

Variations in Lipid Content of High-Seas Chum and Pink Salmon

by

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Abstract

The potential use of total lipid content and lipid classes in the white muscle and liver of pink and chum salmon was examined for estimating their trophic condition during their high-seas life. In winter, the total lipid contents of chum and pink salmon were extremely low and the total lipid content of the white muscle of pink salmon varied by capture location. The total lipid content in the white muscle of immature chum salmon was significantly lower than in maturing chum salmon in spring. The total lipid of the white muscle in maturing pink salmon in the Sea of Japan was significantly higher than in pink salmon in the North Pacific Ocean. In summer, the total lipid content of the white muscle increased in both species, but a significant difference in the total lipid content was observed according to the capture locations. The extremely low lipid contents in winter suggest that chum and pink salmon are confronted with a great difficulty to live during this season.

Introduction

All animals require dietary lipids for metabolic energy and the synthesis of cell membranes. Despite the common use of biochemical techniques to assess growth and nutrition of fish species, particularly salmonids, surprisingly little is known about lipid changes in high-seas salmon. We examined the potential use of total lipid content and lipid classes in the white muscle and liver for estimating the trophic condition of high-seas pink and chum salmon.

Materials and Methods

A total of 80 salmon (10 chum and 70 pink salmon), captured at four stations in the North Pacific Ocean (45°N, 160°E; 46°N, 168°W; 45°N, 179°E; 45°N, 165°E) by R/V *Kaiyo-maru* and *Wakatake-maru* in January 1996 and February 1998, were used as winter-season samples. A total of 255 salmon (111 chum and 144 pink salmon), captured at seven stations in the North Pacific Ocean (45-54°N, 165°W; 51-56°N, 145°W; 44-45°N, 165°W; 43-46°N, 145°W; 41°N, 155°E; 45-54°N, 165°W; 42-46°N, 145°W) by R/V *Wakatake-maru* and F/V *Great Pacific*, and two stations in the Sea of Japan (41°N, 137°E; 39°N, 135°E) by R/V *Wakatake-maru* in April and May of 1998 and 1999, were used as spring-season samples. A total of 337 salmon (159 chum and 178 pink salmon), captured at six stations in the North Pacific Ocean (44-57°N, 180°; 52°N, 145°W; 45-48°N, 180°; 57°N, 180°; 42-48°N, 180°; 50°N, 165°E) by R/V *Wakatake-maru*, *Hokou-maru* and *Oshoro-maru* in June and July of 1993, 1998 and 1999, were used as summer-season samples. The total lipids in the white muscle and liver were extracted with chloroform/methanol and measured gravimetrically (Bligh and Dryer, 1959). The total lipids were separated into polar lipid and neutral lipid fractions with Sep-Pak (Waters Co. U.S.A.) and measured gravimetrically (Juaneda and Rocquelin, 1985). Statistically significant differences for total lipids were determined with the Student's t-test.

Results

Winter

Total white muscle lipid content in pink salmon captured in January 1996 at 45°N, 160°E (<6.9%, mean = 3.3 %) was significantly higher ($P < 0.001$) than in pink salmon captured at 46°N, 168°W (<1.8%, mean = 1.0 %) (Table 1, Fig. 1). The lipid contents were correlated with body weight (Fig. 1).

Total lipid content in chum salmon captured in February 1998 at 45°N, 179°E was low in the white muscle (<1.7%, mean=1.1 %) and liver (<4.2%, mean=3.2 %). Total lipid content in pink salmon captured at 45°N, 165°E, was also low in the white muscle (<1.7%, mean=1.4%) and liver (<4.2%, mean=3.4 %). Polar lipids in the white muscle were unchanged in winter, but neutral lipids varied in the both muscle and liver (Table 3).

Spring

Total lipid content in the white muscle of maturing chum salmon captured in May 1999 was <15.6% (mean = 4.4 %) at 45-54°N, 165°W and <10.9 % (mean = 4.1 %) at 51-56°N, 145°W. Total lipid content in white muscle of immature chum salmon at 44-45°N, 165°W (<4.1%, mean = 1.9 %) and at 43-46°N, 145°W (<2.1 %, mean = 1.3 %) were significantly lower ($P < 0.001$) than in maturing chum salmon at the two locations. Total lipid contents of immature

and maturing chum salmon captured at the two locations were similar. The lipid contents were not correlated with body weight at either location (Fig. 2).

Total lipid in white muscle of maturing pink salmon in the Sea of Japan was significantly higher ($P < 0.001$) in 1998 ($< 10.6\%$, mean = 6.3%) and 1999 (< 9.8 , mean = 7.0%) than in pink salmon captured in the eastern and western North Pacific Ocean (< 5.8 , mean = 3.3%; < 5.0 , mean = 2.7%; < 6.5 mean = 2.7%)(Table 5). The lipid contents were correlated with body weight (Fig. 3).

Summer

Total lipid contents in the white muscle of chum salmon caught at $52^{\circ}\text{N}, 145^{\circ}\text{W}$ in July of 1998 was high ($< 18.6\%$, mean = 12.0 %) Total lipid content in white muscle of chum salmon at $44\text{-}57^{\circ}\text{N}, 180^{\circ}\text{W}$ ($< 4.9\%$, mean = 2.2 %) and at $45\text{-}48^{\circ}\text{N}, 180^{\circ}\text{W}$ ($< 15.0\%$, mean = 3.9 %) were significantly lower ($P < 0.001$) than in chum salmon caught at $52^{\circ}\text{N}, 145^{\circ}\text{W}$ and $57^{\circ}\text{N}, 180^{\circ}$ (Table 6). The lipid contents were not correlated with body weight at either location (Fig. 4).

Total lipid contents in pink salmon captured in July of 1998 at $52^{\circ}\text{N}, 145^{\circ}\text{W}$ was high in the white muscle ($< 18.5\%$, mean = 11.3 %). Total lipid content in white muscle of pink salmon at $42\text{-}48^{\circ}\text{N}, 180^{\circ}$ ($< 10.4\%$, mean = 5.8 %) was significantly lower ($P < 0.001$) than in pink salmon caught at other locations (Table 6). The lipid contents were correlated with body weight (Fig.5).

Discussion

There are few reports of lipid content in high sea salmonids (Azuma et al., 1998). Our results show that the total lipid contents of chum and pink salmon were low in winter. In general, the polar lipid content, which is a component of cell membrane, did not vary significantly with species or time of year, and remained at approximately 1 % in fish muscle. Neutral lipids, which are used by salmon as an energy source, were very low in winter (Table 3). The low lipid content in the muscle suggests that chum salmon do not have adequate food supplies in the winter. Such a low lipid content affects the survival of the salmon in high-seas during this season. Total lipid content of the white muscle of pink salmon varied by capture location (Fig. 1), but the reason for the difference is not clear.

Total lipid in the white muscle increased in maturing chum salmon in spring, but no increase was observed in immature salmon Further research is needed to discover the reason for this difference. There was a difference in body size between pink salmon captured in the Sea of Japan in 1998 and in 1999. However, total lipid in pink salmon muscle did not differ between sampling years. Total lipid in pink salmon was lower in the North Pacific Ocean than in the Sea of Japan in both 1998 and 1999, suggesting that the Sea of Japan may have better trophic conditions than the North Pacific Ocean in spring.

Total lipids in the white muscle of chum and pink salmon caught at high latitude stations were high in summer, but the contents in the white muscle caught at low latitude stations were

significantly low. Differences of total lipids in the white muscle could be related to latitudinal differences in trophic conditions and could also be related to stock differences or differences in degree of maturation.

Further study of seasonal and spatial variation in lipid content among North Pacific salmonids is needed to better estimate changes in trophic conditions experienced by salmon during their high seas residency.

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Table 1. Biological characteristics and total lipid contents (TL) in the white muscle of pink salmon caught in the eastern and western North Pacific Ocean in winter of 1996. The values indicate the mean and standard deviation in brackets.

Stage	Location	Date	No. of Fish	FL (cm)	BW (g)	CF	TL (%)
Immature	45°N,160°E	Jan. 11	20	23.8(1.8)	123 (32)	8.9 (0.7)	3.3 (0.3)
Immature	46°N,168°W	Jan. 18	40	25.1(1.8)	138 (32)	8.5 (0.7)	1.0 (0.3)

FL, Fork length; BW, Body weight; CF, Condition factor.

Table 2. Biological characteristics of chum and pink salmon caught in the North Pacific Ocean in winter of 1998. The values indicate the mean and standard deviation in brackets.

Species	Stage	Location	Date	No. of Fish	FL (cm)	BW (g)	CF
Chum salmon	Immature	45°N,179°E	Feb. 21	10	35.4(1.2)	428 (63)	9.6 (0.7)
Pink salmon	Immature	45°N,165°E	Feb. 10	10	28.9 (1.9)	216 (40)	9.4 (0.3)

FL, Fork length; BW, Body weight; CF, Condition factor.

Table 3. Total lipid (TL), polar lipid (PL) and neutral lipid (NL) contents in the white muscle and liver of chum and pink salmon caught in the North Pacific Ocean in the winter of 1998. Biological characteristics were shown in Table 2. The values indicate the mean and standard deviation in brackets.

Species	Muscle			Liver		
	TL(%)	PL (%)	NL (%)	TL(%)	PL (%)	NL (%)
Chum salmon	1.1 (0.3)	0.7 (0.1)	0.3 (0.2)	3.2 (0.6)	1.9 (0.3)	1.3 (0.4)
Pink salmon	1.4 (0.2)	0.7 (0.1)	0.5 (0.2)	3.4 (0.6)	2.4 (0.5)	1.0 (0.1)

Table 4. Biological characteristics and total lipid contents (TL) in the white muscle of chum salmon caught in the North Pacific Ocean in the spring of 1999. The values indicate the mean and standard deviation in brackets.

Stage	Location	Date	No. of Fish	FL (cm)	BW (g)	CF	TL (%)
Mature	45-54°N,165°W	May 4- 8	35	58.4 (3.9)	2,430 (610)	11.9 (1.3)	4.4 (2.8)
Mature	51-56°N,145°W	May 19-21	32	57.5 (2.9)	2,250 (510)	11.7 (1.9)	4.1 (2.3)
Immature	44-45°N,165°W	May 8	23	33.2 (6.6)	460 (240)	11.7 (1.1)	1.9 (0.8)
Immature	43-46°N,145°W	May 16-17	21	34.5 (4.7)	458 (164)	11.0 (1.7)	1.3 (0.3)

FL, Fork length; BW, Body weight; CF, Condition factor.

Table 5. Biological characteristics and total lipid contents (TL) in the white muscle of pink salmon caught in the Sea of Japan (SE), the eastern North Pacific Ocean (ENPO) and the western North Pacific Ocean (WNPO) in the springs of 1998 and 1999. The values indicate the mean and standard deviation in brackets.

Area	Location	Date	No. of Fish	FL (cm)	BW (g)	CF	TL (%)
SJ	41°N,137°E	April 25, 1998.	18	34.0 (2.1)	497 (95)	12.6 (1.1)	7.0 (1.6)
SJ	39°N,135°E	April 18,1999	50	41.0 (2.1)	831 (308)	11.9 (4.1)	6.3 (1.5)
WNPO	41°N,155°E	May 10, 1998	25	35.0 (1.7)	435 (68)	10.1 (0.8)	3.3 (0.9)
ENPO	45-54°N,165°W	May 4-8, 1999	26	35.5 (3.0)	475 (107)	10.5 (1.2)	2.7 (1.1)
ENPO	42-46°N,145°W	May 16-17, 1999	25	36.9 (3.5)	519 (144)	10.2 (0.7)	2.7 (1.5)

FL, Fork length; BW, Body weight; CF, Condition factor.

Table 6. Biological characteristics and total lipid contents (TL) in the white muscle of chum and pink salmon caught in the North Pacific Ocean in the summer of 1993,1998 and 1999. The values indicate the mean and standard deviation in brackets.

Species	Location	Date	No. of Fish	FL (cm)	BW (g)	CF	TL (%)
Chum salmon	44-57°N,180°	Jun. 23-July 7,1993.	34	51.6 (9.6)	1,791 (1,034)	11.6 (1.1)	2.2 (1.0)
	52°N,145W	July 7,1998	25	51.4 (3.7)	1,679 (452)	12.1 (0.7)	12.0 (3.5)
	45-48°N,180°	Jun 22-27,1999	51	41.4 (7.7)	862 (488)	10.9 (1.9)	3.9 (2.4)
	57°N,180°	July7-10,1999	49	54.4 (6.3)	2,125 (804)	12.5 (1.2)	9.3 (3.9)
Pink salmon	52°N,145°W	July 7,1998	28	49.3 (2.6)	1,602 (368)	13.1 (1.5)	11.3 (4.1)
	42-48°N,180°	Jun19-27,1999	50	40.4 (2.6)	782 (156)	11.8 (1.4)	5.8 (1.8)
	57°N,180°	July 6, 1999	50	44.2 (3.2)	1,202 (264)	13.7 (1.3)	10.1 (2.6)
	50°N,165°E	Jun 29,1999	50	44.2 (2.3)	1,320 (189)	15.2 (1.4)	12.4 (2.9)

FL, Fork length; BW, Body weight; CF, Condition factor.

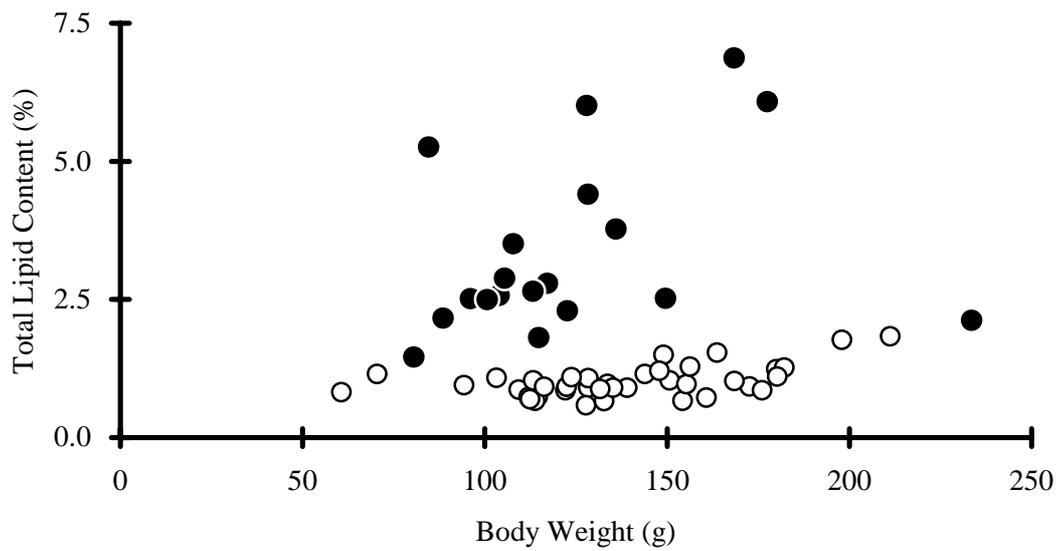


Figure 1. Relationship between total lipid content in the white muscle and body weight in pink salmon caught in the western North Pacific Ocean (● ; 45°N, 160°E) and the eastern North

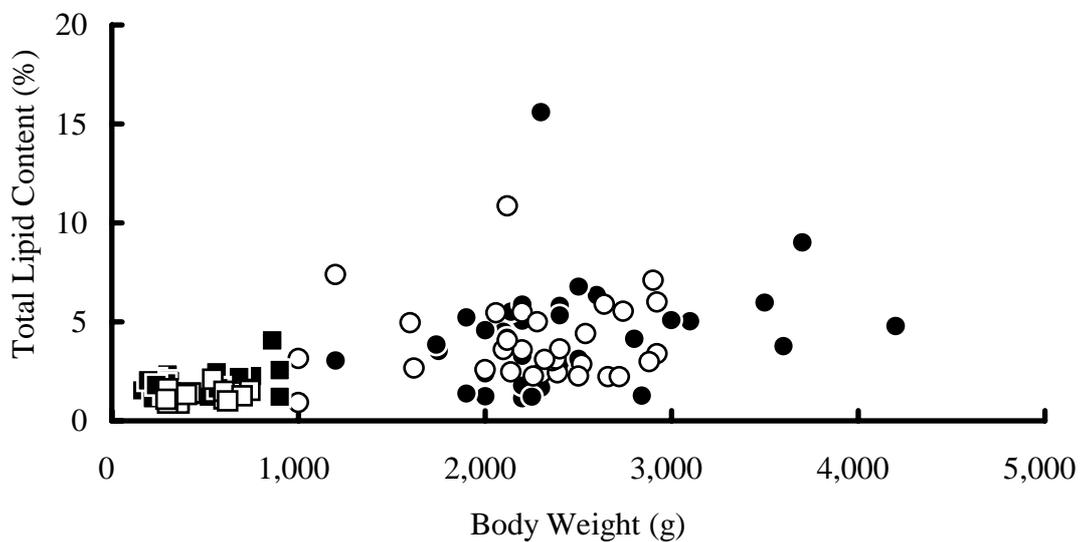


Figure 2. Relationship between total lipid content in the white muscle and body weight of maturing chum salmon caught in the eastern North Pacific Ocean (● ; 45-54°N, 165°W; ○ ; 51-56°N,145°W) and immature chum salmon that were caught in the eastern North Pacific Ocean (□ ; 44-45°N, 165°W; ■ ; 43-46°N, 145°W) in spring.



Figure 3. Relationship between total lipid content in the white muscle and body weight of pink salmon caught in the Sea of Japan (\blacklozenge ; 41°N , 137°E : \circ ; 39°N , 135°E) and in the North Pacific Ocean (\square ; 41°N , 155°E : \bullet ; $45\text{-}54^{\circ}\text{N}$, 165°W : \diamond ; $42\text{-}46^{\circ}\text{N}$, 145°W) in the springs of 1998 and 1999.

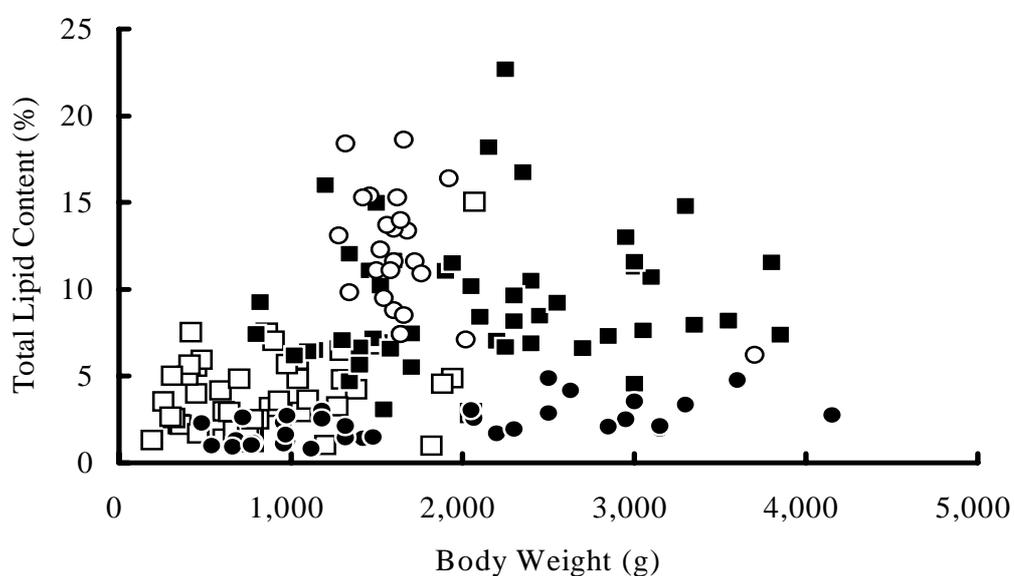


Figure 4. Relationship between total lipid content in the white muscle and body weight of chum salmon caught in the North Pacific Ocean (\square ; $45\text{-}48^{\circ}\text{N}$, 180° : \blacksquare ; 57°N , 180°W : \circ ; 52°N , 145°W : \bullet ; $44\text{-}57^{\circ}\text{N}$, 180°) in the summers of 1993, 1998 and 1999.

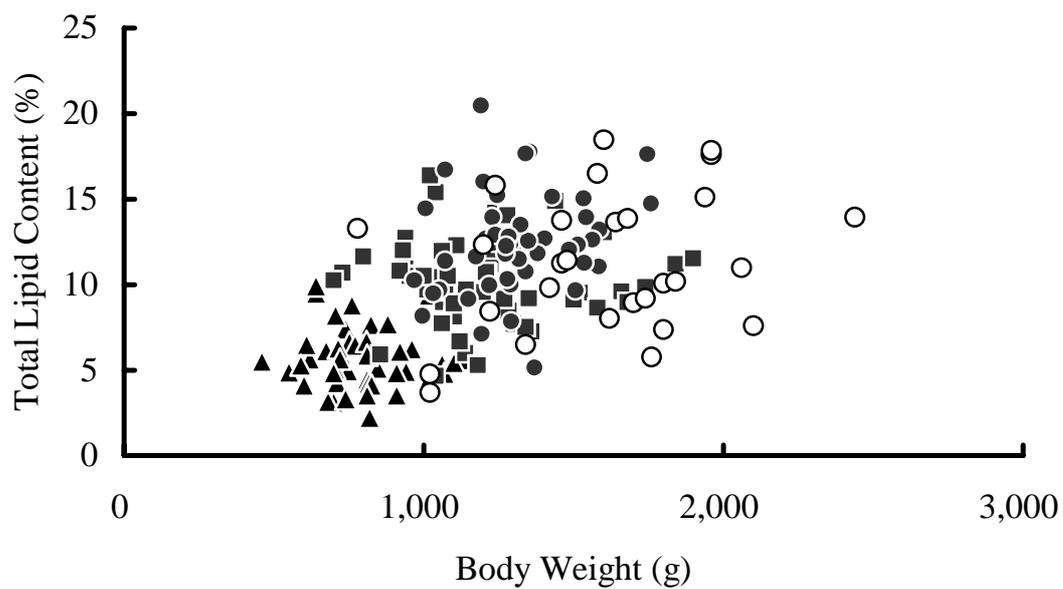


Figure 5. Relationship between total lipid content in the white muscle and body weight of pink salmon caught in the North Pacific Ocean (■ ;57°N,180°W :○ ; 52°N,145°W: ● ;50°N,165°E:▲ 42-48°N,180°W) in the summer of 1993, 1998 and 1999.