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Seasonal Changes in the Total Lipid Content of Immature Chum Salmon in the Bering Sea and North Pacific Ocean 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 and North Pacific Ocean 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 the summer was significantly lower than fish of the same age caught in the fall. The mean TL content of ocean age-.1 fish caught during the summer of 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 during the fall of 2002 and 2003 was 7.3% (n=180) and 5.2% (n=198), respectively. Low lipid contents of young (ocean age-.1) chum salmon caught during summer suggests this is a period when young fish grow at the expense of lipid storage. High lipid content of fish caught in the fall suggests this is a period when lipid is stored at the expense of growth, which likely promotes survival of the fish through the winter. Total lipid content was significantly and inversely correlated with moisture content, which together with lipid content totaled about 80% of the white muscle. We recommend continued monitoring seasonal and age-specific lipid content of chum salmon during their oceanic migrations as an indicator of their growth potential and body condition.

Key words: total lipid content, immature chum salmon, Bering Sea, North Pacific Ocean

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; Novotony and Beeman 1990; Higgs et al. 1995; Berg et al. 1998). 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 caught 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).

Winter and spring collections of high-seas caught chum and pink salmon where characterized by low neutral lipid levels and high proportions of docosahexaenoic acid (DHA), which demonstrated these fish were starving (Nomura et al. 2000, 2001).

As fish starve, they deplete their reserves of 18:1 and 16:0 fatty acids more than DHA (Kiessling and Kiessling 1993), therefore, the proportion of DHA increases with continued starvation (Nomura et al. 2000). Lipid content determinations of salmon during their high-seas migrations is an estimate of their energy storage condition and growth potential (Nomura et al. 2000, 2001). It has generally been assumed that salmonids consume prey heavily during

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summer and fall and, therefore, lipid content would be higher during these periods than during winter and spring. This study updates an earlier report (Nomura et al. 2004) by summarizing the age-specific lipid contents of high-seas caught chum salmon on a larger spatial and temporal scale.

Materials and Methods

Chum salmon were caught by surface trawl during the summer (June-July) and fall (September) 2002-2004 cruises of the R/V *Kaiyo-maru* in the Bering Sea and North Pacific Ocean in 2002 through 2004 (Fig. 1; Tables 1-5). Fork length (FL, cm) and body weight (BW, g) of some chum salmon were measured during the survey. After measuring, these fish were frozen as round samples at -30℃. Other round samples of chum salmon were frozen (-30℃) prior to measurement. In this case, fork length and body weight were measured at the laboratory after thawing. 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 ap-

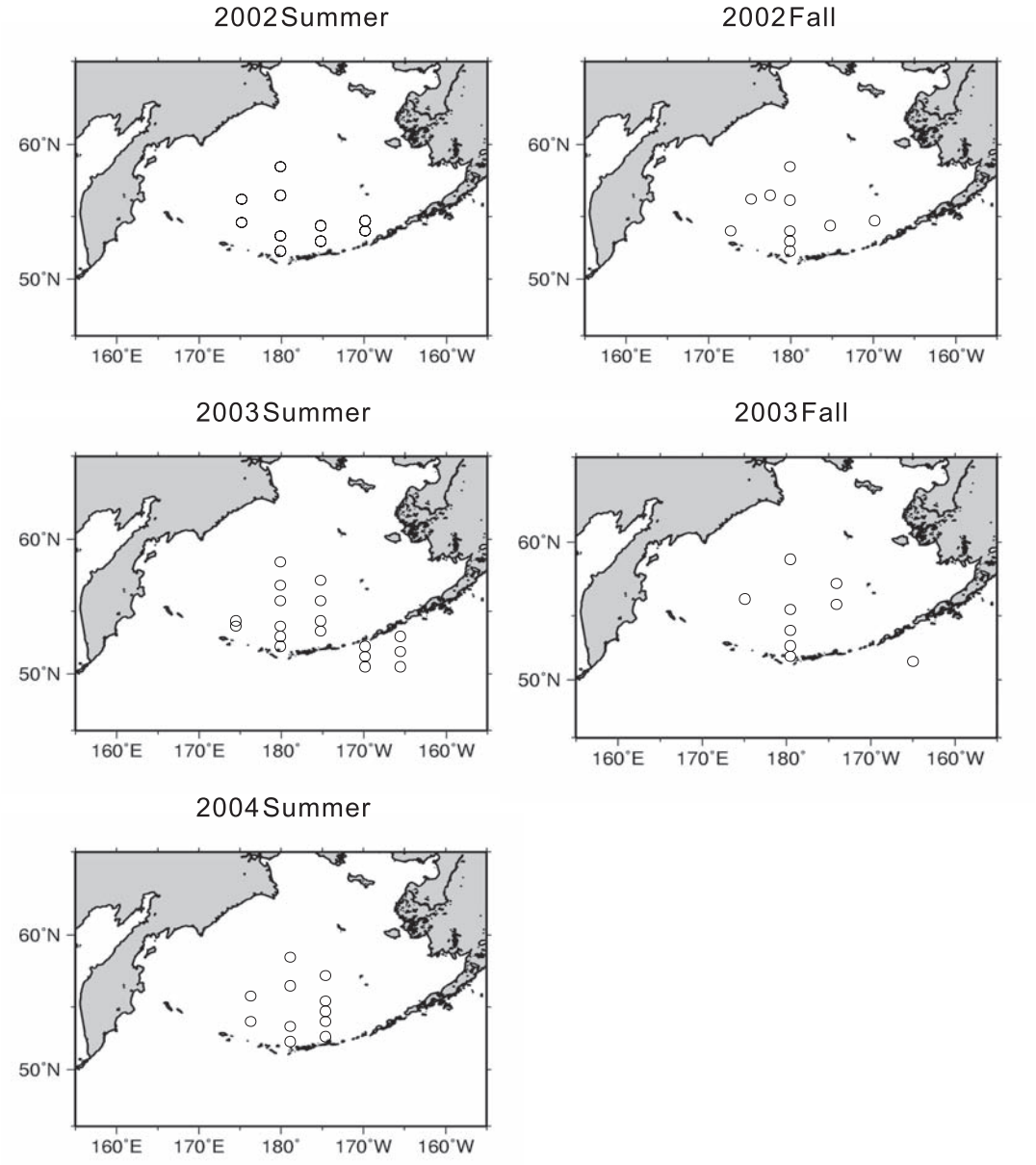


Fig. 1. Station locations where immature chum salmon were caught during the summer and fall cruise of the R/V *Kaiyo-maru*, 2002-2004.

Table 1. Sampling location, date, and age of chum salmon analyzed for lipid content from caught in the Bering Sea during summer (June-July), 2002.

Station	Latitude	Longitude	Date	Number of fish				
				Ocean age				
				1	2	3	4	Total
1	52˚31′N	179˚58′W	June 29	1	6	1	1	9
2	53˚30′N	179˚59′W	June 30	30	0	0	0	30
3	58˚28′N	179˚43′E	July 2	0	1	0	0	1
4	57˚29′N	179˚46′E	July 2	0	0	3	2	5
5	55˚58′N	174˚44′E	July 4	3	11	9	0	23
6	54˚59′N	174˚43′E	July 4	3	14	2	0	19
7	52˚59′N	175˚17′W	July 9	7	0	0	1	8
8	54˚09′N	174˚59′W	July 9	1	26	6	0	33
9	55˚00′N	170˚27′W	July 13	1	7	1	1	10
10	54˚06′N	170˚24′W	July 13	2	4	2	0	8
Total				48	69	24	5	146

Table 2. Sampling location, date, and age of chum salmon analyzed for lipid content from caught in the Bering Sea during fall (September), 2002.

Station	Latitude	Longitude	Date	Number of fish				
				Ocean age				
				1	2	3	4	Total
1	53˚51'N	172˚21′W	Sept. 3	9	36	5	0	50
2	58˚30'N	180˚00′	Sept. 8	45	1	1	0	47
3	55˚20'N	180˚00′	Sept. 10	22	18	1	0	41
4	53˚33'N	179˚42′E	Sept. 11	11	3	0	0	14
5	52˚28'N	179˚43′E	Sept. 12	9	8	2	0	19
6	51˚41'N	179˚46′W	Sept. 12	0	14	4	3	21
7	54˚59'N	175˚02′W	Sept. 15	18	36	5	0	59
8	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
10	54˚10'N	172˚30′E	Sept. 18	17	6	0	0	23
Total				180	122	18	3	323

Table 3. Sampling location, date, and age of chum salmon analyzed for lipid content from caught in the Bering Sea and North Pacific Ocean during summer (June-July), 2003.

Station	Latitude	Longitude	Date	Number of fish				
				Ocean age				
				1	2	3	4	Total
1	53˚50'N	174˚59′E	June 30	2	2	2	0	6
2	53˚05'N	174˚44′E	June 30	5	11	3	0	19
3	58˚24'N	179˚44′E	July 2	0	0	7	1	8
4	57˚23'N	179˚42′E	July 3	3	15	6	0	24
5	55˚40'N	179˚58′W	July 4	14	12	1	0	27
6	53˚25'N	179˚42′W	July 5	7	10	0	0	17
7	52˚35'N	179˚44′E	July 5	24	2	2	0	28
8	51˚34'N	179˚44′W	July 6	8	7	7	0	22
9	53˚49'N	174˚59′W	July 9	0	4	1	0	5
10	55˚49'N	175˚00′W	July 10	5	4	0	0	9
11	54˚49'N	175˚09′W	July 10	0	4	6	0	10
12	57˚03'N	175˚20′W	July 11	1	8	0	0	9
13	52˚09'N	169˚56′W	July 14	0	5	2	0	7
14	50˚50'N	169˚48′W	July 15	10	4	0	0	14
15	49˚52'N	170˚14′W	July 15	4	4	0	0	8
16	50˚03'N	165˚14′W	July 16	3	1	0	0	4
17	51˚55'N	164˚46′W	July 17	3	7	2	0	12
18	51˚06'N	165˚12′W	July 17	0	3	1	0	4
Total				89	103	40	1	233

Table 4. Sampling location, date, and age of chum salmon analyzed for lipid content from caught in the Bering Sea and North Pacific Ocean during fall (September), 2003.

Station	Latitude	Longitude	Date	Number of fish				
				Ocean age				
				1	2	3	4	Total
1	50˚10′N	165˚05′W	Sept. 1	47	2	1	0	50
2	56˚55′N	174˚44′W	Sept. 6	14	7	7	1	29
3	55˚59′N	175˚00′W	Sept. 7	8	11	1	0	20
4	51˚23′N	179˚56′W	Sept. 11	2	20	2	0	24
5	52˚30′N	179˚49′W	Sept. 12	9	14	3	0	26
6	53˚28′N	179˚43′W	Sept. 12	26	4	0	0	30
7	54˚31′N	179˚59′W	Sept. 13	14	4	2	0	20
8	56˚34′N	179˚49′W	Sept. 14	39	10	1	0	50
9	56˚01′N	174˚59′E	Sept. 16	39	11	0	0	50
Total				198	83	17	1	299

Table 5. Sampling location, date, and age of chum salmon analyzed for lipid content from caught in the Bering Sea during summer (June-July), 2004.

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

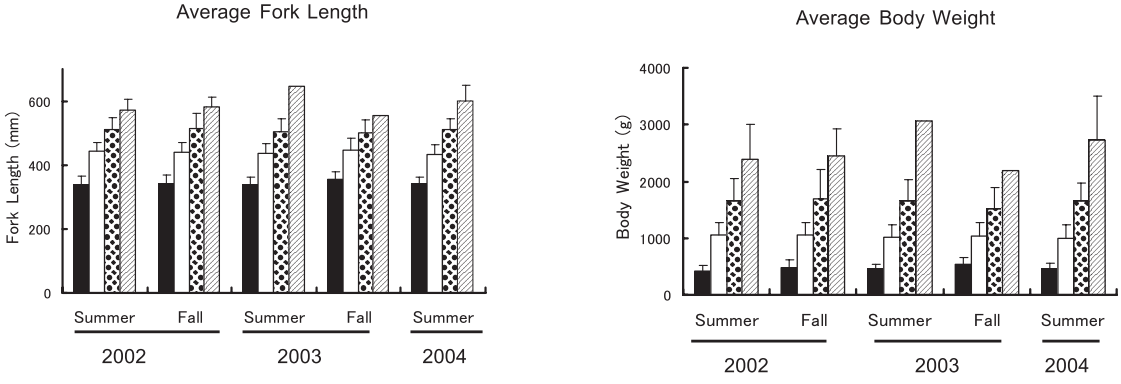


Fig. 2. Fork length and body weight of immature chum salmon caught in the Bering Sea and North Pacific Ocean in summer (June-July) and fall (September) 2002-2004 stratified by ocean age. Bar height is the mean, and line length is one standard deviation. Solid bar, ocean age -.1; open bar, ocean age -.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

proximate 10 g sample of the homogenized white muscle was collected, weighed, and kept frozen at -30˚C until further analysis.

The frozen white muscle homogenate was thwed and a small portion was dried for 24 hours at 110˚C for determination of moisture content. The remaining sample was homogenized with 60 ml of methanol and 120 ml of chloroform for lipid extraction

Table 6. Mean (standard deviation) of 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 and North Pacific Ocean during summer and fall, 2002-2004. F, female; M, male.

Year Season	Sex	No. of fish	FL (mm)	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 (24.1)	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)

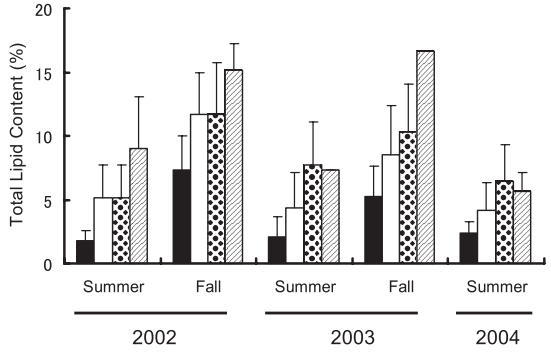


Fig. 3. Total lipid content in white muscle of immature chum salmon caught in the Bering Sea and North Pacific Ocean in summer (June-July) and fall (September) 2002-2004 by ocean age. Bar height is the mean, and line length is one standard deviation. Solid bar, ocean age -.1; open bar, ocean age -. 2;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

(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 extracted lipid was measured gravimetrically.

Results

A total of 660 chum salmon muscle samples were analyzed from immature fish caught during the summer and 622 samples were analyzed from immature fish caught during the fall. Average of fork length (FL), body weight (BW) and condition factor ($BW/FL^3X1,000$) of immature chum salmon used for this study was shown in Fig. 2 and Tables 6-9.

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. 3). Average TL content in the white muscle of immature ocean age -.1 chum salmon increased 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. 3). The TL in ocean age -.2 chum salmon increased to 11.7% (n=122) and 8.5% (n=83) in fall 2002 and 2003. Increases in average TL observed in each age group during fall was significantly higher than the value observed in fish of the same age collected during summer (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. 4-6). In contrast, no significant differences in TL content of female amd male fish were observed among age groups (T-test, $p > 0.05$), or between TL content and condition factor in ocean age-.1 and -.2 fish (ANOVA, $P>0.05$; Tables 6-9, Figs. 7-8).

Comparison of moisture and TL content showed a significant inverse correlation (r^2=0.94; Fig. 9). Data indicated total of lipid and moisture content in white muscle accounted for approximately 80% of the white muscle.

Discussion

Our results clearly demonstrated that TL content of chum salmon increased from summer to fall for immature ocean age -.1 to -.4 caught in the Bering

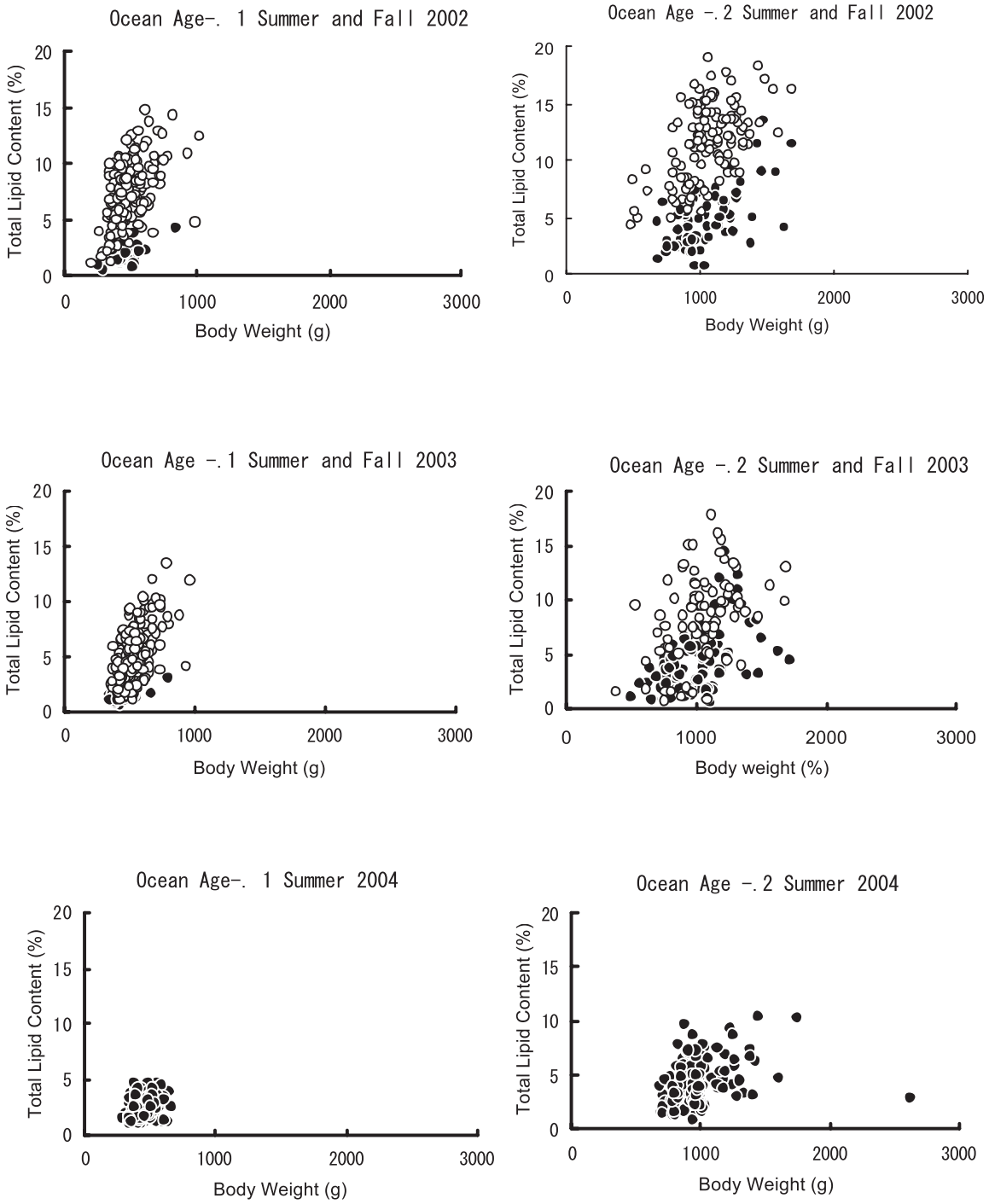


Fig. 4. Relationship between body weight and total lipid content in the muscle of ocean age -.1 and age -.2 immature chum salmon caught in the Bering Sea and North Pacific Ocean in June - July（solid circles）2002-2004 and September (open circles) 2002-2003.

Table 7. Mean (standard deviation) of 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 and North Pacific Ocean during summer and fall, 2002-2004. F, female; M, male.

Year Season	Sex	No. of fish	FL (mm)	BW (g)	TL (%)	Moisture (%)
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	440.1 (31.3)	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)

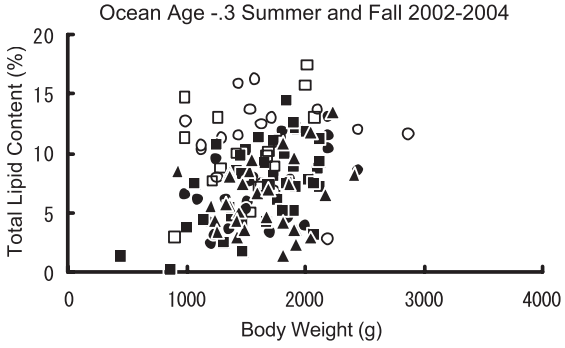


Fig. 5. Relationship between body weight and total lipid content in the muscle of ocean age -.3 immature chum salmon caught in the Bering Sea and North Pacific Ocean in June - July and September 2002-2004. Solid circle, summer 2002; open circle, fall 2002; solid square, summer 2003; open square, fall 2003; solid triangle, summer 2004.

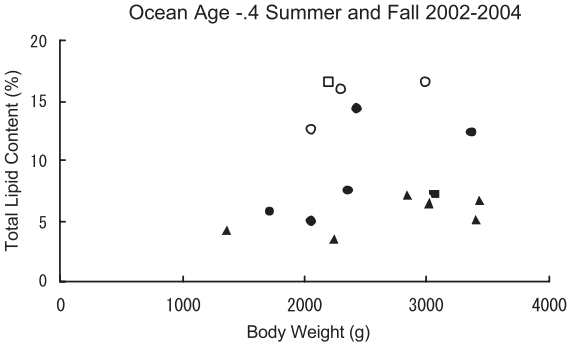
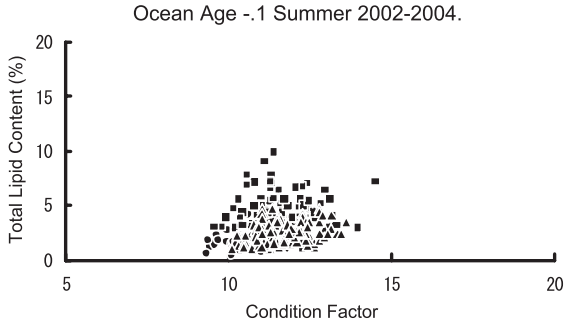


Fig. 6. Relationship between body weight and total lipid content in the muscle of ocean age -.4 immature chum salmon caught in the Bering Sea and North Pacific Ocean in June - July and September 2002-2004. Solid circle, summer 2002; open circle, fall 2002; solid square, summer 2003; open square, fall 2003; solid triangle, summer 2004.



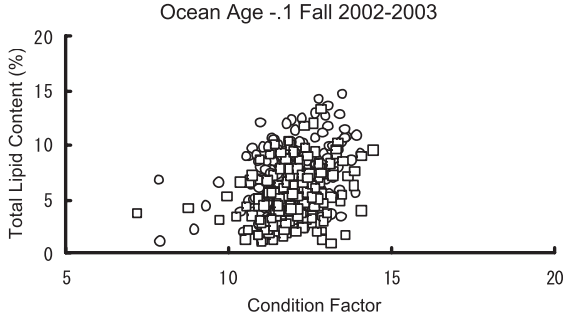


Fig. 7. Relationship between condition factor and total lipid content in the muscle of ocean age -.1 immature chum salmon caught in the Bering Sea and North Pacific Ocean in June - July 2002 (solid circle), 2003 (solid square) and 2004 (solid triangle).

Sea and North Pacific Ocean. 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

Table 8. Mean (standard deviation) of 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 and North Pacific Ocean during summer and fall, 2002-2004. F, female; M, male.

Year Season	Sex	No. of fish	FL (mm)	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	503.4 (41.4)	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 (standard deviation) of 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 and North Pacific Ocean during summer and fall, 2002-2004. F, female; M, male.

Year Season	Sex	No. of fish	FL (mm)	BW (g)	TL (%)	Moisture (%)
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)	2445.0 (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)

female and 1.2% in male chum salmon; Nomura et al. 2000, 2001) does not occur in this age-group during summer and fall. As demonstrated by previous studies (Nomura et al. 2000, 2001, 2002, 2004) and reinforced by this study, the effect of salmon age must be considered when examining lipid levels in samples collected in offshore waters.

During their ocean migrations, salmon use energy for movement, metabolism, and growth (Higgs et al. 1995; Crossin et al. 2003). Lower lipid content in young chum salmon as compared to old fish 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 during the summer expenditure of energy for growth in ocean age .1 chum salmon takes priority over lipid storage. During fall the reverse occurs, and lipid storage occurs at the expense of

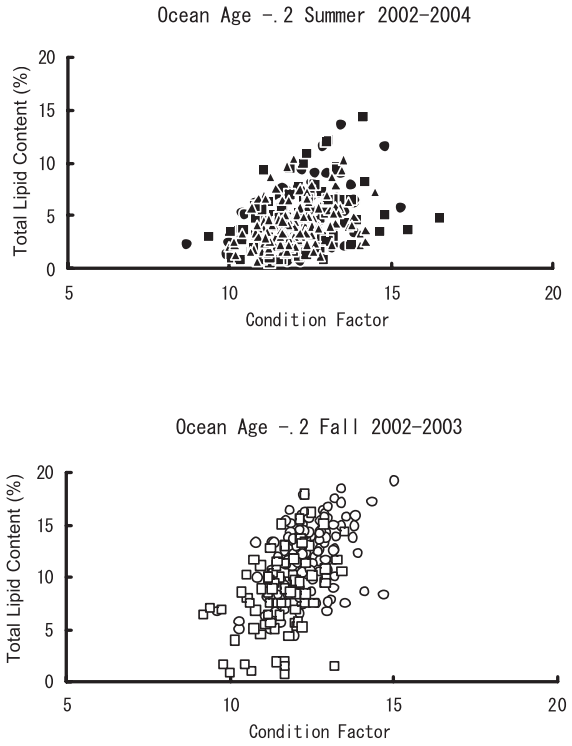


Fig. 8. Relationship between condition factor and total lipid content in the muscle of ocean age -.1 immature chum salmon caught in the Bering Sea and North Pacific Ocean in September 2002 (open circle) and 2003 (open square).

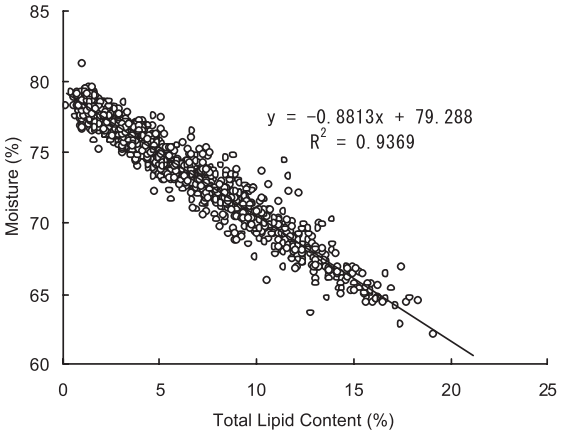


Fig. 9. Relationship between condition factor and total lipid content in the muscle of ocean age -.2 immature chum salmon caught in the Bering Sea and North Pacific Ocean in June-July 2002 (solid circle), 2003 (solid square) and 2004 (solid triangle).

growth, which promotes survival of the fish through the winter. If this hypothesis is true, then growth to avoid size-selective predation (Ricker 1964, 1976; Weatherly and Gill 1995) may not occur throughout the year, particularly in the fall when consumption rates may be high. Food availability and high prey consumption rates in the late summer and fall may be critical for attaining sufficient lipid strage for salmon, particularly young fish, to survive winter.

The close inverse relationship between lipid and moisture content enables accurately estimation of lipid levels from moisture in salmon muscle tissue (Crossin and Hinch 2005). Moisture determination requires less time, lower cost, and can improve estimates of salmon condition by permitting a greater number of samples to be examined.

We recommend continued monitoring of seasonal and age-specific lipid content of chum salmon during their ocean migration as an indicator of their growth potential and body condition.

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2002年から2004年の夏期と秋期にベーリング海および北太平洋で採集された未成熟サケの筋肉内総脂質含量の季節変化

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本報告は2002年から2004年の夏期（6月-7月）と秋期（9月）にベーリング海および北太平洋で採集された未成熟サケの筋肉内総脂質含量と水分含量に関する報告である．合計1282尾の未成熟サケの筋肉からクロロホルムとメタノールを用いて抽出し重量法により総脂質量を測定した．夏期に採取した海洋生活1年の若齢魚では総脂質含量は秋期に採集された個体より有意に低い値を示した．夏期に採取した海洋生活1年の個体の筋肉内平均総脂質含量はそれぞれ2002年で1.8％（供試尾数48尾），2003年で2.1％（供試尾数89尾），2004年で2.4％（供試尾数58尾）であった．秋期に採取した海洋生活1年の個体の筋肉内平均総脂質含量はそれぞれ2002年で7.3％（供試尾数180尾），2003年で5.2％（供試尾数198尾）であった．海洋生活１年魚の夏期に採集された個体の筋肉内総脂質含量が低いことは，この時期が脂質貯蔵より成長を優先する時期であることを示唆している．秋期の高い総脂質含量はこの時期は冬期の生残率を向上するため成長より脂質の蓄積を優先している時期を示唆している．総脂質含量と水分含量には負の相関があり，総脂質含量と水分含量の総和は体重の約80%であった．