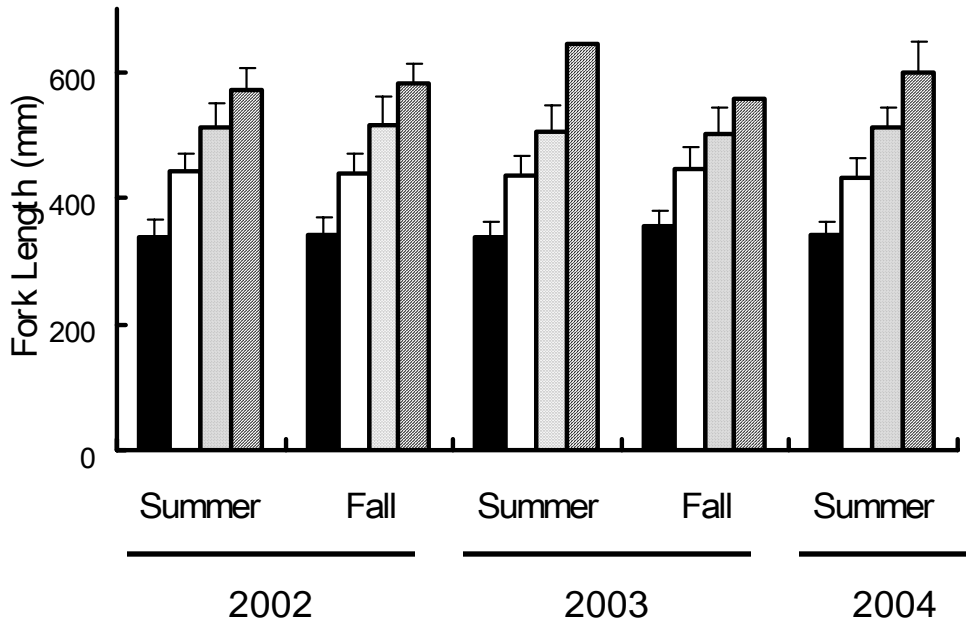


Fig. 4. Fork length of immature chum salmon caught in the Bering Sea in summer (June-July) and fall (September) 2002-2004 by ocean age. Bar height is the mean, and line length is one standard deviation. Solid bar=ocean age -1, open bar=ocean age -2, stippled bar=ocean age -3, and slanted line bar=ocean age -4.

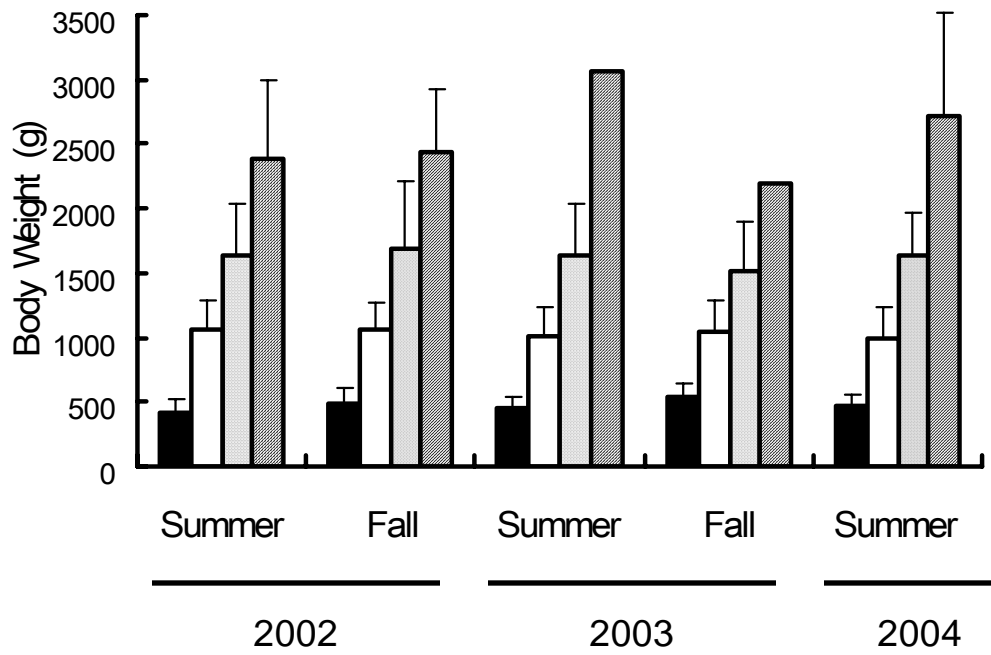


Fig. 5. Body weight of immature chum salmon caught in the Bering Sea in summer (June-July) and fall (September) 2002-2004 by ocean age. Bar height is the mean, and line length is one standard deviation. Solid bar=ocean age -1, open bar=ocean age -2, stippled bar=ocean age -3, and slanted line bar=ocean age -4.

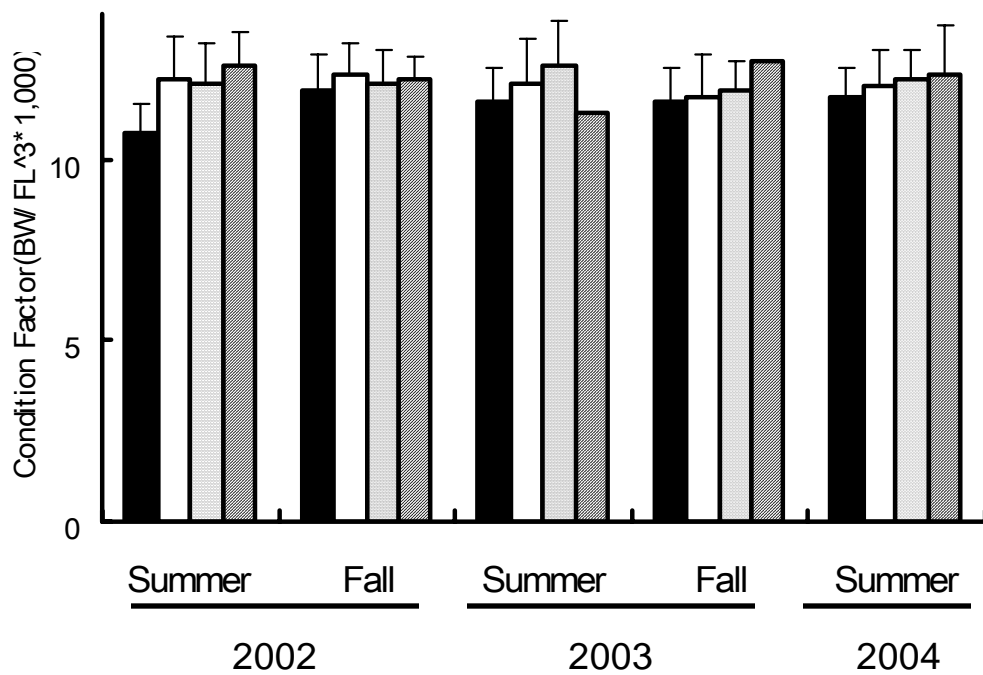


Fig. 6. Condition factor of immature chum salmon caught in the Bering Sea in summer (June-July) and fall (September) 2002-2004 by ocean age. Bar height is the mean, and line length is one standard deviation. Solid bar=ocean age -.1, open bar=ocean age -.2, stippled bar=ocean age -.3, and slanted line bar=ocean age -.4.

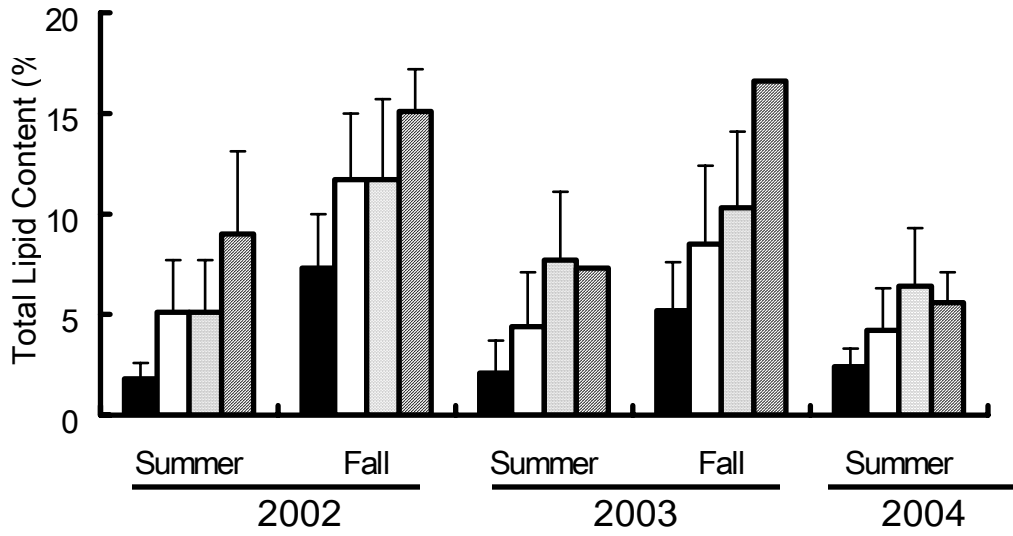


Fig. 7. Total lipid content in white muscle of immature chum salmon caught in the Bering Sea in summer (June-July) and fall (September) 2002-2004 by ocean age. Bar height is the mean, and line length is one standard deviation. Solid bar=ocean age -.1, open bar=ocean age -.2, stippled bar=ocean age -.3, and slanted line bar=ocean age -.4.

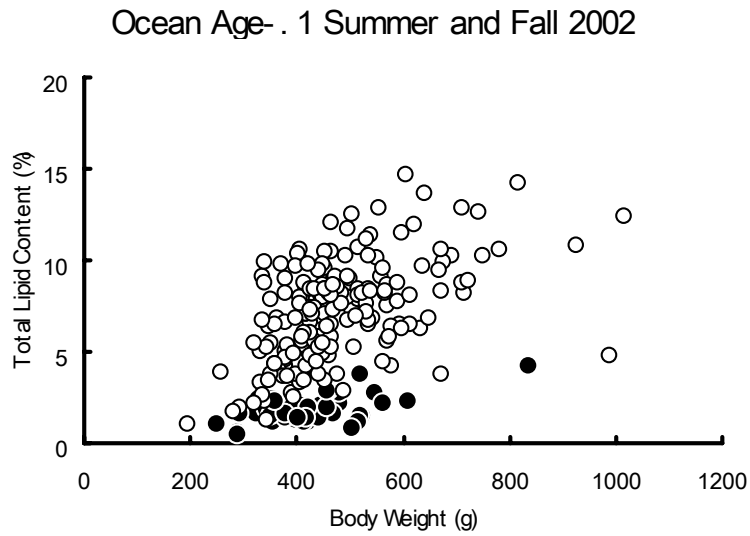


Fig. 8. Relationship between body weight and total lipid content in the muscle of ocean age -.1 immature chum salmon caught in the Bering Sea in June - July (solid

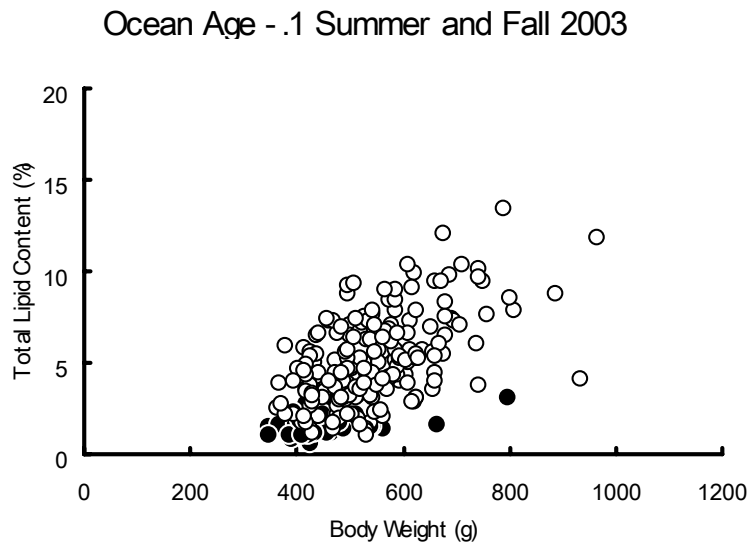


Fig. 9. Relationship between body weight and total lipid content in the muscle of ocean age -.1 immature chum salmon caught in the Bering Sea in June - July (solid

Ocean Age- .1 Summer 2004

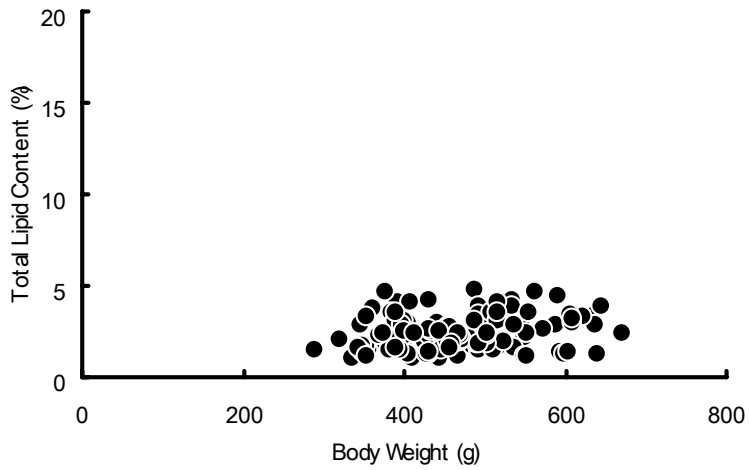


Fig. 10. Relationship between body weight and total lipid content in the muscle of ocean age -.1 immature chum salmon caught in the Bering Sea in June - July 2004.

Ocean Age - .2 Summer and Fall 2002

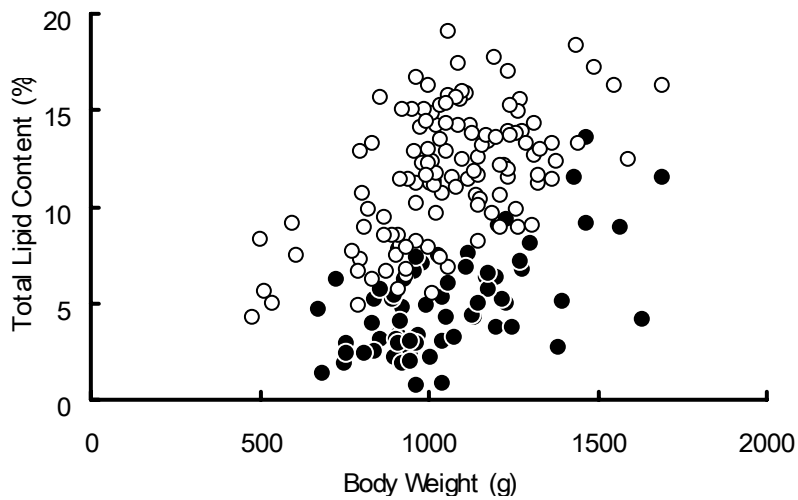


Fig. 11. Relationship between body weight and total lipid content in the muscle of ocean age -.2 immature chum salmon caught in the Bering Sea in June - July(solid circles) and September (open circles) 2002.

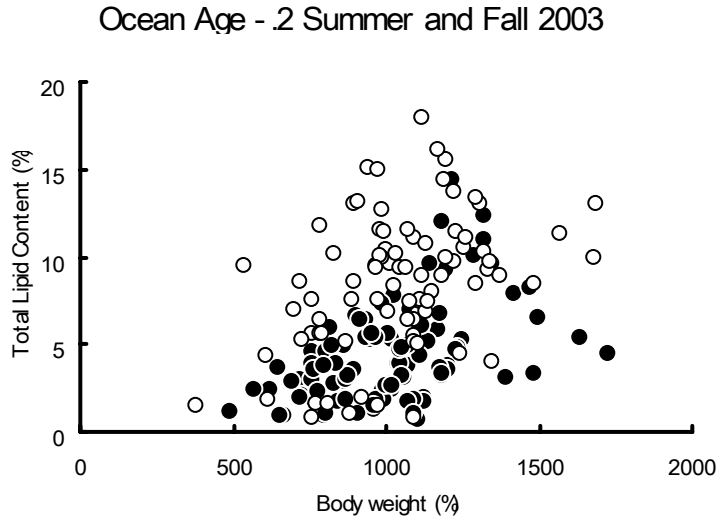


Fig. 12. Relationship between body weight and total lipid content in the muscle of ocean age -.2 immature chum salmon caught in the Bering Sea in June - July(solid circles) and September (open circles) 2003.

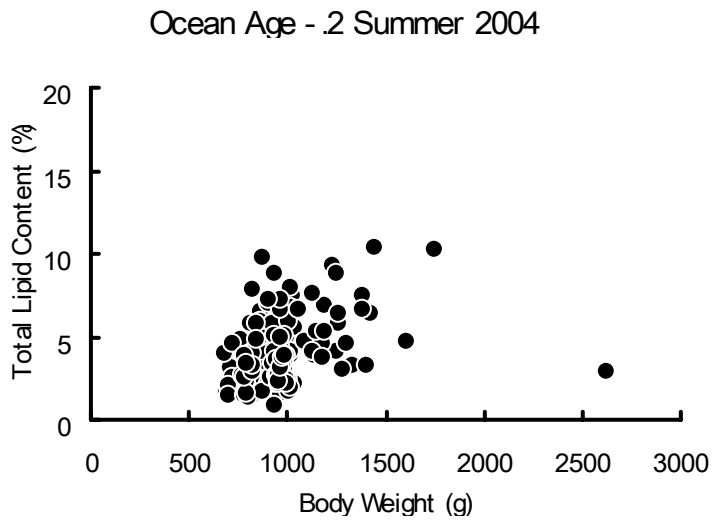


Fig. 13. Relationship between body weight and total lipid content in the muscle of ocean age -.2 immature chum salmon caught in the Bering Sea in June - July 2004.

Ocean Age - .3 Summer and Fall 2002-2004

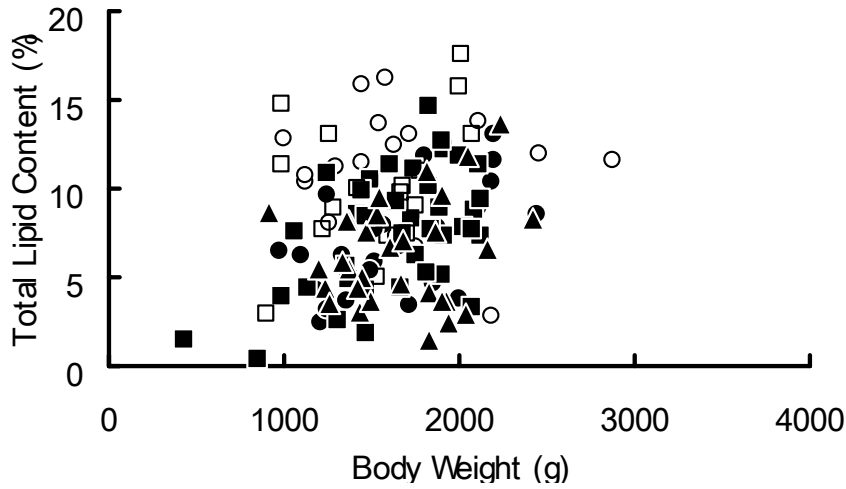


Fig. 14. Relationship between body weight and total lipid content in the muscle of ocean age -.3 immature chum salmon caught in the Bering Sea in June - July and September 2002-2004. Solid circle=summer 2002, open circle=fall 2002, solid square=summer 2003, open square=fall 2003, and solid triangle=summer 2004.

Ocean Age - .4 Summer and Fall 2002-2004

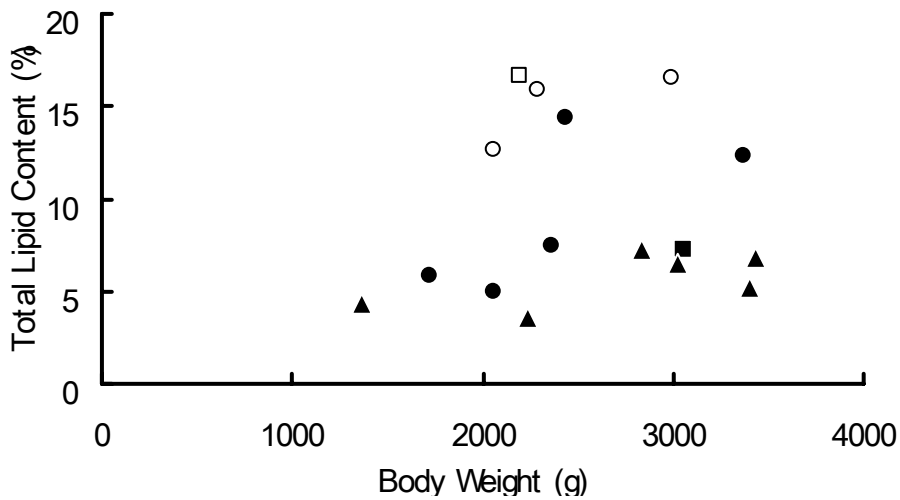


Fig. 15. Relationship between body weight and total lipid content in the muscle of ocean age -.4 immature chum salmon caught in the Bering Sea in June - July and September 2002-2004. Solid circle=summer 2002, open circle=fall 2002, solid square=summer 2003, open square=fall 2003, and solid triangle=summer 2004.

Ocean Age -.1 Summer 2002- 2004.

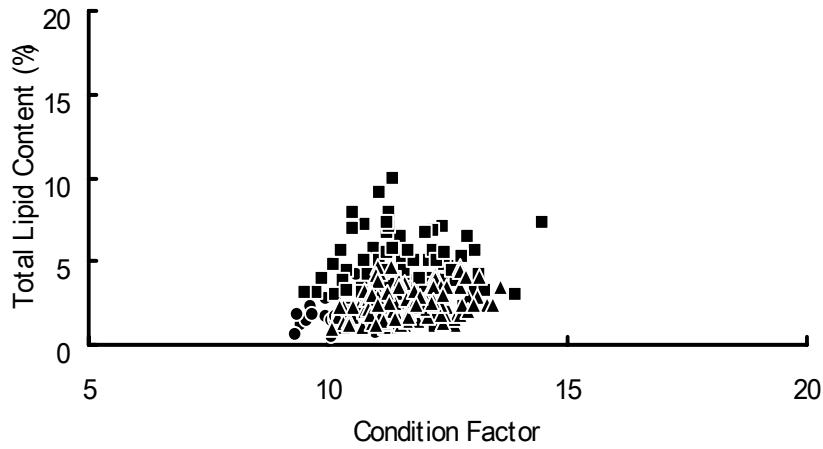


Fig.16. Relationship between condition factor and total lipid content in the muscle of ocean age -.1 immature chum salmon caught in the Bering Sea in June - July 2002-2004. Solid circle=2002, solid square=2003, and solid triangle=2004

Ocean Age -.1 Fall 2002- 2003

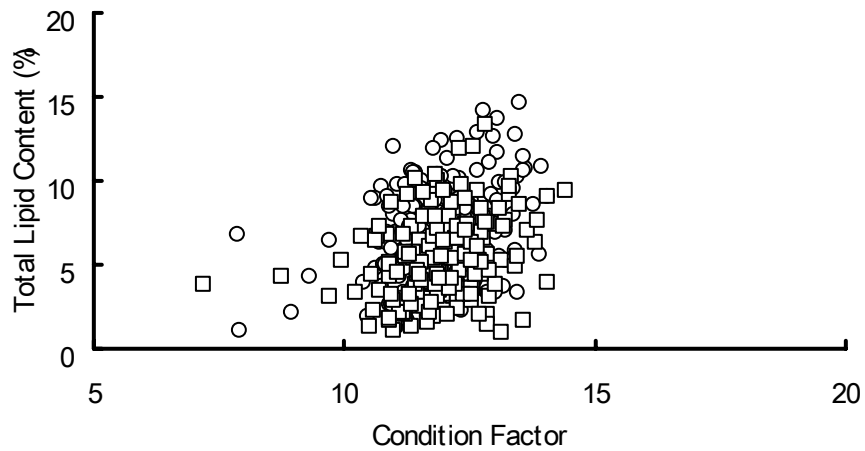


Fig.17. Relationship between condition factor and total lipid content in the muscle of ocean age -.1 immature chum salmon caught in the Bering Sea in September 2002-2003. Open circle=2002 and open square=2003.

Ocean Age - .2 Summer 2002- 2004

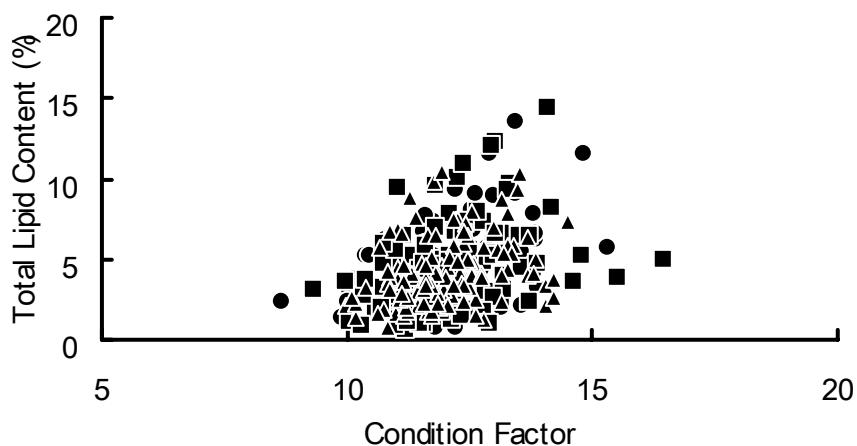


Fig.18. Relationship between condition factor and total lipid content in the muscle of ocean age - .2 immature chum salmon caught in the Bering Sea in June-July 2002 - 2004. Solid circle=2002, solid square=2003 and solid triangle=2004.

Ocean Age - .2 Fall 2002- 2003

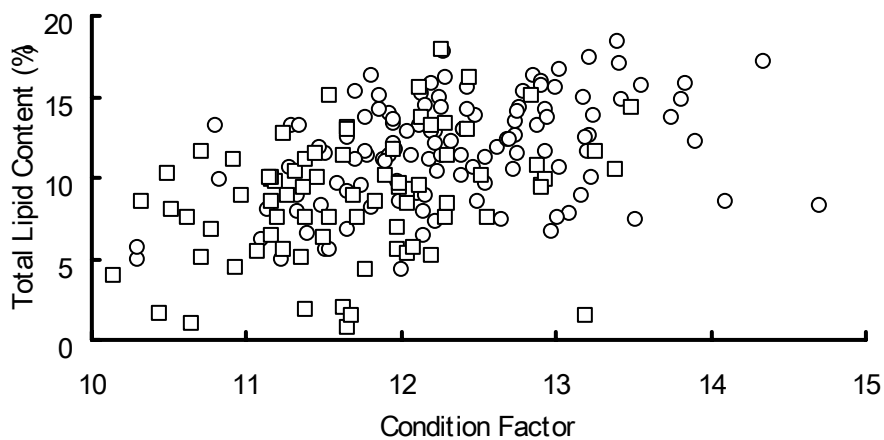


Fig.19. Relationship between condition factor and total lipid content in the muscle of ocean age - .2 immature chum salmon caught in the Bering Sea in September 2002 - 2003. Open circle=2002 and open square=2003.

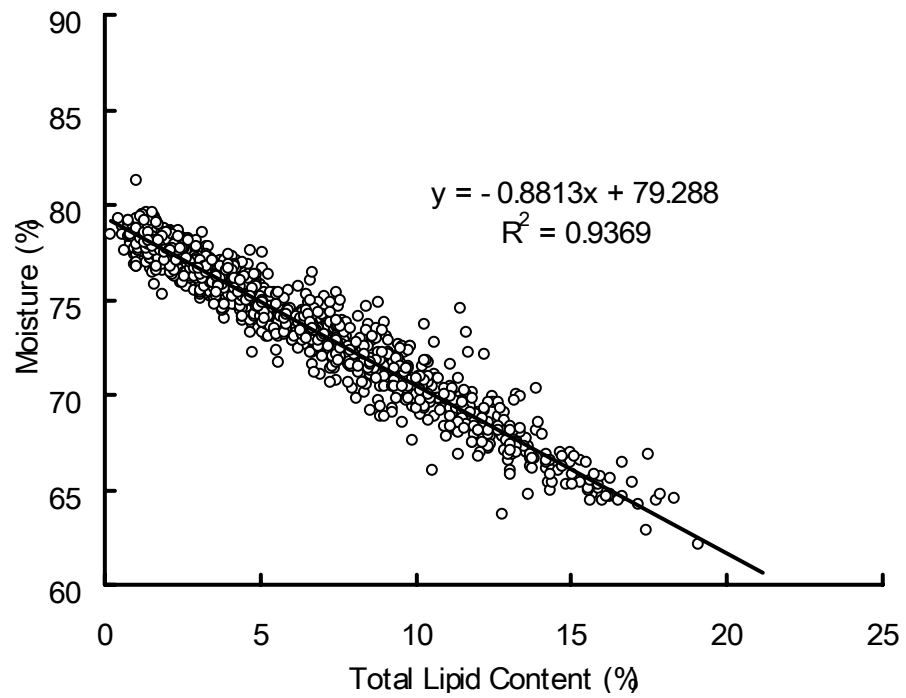


Fig. 20. Relationship between total lipid content and moisture content in white muscle of chum salmon caught in the Bering Sea in June-July and September 2002-2004 (n=1,282).