NPAFC
Doc. 795
Rev.

Total Lipid Content in the White Muscle of Immature Chum Salmon Caught in the Bering Sea in Summer and Fall 2002

by

Tetsuichi Nomura[1], Shigehiko Urawa[1], Tomonori Azumaya[2],

Masa-aki Fukuwaka[2], and Nancy Davis[3]

[1] *National Salmon Resources Center, 2-2 Nakanoshima, Toyohira-ku, Sapporo 062-0922, Japan.*
[2] *Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Katsurakoi 116, Kushiro 085-0802, Japan*
[3] *School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA 98195-5020, USA*

Submitted to the

NORTH PACIFIC ANADROMOUS FISH COMMISSION

By

JAPAN

October 2004

This paper may be cited in the following manner:
Nomura, T., S. Urawa, T. Azumaya, M. Fukuwaka, and N. Davis. 2004. Total lipid content in the white muscle of immature chum salmon caught in the Bering Sea in summer and fall 2002. (NPAFC Doc. 795) 19 p. National Salmon Resources Center, Toyohira-ku, Sapporo 062-0922, Japan.

Total Lipid Content in the White Muscle of Immature Chum Salmon Caught in the Bering Sea in Summer and Fall 2002

Tetsuichi Nomura[1], Shigehiko Urawa[1], Tomonori Azumaya[2],

Masa-aki Fukuwaka[2], and Nancy Davis[3]

[1] *National Salmon Resources Center, 2-2 Nakanoshima, Toyohira-ku, Sapporo 062-0922, Japan.*
[2] *Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Katsurakoi 116, Kushiro 085-0802, Japan*
[3] *School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA 98195-5020, USA*

Abstract

The assumption is generally made that salmon in the ocean consume prey heavily in the summer and fall and, therefore, the lipid level in the muscle of these fish would be high during both these seasons of the year. This study is the first to report the total lipid (TL) content in the white muscle of chum salmon by age group from fish caught in the international waters of the Bering Sea in summer (June and July) and fall (September). The TL was extracted from the white muscle of 491 immature chum salmon using chloroform and methanol and the lipid was measured by weight after evaporation of the solvents. Young chum salmon (age 0.1) caught during the summer contained significantly lower TL (t-test; df=226, p=<0.001) than fish of the same age caught during the fall. In summer the mean TL in the muscle of age 0.1 female (n=21) and male (n=27) chum salmon was low (1.8% for both sexes). However, in fall the mean TL contained in age 0.1 female (n=92) and male (n=88) fish increased substantially (7.5% and 7.1%, respectively). A previous study hypothesized that young (age 0.1) chum salmon would have a relatively low TL content in summer because fish are growing quickly at the expense of lipid storage at this time of year. It was further hypothesized that in the fall, growth rate would decrease and lipid storage increase to promote the fish's survival through the winter when food rations may be severely limited. Results of this study provide evidence of a seasonal shift in lipid storage during summer and fall for young chum salmon in the ocean. Continued monitoring of immature chum salmon for lipid levels is recommended for surveys conducted throughout the year.

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). Although there have been a large number of lipid studies on cultured fish and artificial food (Wilson 1991), little is known about high-seas salmonid lipid content. Examination of triacylglycerol and protein content, and nucleic acid ratios have been used to characterize Pacific salmon growth (Azuma et al. 1998). In the winter and spring, chum and pink salmon in the North Pacific Ocean are in a starving condition, as demonstrated by the low levels of neutral lipid and the high proportion of docosahexaenoic acid (DHA) in the muscle from salmon collected at this time of year (Nomura et al. 2000, 2001).

Previous studies have demonstrated that lipid content in salmon during their high-seas migrations can be used to estimate the fish's energy storage condition and potential for growth (Nomura et al. 2000, 2001, 2002). The assumption is generally made that salmon in the ocean consume prey heavily in the summer and fall, and, therefore, the lipid content in the muscle would be higher during these periods of the year. This study is the first to report the total lipid (TL) content in the white muscle of chum salmon by age group from fish caught in the international waters of the Bering Sea in summer (June and July) and fall (September).

Materials and Methods

Immature chum salmon were caught by surface trawl during the summer (June and July), and fall (September) 2002 salmon research cruise of the R/V *Kaiyo maru* in the Bering Sea (Fig. 1). For a few chum salmon, biological data were collected by researchers on board the ship immediately after the fish was caught. These data included measurement of fork length (FL, cm), body weight (BW, g), gonad weight, and determination of sex. In addition, a scale sample was collected for age determination. Following this examination, the head was removed and the rest of the fish was frozen at -30°C for further processing at the National Salmon Resources Ctr., Sapporo (NASREC). The remaining portion of chum salmon were not processed on board the ship. In this case, chum salmon were kept as round samples and frozen at -30°C until biological processing could be completed at NASREC, where biological data and a scale sample were collected. From this point the procedure, all samples were treated in an identical manner. A fillet (one-half of the body musculature) was carefully removed from the thawed chum salmon, and the skin and red muscle carefully removed from the fillet, leaving only white muscle. The fillet was homogenized in a food processor and a sample of approximately 10 g was collected and weighed. The 10-g samples were placed in the freezer for later lipid extraction. After thawing, the homogenized muscle was combined with 60 ml of methanol and 120 ml of chloroform according to the method of Folch et al. (1957). The homogenate was filtered through lipid-free paper into a glass vessel, and the crude extract and water were mixed in a separator funnel in the volumetric proportion of 8:4:3 (chloroform:methanol:water). The lower phase was collected and the solvent was evaporated with a rotary evaporator. In the final step, the total lipid present was determined by weight.

Results

A total of 152 immature chum salmon caught in June and July was analyzed for TL content. Most of these samples were obtained from age 0.2 fish (45%; Table 1). More samples were collected in September, when a total of 339 fish were analyzed for TL content. Most of these chum salmon samples were age 0.1 fish (53%; Table 2).

In June and July, average TL content in age 0.1 chum salmon was the lowest value observed in this study (1.8%; Table 3). The TL content of age 0.2 and 0.3 fish was similar to each other (5.1% and 6.7%; Tables 4, 5). The highest TL content in the summer samples was obtained from age 0.4 immature chum salmon (9.0%;Table 6 and Fig. 2).

Average TL content of immature chum salmon was substantially higher in samples collected in September (Fig. 2). The TL contained in age 0.1 fish was 7.3% (Table 7), and increased to 11.7% and 12.0% in age 0.2, and 0.3 chum salmon (Tables 8, 9). The highest TL content, 14.8%, was observed in age 0.4 fish (Table 10). In September the average TL content observed in each age of fish was significantly higher than the value observed in fish of the same age collected in June and July (T-test; df=226, $P<0.001$ age.0.1; df=189, $P<0.001$ age .0.2; df=28, $P<0.001$ age 0.3; and df= 7, $P=0.018$ age 0.4 chum salmon; Figs. 3-6).

The TL content of male and female chum salmon of the same age was similar, and there was no significant difference in TL between sexes of immature chum salmon ages 0.1 to 0.4 (T-test, $p > 0.05$). Similarly, there was no significant difference between TL content and condition factor ($BW/(FL)^3 x1000$) of age 0.1 and 0.2 chum salmon (ANOVA, $P>0.05$; Figs. 7 and 8).

Discussion

The effect of fish age must be taken into consideration when examining salmon lipid levels in samples collected in offshore waters (Nomura et al. 2000, 2001, 2002). Our results clearly demonstrate that the TL content in the white muscle of immature chum salmon increases from summer to fall in the Bering Sea. Although young chum salmon (age 0.1) in summer had lower lipid levels than older salmon, the starved condition observed in winter and spring by Nomura et al. 2000, 2001 (winter TL=1.1% and spring TL=1.4%, females and 1.2%, males) does not appear to carry-over into the summer and fall.

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. Nomura et al. (2002) hypothesized that young (age 0.1) chum salmon might have a low TL content in summer because this is a period when small, young chum salmon grow quickly using their energy for growth rather than storage. Without having access to samples collected in the fall, they further hypothesized that during fall, growth rates would decrease, and lipid storage would increase to promote the fish's survival through

the winter when food rations might be severely limited. Results of this study support this hypothesis by demonstrating there is a seasonal shift in the fall towards increasing lipid content in immature chum salmon in the ocean. In addition, Azuma et al. (1998) suggested that immediately prior to the onset of winter, juvenile chum salmon slow their growth rate to maintain energy reserves based on biochemical analysis of RNA:DNA and protein:DNA ratios. These results suggest that growth to avoid size-selective predation (Ricker 1964, 1976, Weatherly and Gill 1995) may not occur during fall, even when food consumption rates maybe high.

In conclusion, high consumption rates and, therefore, the availability of food in late summer and fall may be critical for winter survival of young chum salmon. We recommend monitoring TL content of individual age groups of immature chum salmon throughout the year and assessing seasonal shifts in energy allocation by salmon during their ocean phase of life.

Acknowledgements

We appreciate the efforts of the captain, crew, and scientific staff of the R/V *Kaiyo maru* in obtaining samples and collecting biological data. Support for the U.S. author was provided by the Auke Bay Laboratory, National Marine Fisheries Service (NOAA contract no. 50ABNF10002).

References

Azuma, T., T. Yada, Y. Ueno, and M. Iwata. 1998. Biochemical approach to assessing growth characteristics in salmonids. N. Pac. Anadr. Fish Comm. Bull., 1: 103-111.

Folch, A.J., M. Lees, and G.H. Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem., 226: 497-509.

Nomura, T., M. Fukuwaka, N. Davis, and M. Kawana. 2002. Total lipid contents in the white muscle, liver, and gonad of chum salmon caught in the Bering Sea and the Gulf of Alaska in summer 2001. NPAFC Doc. 615. Nat. Salmon Res. Ctr. Sapporo. 12 p.

Nomura, T., K.W. Myers, C.M. Kondzela, J.M. Murphy, H. Honma, and H.R. Carlson. 2001. Variation in lipid content in the muscle of chum and pink salmon in the Gulf of Alaska in May 1999. Bull. Nat. Salmon Res. Ctr., 4: 13-18.

Nomura, T., S. Urawa, and Y. Ueno. 2000. Variations in muscle lipid content of high-seas chum and pink salmon in winter. N. Pac. Anadr. Fish Comm. Bull., 2: 347-352.

Novotony, J.F., and J.W. Beeman. 1990. Use of a fish health condition profile in assessing the health and condition of juvenile chinook salmon. Prog. Fish-Cult., 52: 162-170.

Ricker, W.E. 1964. Ocean growth and mortality of pink and chum salmon. J. Fish. Res. Board Can., 21: 905-931.

Ricker, W.E. 1976. Review of the rate of growth and mortality of Pacific salmon in salt water, and noncatch mortality caused by fishing. J. Fish. Res. Board Can. 33: 1483-1524.

Watanabe, T. 1982. Lipid nutrition in fish. Comp. Biochem. Physiol. B, 73: 3-75.

Weatherley, A.H. and H.G. Gill. 1987. Protein, lipid and caloric contents. pp. 101-146. In The biology of fish growth. Academic Press. London. 443 p.

Weatherley, A.H. and H.G. Gill. 1995. Growth. pp. 103-158. In C. Groot, L. Margolis and W.C. Clarke. (eds.) Physiological ecology of Pacific salmon. UBC Press, Vancouver. 510 p.

Wilson, R.P. 1991. Handbook of nutrient requirement of finfish. CRC Press, London. 196 p.

Table 1. Survey station number, location, date, and number of chum salmon sampled in the Bering Sea for total lipid content in June and July 2002. Ocean age X indicates the age of the fish could not be determined from scales.

Station	Latitude	Longitude	Date	Number of Fish					
				Ocean Age					
				1	2	3	4	X	Total
26	52º50´N	180º00´	June 29	1	6	1	1	2	11
24	53º50´N	180º00´	June 30	30	0	0	0	0	30
18	58º50´N	180º00´	July 2	0	1	1	0	0	2
19	57º50´N	180º00´	July 2	0	0	3	2	0	5
3	56º00´N	175º00´E	July 4	3	11	9	0	1	24
4	55º00´N	175º00´E	July 4	3	14	2	0	0	19
39	53º00´N	175º00´W	July 9	7	0	0	1	1	9
38	54º00´N	175º00´W	July 9	1	26	6	0	0	33
52	55º00´N	170º00´W	July 12	1	7	2	1	0	11
53	54º00´N	170º00´W	July 13	2	4	2	0	0	8
Total				48	69	26	5	4	152

Table 2. Survey station number, location, date, and number of chum salmon sampled in the Bering Sea for total lipid content in September 2002. Ocean age X indicates the age of the fish could not be determined from scales.

Station	Latitude	Longitude	Date	Number of Fish					
				Ocean Age					
				1	2	3	4	X	Total
46	54º00´N	172º50´W	Sept. 3	9	36	5	0	0	50
18	58º50´N	180º00´	Sept. 3	45	1	1	0	3	50
21	55º50´N	180º00´	Sept. 10	22	18	1	0	8	49
24	53º50´N	180º00´	Sept. 11	11	3	0	0	1	15
26	52º28´N	179º43´E	Sept. 12	9	8	2	1	2	22
27	51º43´N	179º46´W	Sept. 12	0	14	4	3	0	21
4	54º59´N	175º01´E	Sept. 15	18	36	5	0	1	60
3	56º10´N	175º00´E	Sept. 16	30	0	0	0	0	30
9	56º37´N	177º17´E	Sept. 16	19	0	0	0	0	19
1	54º10´N	172º30´E	Sept. 18	17	6	0	0	0	23
Total				180	122	18	4	15	339

Table 3. Mean fork length (FL), body weight (BW), and total lipid (TL) content in white muscle of age 0.1 immature chum salmon, grouped by survey station and sex. Chum salmon were caught in the Bering Sea in June and July 2002. Standard deviations are enclosed in parentheses.

Station	Sex	Number of Fish	FL (cm)	BW (g)	TL (%)
26	Female	1	33.3	349	1.2
24	Female	12	32.9 (2.4)	398 (73.3)	1.8 (0.5)
	Male	18	33.5 (1.9)	404 (57.1)	1.6 (0.6)
3	Female	1	35.2	479	2.2
	Male	2	41.4 (2.2)	723 (160.5)	3.2 (1.4)
4	Female	1	37.2	563	2.1
	Male	2	34.9 (0.6)	488 (42.4)	2.9 (1.3)
39	Female	3	34.6 (1.6)	416 (58.0)	1.9 (0.7)
	Male	4	31.3 (0.9)	300 (17.7)	1.0 (0.6)
38	Female	1	36.0	549	2.7
52	Female	1	35.8	504	0.8
53	Female	1	31.8	360	2.3
	Male	1	35.0	459	2.9
All	Female	21	33.7 (2.3)	421 (79.7)	1.8 (0.6)
	Male	27	33.9 (2.9)	421 (114.4)	1.8 (0.9)
	Total	48	33.8 (2.6)	421 (99.7)	1.8 (0.8)

Table 4. Mean fork length (FL), body weight (BW), and total lipid (TL) content in white muscle of age 0.2 immature chum salmon, grouped by survey station and sex. Chum salmon were caught in the Bering Sea in June and July 2002. Standard deviations are enclosed in parentheses.

Station	Sex	Number of Fish	FL (cm)	BW (g)	TL (%)
26	Female	3	44.1 (2.8)	881 (180.1)	3.3 (2.0)
	Male	3	45.5 (4.2)	917 (313.6)	5.1 (2.4)
18	Female	1	47.8	1,469	13.6
3	Female	4	45.1 (2.6)	1109 (268.0)	5.5 (1.1)
	Male	7	46.8 (3.3)	1222 (320.5)	6.2 (3.2)
4	Female	5	42.0 (2.7)	1,011 (177.4)	5.5 (3.2)
	Male	9	43.3 (3.2)	1,089 (289.4)	4.1 (3.1)
38	Female	12	44.8 (2.0)	1,085 (159.2)	5.8 (2.5)
	Male	14	43.9 (2.5)	1,025 (187.9)	4.7 (2.2)
52	Female	3	42.1 (1.5)	904 (59.9)	4.4 (1.6)
	Male	4	43.9 (0.6)	1,009 (174.3)	4.0 (1.9)
53	Female	3	42.0 (2.7)	922 (201.9)	4.4 (1.7)
	Male	1	42.6	1,075	3.3
All	Female	31	43.9 (2.5)	1,036 (198.1)	5.4 (2.7)
	Male	38	44.4 (3.0)	1,068 (249.9)	4.7 (2.6)
	Total	69	44.1 (2.8)	1,053 (227.1)	5.1 (2.6)

Table 5. Mean fork length (FL), body weight (BW), and total lipid (TL) content in white muscle of age 0.3 immature chum salmon, grouped by survey station and sex. Chum salmon were caught in the Bering Sea in June and July 2002. Standard deviations are enclosed in parentheses.

Station	Sex	Number of Fish	FL (cm)	BW (g)	TL (%)
26	Female	1	48.2	1,246	9.6
18	Male	1	65.4	3,584	2.8
19	Female	1	55.0	1,882	7.8
	Male	2	55.6 (0.7)	2,195 (4.2)	12.3 (1.1)
3	Female	5	50.9 (2.5)	1,597 (232.0)	5.1 (2.0)
	Male	4	50.6 (4.4)	1,678 (471.6)	6.1 (2.1)
4	Male	2	48.9 (5.5)	1,691 (707.1)	7.3 (4.4)
38	Female	5	50.4 (5.6)	1,616 (553.0)	7.8 (2.5)
	Male	1	50.6	1,354	3.6
52	Female	1	53.4	1,567	8.0
	Male	1	56.6	2,388	6.0
53	Female	1	48.0	1,211	2.4
	Male	1	52.3	1,649	6.7
All	Female	13	51.0 (3.9)	1,594 (373.2)	6.4 (2.6)
	Male	13	52.6 (5.4)	1,900 (676.3)	7.1 (3.3)
	Total	26	51.8 (4.7)	1,747 (557.4)	6.7 (2.9)

Table 6. Mean fork length (FL), body weight (BW), and total lipid (TL) content in white muscle of age 0.4 immature chum salmon, grouped by survey station and sex. Chum salmon were caught in the Bering Sea in June and July 2002. Standard deviations are enclosed in parentheses.

Station	Sex	Number of Fish	FL (cm)	BW (g)	TL (%)
26	Male	1	57.8	2,361	7.4
19	Female	1	62.0	3,366	12.3
	Male	1	55.6	2,066	5.0
39	Female	1	52.4	1,717	5.8
52	Female	1	57.6	2,433	14.3
All	Female	3	57.3 (4.8)	2,505 (826.9)	10.8 (4.5)
	Male	2	56.7 (1.6)	2,211 (212.8)	6.2 (1.7)
	Total	5	57.1 (3.5)	2,387 (615.8)	9.0 (4.1)

Table 7. Mean fork length (FL), body weight (BW), and total lipid (TL) content in white muscle of age 0.1 immature chum salmon, grouped by survey station and sex. Chum salmon were caught in the Bering Sea in September 2002. Standard deviations are enclosed in parentheses.

Station	Sex	Number of Fish	FL (cm)	BW (g)	TL (%)
46	Female	5	35.5 (2.8)	579 (150.1)	8.7 (4.7)
	Male	4	37.6 (1.7)	697 (72.8)	12.1 (2.1)
18	Female	25	33.6 (2.2)	451 (97.0)	7.8 (2.5)
	Male	20	33.3 (1.9)	434 (62.3)	8.3 (1.6)
21	Female	14	35.6 (3.3)	439 (161.9)	6.9 (2.3)
	Male	8	35.4 (2.3)	521 (112.2)	6.2 (2.6)
24	Female	4	35.0 (3.1)	542 (134.5)	9.8 (2.0)
	Male	7	32.8 (2.2)	446 (106.9)	7.7 (2.5)
26	Female	5	34.7 (0.8)	463 (66.2)	9.7 (2.2)
	Male	4	36.3 (1.0)	559 (46.2)	8.0 (3.1)
4	Female	8	36.5 (3.3)	613 (185.5)	8.6 (3.2)
	Male	10	35.4 (2.7)	545 (115.8)	7.0 (2.5)
3	Female	16	32.8 (1.3)	415 (72.0)	5.9 (6.4)
	Male	14	33.2 (1.6)	427 (66.3)	6.4 (2.6)
9	Female	8	32.1 (2.0)	405 (52.5)	6.0 (2.2)
	Male	11	31.9 (1.9)	377 (71.3)	4.5 (2.5)
1	Female	7	35.1 (2.2)	535 (97.7)	7.7 (2.1)
	Male	10	34.3 (1.8)	517 (84.8)	6.7 (1.8)
All	Female	92	34.2 (2.7)	486 (129.7)	7.5 (2.7)
	Male	88	33.9 (2.4)	474 (108.9)	7.1 (2.7)
	Total	180	34.1 (2.5)	480 (119.8)	7.3 (2.7)

Table 8. Mean fork length (FL), body weight (BW), and total lipid (TL) content in white muscle of age 0.2 immature chum salmon, grouped by survey station and sex. Chum salmon were caught in the Bering Sea in September 2002. Standard deviations are enclosed in parentheses.

Station	Sex	Number of Fish	FL (cm)	BW (g)	TL (%)
46	Female	20	45.1 (2.4)	1,142 (165.0)	12.4 (3.6)
	Male	16	45.2 (1.9)	1148 (136.4)	12.5 (2.5)
18	Female	1	42.8	956	12.9
21	Female	6	43.2 (3.0)	983 (183.0)	10.6 (2.5)
	Male	12	44.4 (2.2)	1,059 (172.8)	10.2 (3.1)
24	Female	2	42.1 (0.6)	938 (4.9)	9.1 (3.3)
	Male	1	45.5	1,098	12.4
26	Female	3	44.7 (2.6)	1,103 (238.4)	10.3 (2.1)
	Male	5	46.9 (2.6)	1,225 (163.2)	14.3 (2.2)
27	Female	10	44.3 (2.8)	1,094 (220.3)	11.7 (4.1)
	Male	4	44.4 (1.1)	1,107 (121.6)	14.1 (2.8)
4	Female	24	43.7 (2.5)	1,053 (195.7)	11.7 (2.5)
	Male	12	42.0 (4.1)	999 (233.9)	12.7 (3.7)
1	Female	2	36.0 (5.0)	685 (260.9)	8.4 (0.1)
	Male	4	37.0 (5.1)	718 (221.8)	5.8 (1.5)
All	Female	68	43.9 (2.9)	1,066 (200.4)	11.6 (3.1)
	Male	54	43.8 (3.7)	1,066 (207.8)	11.8 (3.5)
	Total	122	43.9 (3.3)	1,066 (202.9)	11.7 (3.3)

Table 9. Mean fork length (FL), body weight (BW), and total lipid (TL) content in white muscle of age 0.3 immature chum salmon, grouped by survey station and sex. Chum salmon were caught in the Bering Sea in September 2002. Standard deviations are enclosed in parentheses.

Station	Sex	Number of Fish	FL (cm)	BW (g)	TL (%)
46	Female	3	54.3 (3.6)	2,016 (519.3)	13.7 (2.1)
	Male	2	51.8 (0.1)	1,511 (99.0)	7.9 (7.2)
18	Female	1	45.5	1,126	12.0
21	Female	1	49.2	1,448	7.4
26	Female	1	51.8	1,631	16.3
	Male	1	59.6	2,875	21.2
27	Female	3	55.5 (3.4)	2,084 (382.1)	13.3 (2.6)
	Male	1	53.8	1,722	12.8
4	Female	2	47.7 (1.8)	1,397 (200.1)	10.9 (4.0)
	Male	3	47.3 (3.6)	1,254 (341.7)	9.3 (2.2)
All	Female	10	52.6 (4.0)	1,817 (438.3)	12.7 (3.2)
	Male	8	50.6 (5.1)	1,564 (594.3)	11.2 (5.3)
	Total	18	51.7 (4.5)	1,705 (513.8)	12.0 (4.2)

Table 10. Mean fork length (FL), body weight (BW), and total lipid (TL) content in white muscle of age 0.4 immature chum salmon, grouped by survey station and sex. Chum salmon were caught in the Bering Sea in September 2002. Standard deviations are enclosed in parentheses.

Station	Sex	Number of Fish	FL (cm)	BW (g)	TL (%)
26	Female	1	59.0	2,486	13.9
27	Female	3	58.3 (2.9)	2,445 (483.5)	15.0 (2.1)
All	Female	4	58.5 (2.4)	2,455 (395.3)	14.8 (1.8)
	Total	4	58.5 (2.4)	2,455 (395.3)	14.8 (1.8)

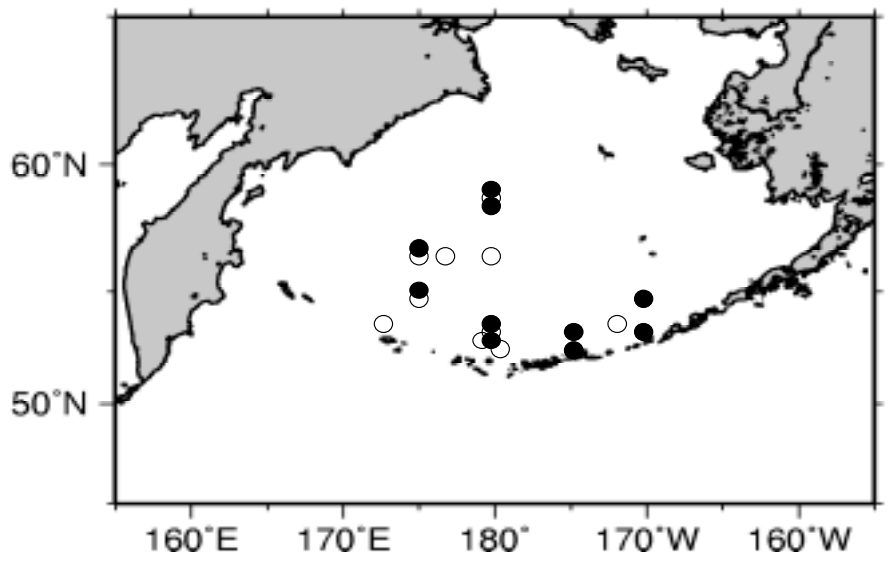

Fig. 1. R/V *Kaiyo maru* survey locations where immature chum salmon were collected for determination of total lipid content. Samples were obtained in June and July 2002 (closed circle) and September 2002 (open circle).

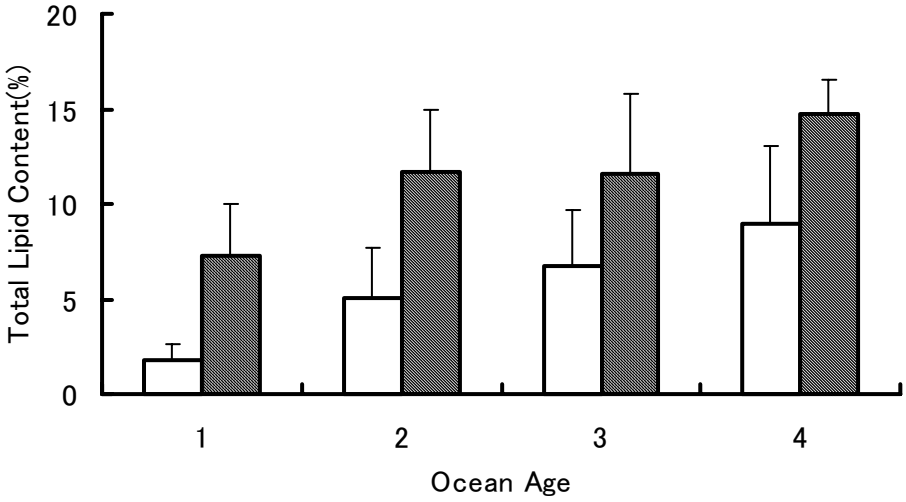

Fig. 2. Total lipid content (percentage of body weight) in white muscle of immature chum salmon caught in the Bering Sea in June and July(open column), and September 2002 (striped column), grouped by ocean age of the fish. Column height indicates the mean and bar height indicates one standard deviation. Sample sizes in June and July samples include age 0.1: n=48, age 0.2: n=69, age 0.3: n=26, and age 0.4: n=5. Sample sizes in September samples include age 0.1: n=180, age 0.2: n=122, age 0.3: n=18, and age 0.4: n=4.

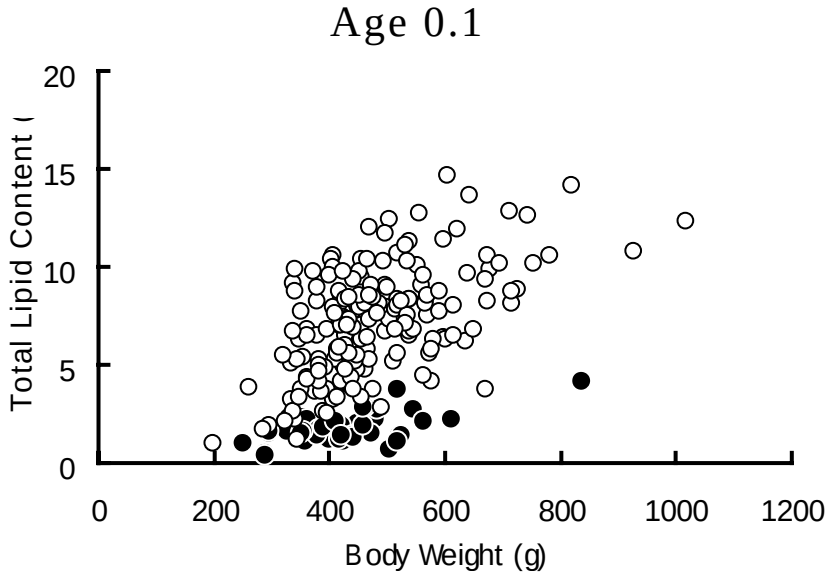

Fig. 3. The relationship between body weight and total lipid content (percentage of body weight) in the white muscle of age 0.1 immature chum salmon caught in the Bering Sea in June and July (closed circle), and September (open circle) 2002.

Fig. 4. The relationship between body weight and total lipid content (percentage of body weight) in the white muscle of age 0.2 immature chum salmon caught in the Bering Sea in June and July (closed circle), and September (open circle) 2002.

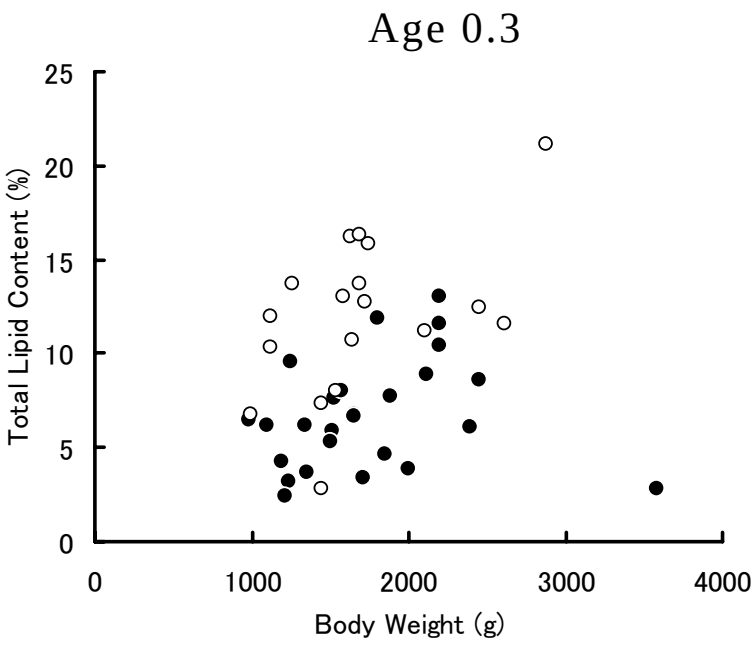

Fig. 5. The relationship between body weight and total lipid content (percentage of body weight) in the white muscle of age 0.3 immature chum salmon caught in the Bering Sea in June and July（closed circle）, and September (open circle) 2002.

Fig. 6. The relationship between body weight and total lipid content (percentage of body weight) in the white muscle of age 0.4 immature chum salmon caught in the Bering Sea in June and July（closed circle）, and September (open circle) 2002.

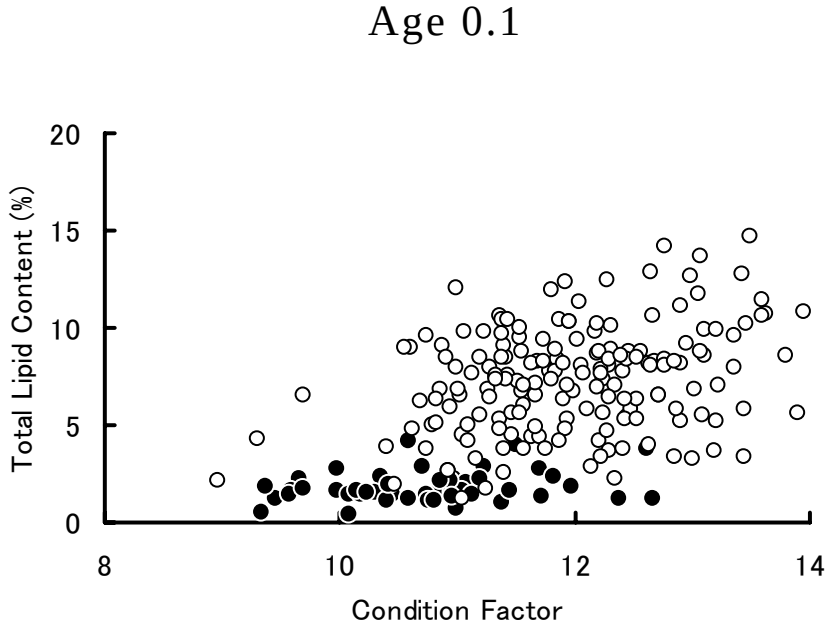

Fig.7. The relationship between condition factor ($BW/(FL)^3 x1000$) and total lipid content (percentage of body weight) in the white muscle of age 0.1 immature chum salmon caught in the Bering Sea in June and July (closed circle), and September (open circle) 2002.

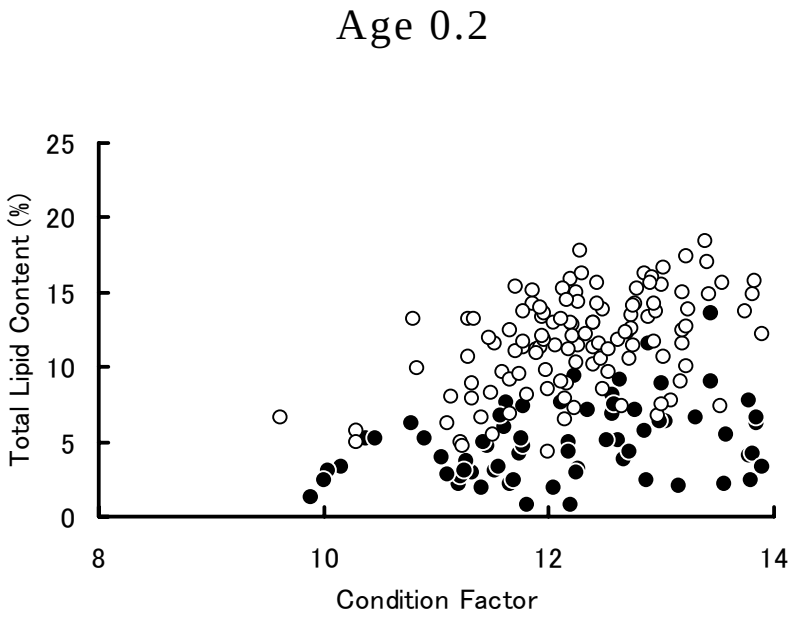

Fig.8. The relationship between condition factor ($BW/(FL)^3 x1000$) and total lipid content (percentage of body weight) in the white muscle of age 0.2 immature chum salmon caught in the Bering Sea in June and July (closed circle), and September (open circle) 2002.