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Tetsuichi Nomura[1], Shigehiko Urawa[1], Morihiko Kawana[1] ,
Masa-aki Fukuwaka[2] and Nancy Davis[3]

[1] *National Salmon Resources Center, Nakanoshima 2-2, Toyohira-ku, Sapporo, 062-0922 Japan.*

[2]*Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Katsurakoi 116, Kushiro, Hokkaido, 085-0802 Japan*

[3]*School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA 98195-5020 USA*

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Variation in Lipid Content in the Muscle of Chum Salmon in the Central North Pacific Ocean and Bering Sea

Tetsuichi Nomura[1], Shigehiko Urawa[1], Morihiko Kawana[1] ,Masa-aki Fukuwaka[2] and Nancy Davis[3]

1 National Salmon Resources Center, Nakanoshima 2-2, Toyohira-ku, Sapporo, 062-0922 Japan.

2 Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Katsurakoi 116, Kushiro, Hokkaido, 085-0802 Japan.

3 School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA 98195-5020 USA

Abstract

Our objective in this paper was to examine the effect of ocean age on TL content and annual change on TL content of muscle in high-seas chum salmon caught in the central North Pacific Ocean and Bering Sea in summer. Chum salmon were collected by gillnet on the T/V *Wakatake-maru* in the central North Pacific Ocean and Bering Sea in June and July 1993, 1998, 1999, 2000, and 2001. We found a significant difference between younger and older chum salmon in the total lipid content in white muscle in 1999, 2000 and 2001. There were annual changes in TL content in the muscle of chum salmon in the central North Pacific Ocean and Bering Sea. Further analysis of the effects of maturity level on TL content should be examined in future analysis of condition of salmon when sample sizes are large enough to stratify samples by ocean age and maturity.

Introduction

In previous papers, total lipid (TL) content and fatty acid composition were studied to investigate trophic condition of chum and pink salmon in the North Pacific Ocean and Gulf of Alaska in winter (Nomura et al. 1999, Nomura et al. 2000) and spring (Nomura et al. 2001, Nomura et al. in press). These studies suggested that in winter, TL content of immature chum salmon is extremely low as compared to maturing chum salmon sampled in the spring (Nomura et al. 1999), and the authors concluded that chum salmon may be in a starving condition in winter (Nomura et al. 1999). Our objective in this paper was to examine the effect of ocean age on TL content and annual change on TL content of muscle in high-seas chum salmon caught in the central North Pacific Ocean and Bering Sea in summer.

Material and Methods

Chum salmon were collected by gillnet on the T/V *Wakatake-maru* in the central North Pacific Ocean and Bering Sea in June and July1993, 1998, 1999, 2000, and 2001. Salmon ages were determined by examination of scale patterns. Fork length (mm) and body weight (g) of chum salmon were measured and a 10 g muscle sample was collected. Tissue samples were frozen at -30° C until analyzed. A total of 615 chum salmon were used in our analysis (Table 1). Total lipids in the white muscle were extracted with the chloroform/methanol method of Folch et al. (1957) and measured gravimetrically. The resulting values were tested for differences in TL content by ocean age using ANOVA and Bonferroni's multiple-comparison test ($P<0.05$).

Table 1. Year, location, date, and number of chum salmon analyzed for total lipid content in the central North Pacific Ocean and Bering Sea.

Year	Location		Date	Number of fish
	Latitude	Longitude		
1993	43.30N-56.30N	179.30W	June 23- July 7	34
1998	56.30N	179.00W	July 15	33
1999	44.00N-58.30N	180.00	July 22- July 5	98
2000	55.30N- 58.30N	177.00E-178.00W	July 1-July 18	200
2001	55.30N-58.30N	177.00E-178.00W	July 2-July 12	250

Results

Biological parameter and average, minimum, and maximum values of total lipid content in the white muscle of chum salmon caught in the central North Pacific Ocean and Bering Sea in June and July of 1993, 1998, 1999, 2000 and 2001, grouped by ocean age was shown in Table 2.

In 1993, 34 fish, smaller number than other year, were analyzed and three had unknown ocean ages. The average TL in the white muscle was 1.0, 1.8, 2.4, 2.9 and 2.7% in age-.1, -.2, -.3, -.4 and age-.5 fish respectively.

In 1998, 33 age-.1 fish alone was analyzed and average TL was 2.8%.

In 1999, 98 fish were analyzed and 13 fish had unknown ocean age. Average

TL was 4.0, 4.6, 8.4 and 9.5% in age-.1, -.2, -.3 and age-.4 fish respectively. Statistical differences were found between age -.2 and age -.3 fish, but no significant differences were observed in ocean age -.1 and -.2, and in age -.3 and -.4.

In 2000, 200 fish were analyzed and five had unknown ocean ages. There were no ocean age-.1 fish in the sample. The average TL content was 6.2% in age-.2 fish and was lower than other ocean ages of chum salmon (Table 2, Fig. 1). Average TL content was 8.1% in age-.3 fish, and 9.9% in age-.4 fish. Statistical differences were found between age -.2 and age -.3 fish, but no significant differences were observed in ocean age -.3, -.4, and -.5 fish (Fig. 1).

In 2001, we obtained samples from chum salmon of ocean age-1, -.2., -.3, -.4 and -.5 salmon for analysis (Table 2, Fig. 2). There were eight fish with unknown ocean ages in the 2001 sample. The average of TL content was 3.3% in age-.1 fish and it was lower than the older fish. Total lipid content was 9.3% in ocean age-.2 fish, and 11.1% in ocean age-.3 fish. Total lipid content values among ocean age -.3, -.4, and -.5 chum salmon were similar. There were significant statistical differences between ocean age -.1 and -.2 fish, but no significant differences were observed in ocean age -.2, -.3, -.4 and -.5 fish (Fig. 2).

There were annual changes in TL content in the muscle of chum salmon in the central North Pacific Ocean (Fig. 3). Total lipid content in ocean age-.1 fish was similar in 1993, 1998, 1999 and 2001. In ocean age-.2 fish, TL content in fish was higher in 2001 than in 1993, 1999 and 2000. Total lipid contents of chum salmon in 2001 were also higher in age-.3 and age-.4 fish. Results are not shown for age-.5 fish because insufficient sample sizes were obtained. In 1993, the average TL content of ocean age-.1, -.2, -.3 and -.4 fish were 1.0%, 1.8%, 2.4% and 2.9% respectively. The average TL content observed in 1993 in each age fish was the lowest TL values observed in this study.

The relationship between TL content in white muscle and body weight indicates that TL content increased with body weight for salmon weighing under 2,000 g (Fig. 4). Salmon smaller than 1,000 g body weight had low values of TL content. Total lipid content increased with body weight in all years in ocean age -.1 to -.3 fish, but in older salmon, age -.4 fish, there was no relation between TL content and body weight (Fig. 4).

Table 2. Biological parameter and average, minimum, and maximum values of total lipid content in the white muscle of chum salmon caught in the central North Pacific Ocean and Bering Sea in June and July of 1993, 1998, 1999, 2000 and 2001, grouped by ocean age.

Year	Ocean Age	No. of Fish	FL*(mm) Average	(S.D.)	BW**(g) Average	(S.D)	C.F.*** Average	(S.D)	Total Lipid Content(%) Average	(S.D)	Min.	Max.
1993	1	1	376		540		10.16		1.0		1.0	1.0
	2	11	433	(32.4)	909	(210.9)	11.07	(0.67)	1.8	(0.69)	1.0	2.7
	3	13	533	(63.9)	1,864	(654.4)	11.82	(0.81)	2.4	(1.23)	0.8	4.9
	4	5	633	(18.8)	3,230	(241.4)	12.71	(0.86)	2.9	(1.16)	2.0	4.8
	5	1	668		4,150		13.92		2.7		2.7	2.7
1998	1	33	335	(10.7)	375	(36.6)	9.97	(0.76)	2.8	(0.81)	1.5	4.8
1999	1	14	332	(21.9)	374	(86.1)	9.97	(0.87)	4.0	(1.85)	1.3	7.5
	2	30	430	(49.4)	938	(320.2)	11.48	(2.04)	4.6	(3.05)	1.2	16.2
	3	28	530	(56.8)	1,912	(656.2)	12.29	(1.28)	8.4	(4.68)	1.0	22.7
	4	13	597	(52.1)	2,645	(793.0)	12.18	(1.84)	9.5	(4.02)	1.0	15.0
2000	2	44	463	(26.6)	1,100	(217.9)	10.84	(0.73)	6.2	(3.37)	0.8	17.1
	3	99	524	(40.4)	1,722	(545.0)	11.65	(1.25)	8.1	(4.00)	1.7	21.3
	4	49	585	(51.7)	2,723	(976.7)	13.06	(1.87)	9.9	(4.55)	3.5	21.4
	5	3	644	(38.8)	3,400	(793.7)	12.59	(0.73)	13.0	(4.80)	7.9	17.5
2001	1	31	348	(32.8)	406	(117.8)	9.72	(0.94)	3.3	(1.43)	1.2	8.5
	2	43	475	(34.7)	1,214	(281.9)	11.14	(0.99)	9.3	(4.61)	2.7	23.4
	3	91	559	(47.1)	2,238	(683.0)	12.60	(1.45)	11.1	(4.11)	2.3	20.7
	4	70	611	(49.7)	3,063	(853.7)	13.14	(1.55)	11.3	(5.16)	4.3	30.4
	5	7	647	(42.1)	3,686	(834.0)	13.41	(0.84)	12.0	(3.51)	7.7	17.6

* FL = Fork Length, ** BW = Body Weight, *** C.F.= Condition Factor ;$(BW/FL^3)X1,000$

Discussion

In this study, we found a significant difference between younger and older chum salmon in the total lipid content in white muscle in 1999, 2000 and 2001 (Figs. 1 and 2). Nomura et al. (2001) and Nomura et al. (in press) reported similar variation of TL content by ocean age in chum salmon in the Gulf of Alaska in spring. Lipids in fish are divided into two groups: polar lipid and neutral lipid. In general, percentage of the

polar lipid content in white muscle, which is a component of the cell membrane, does not vary significantly with species, or time of year, and comprises approximately 1% of muscle tissue (Nomura et al. 1999, Nomura et al. 2000). We suggest that neutral lipids, which are used by salmon as an energy source (Azuma et al. 1998), are responsible for the variation in lipid levels found in salmon muscle tissue across ocean age. Even in summer, lipid levels of younger salmon, age-.1 fish, still had lower lipid levels than older salmon. We conclude that the effect of age must be taken into consideration when examining lipid levels in salmon in offshore waters.

We also observed annual differences in the lipid content of ocean age-.2 -.3 chum salmon (Fig. 3). All ocean age-.2 fish were immature fish, but there are both immature and maturing fish in the ocean age-3 and age-.4 groups in this study. Further analysis of the effects of maturity level on TL content should be examined in future analysis of condition of salmon when sample sizes are large enough to stratify samples by ocean age and maturity.

We conclude that analysis of TL content is an important biological characteristic in monitoring the condition of chum salmon at sea. Furthermore, the effect of ocean age and maturity should be addressed in future studies. Investigations could focus on why young salmon have low lipid stores in white muscle, whether low lipid contents observed in young salmon in summer affect their survival during the following winter, and relative and combined effects of ocean age and maturity on TL content. Further investigation of annual variation in lipid content in each age group of chum salmon will be important for understanding their ocean survival, growth, and fecundity.

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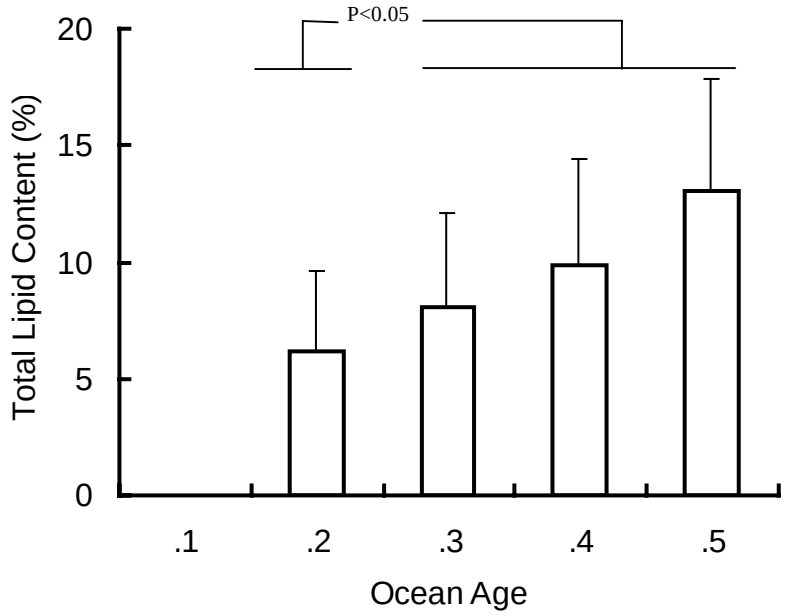

Fig. 1. Total lipid content in white muscle in chum salmon caught in the central North Pacific Ocean and Bering Sea in July 2000 by ocean age. Sample sizes: age-.2 (n=44), age-.3 (n=99), age-.4 (n=49), and age-.5 (n=3). Bars are means, and lines are ± one standard deviation.

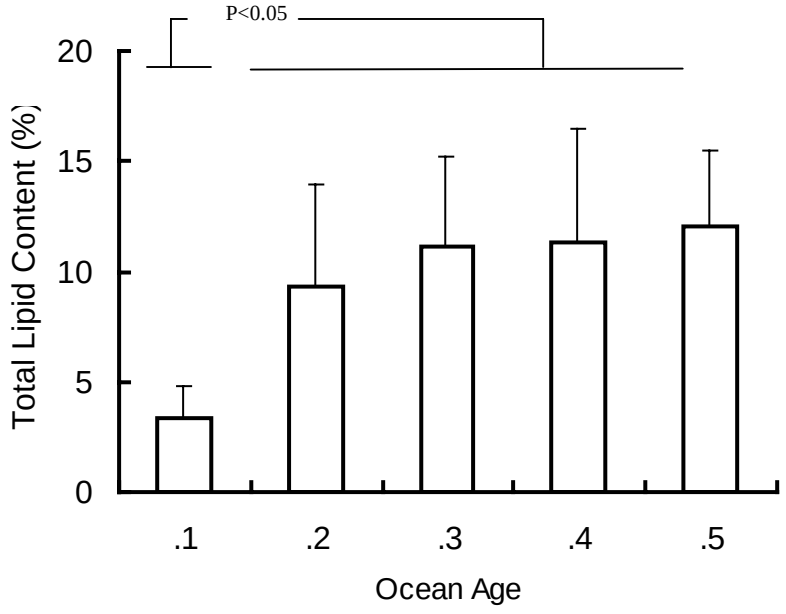

Fig. 2. Total lipid content in white muscle in chum salmon caught in the central North Pacific Ocean and Bering Sea in July 2001 by ocean age. Sample sizes: age-.1 (n=31), age-.2 (n=43), age-.3 (n=91), age-.4 (n=70), and age-.5 (n=7). Bars are means, and lines are ± one standard deviation.

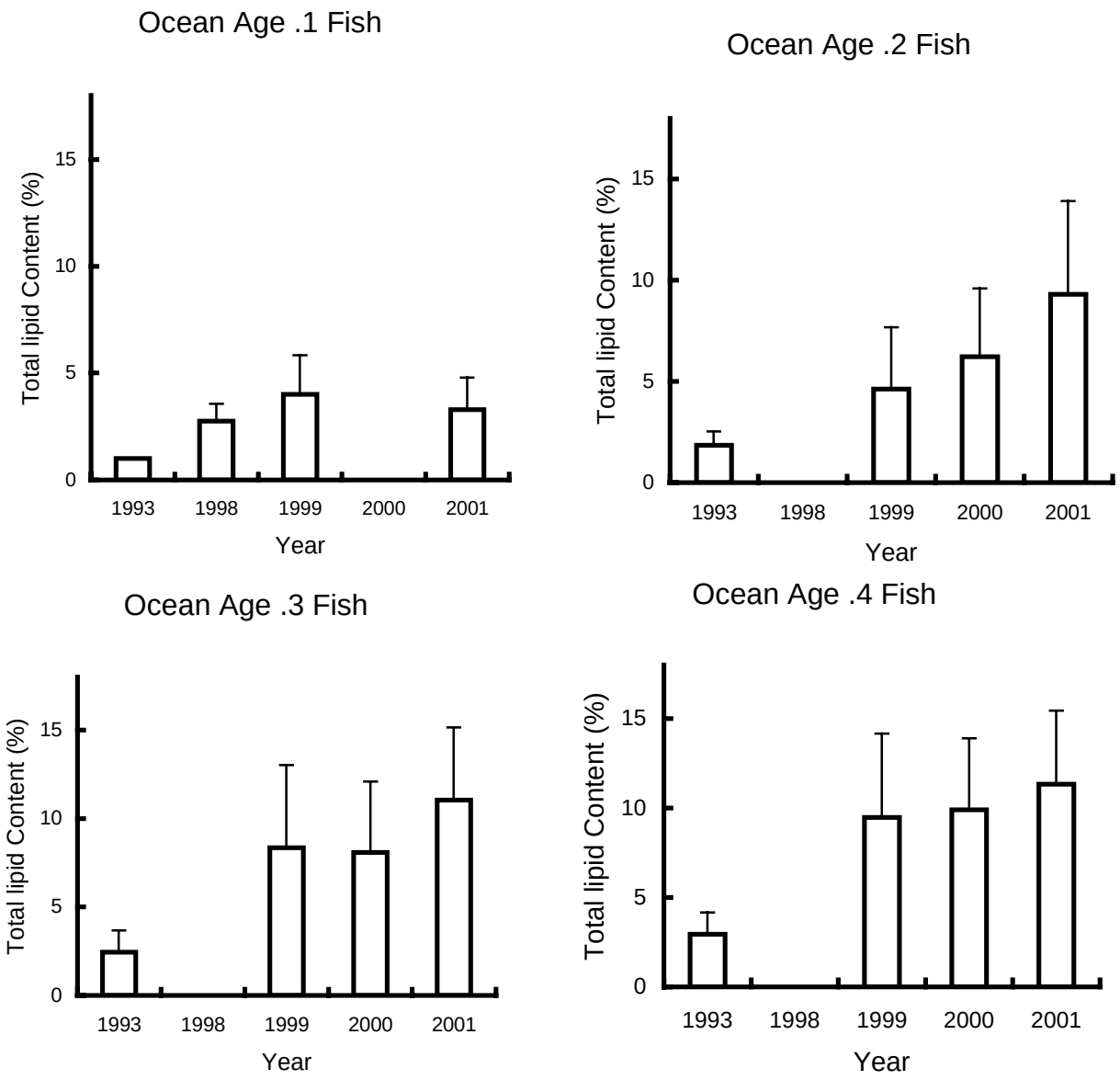

Fig. 3. Total lipid content in white muscle in chum salmon caught in the central North Pacific Ocean and Bering Sea in June and July 1993, 1998, 1999, 2000 and 2001 by ocean age. Bars are means, and lines are ± one standard deviation.

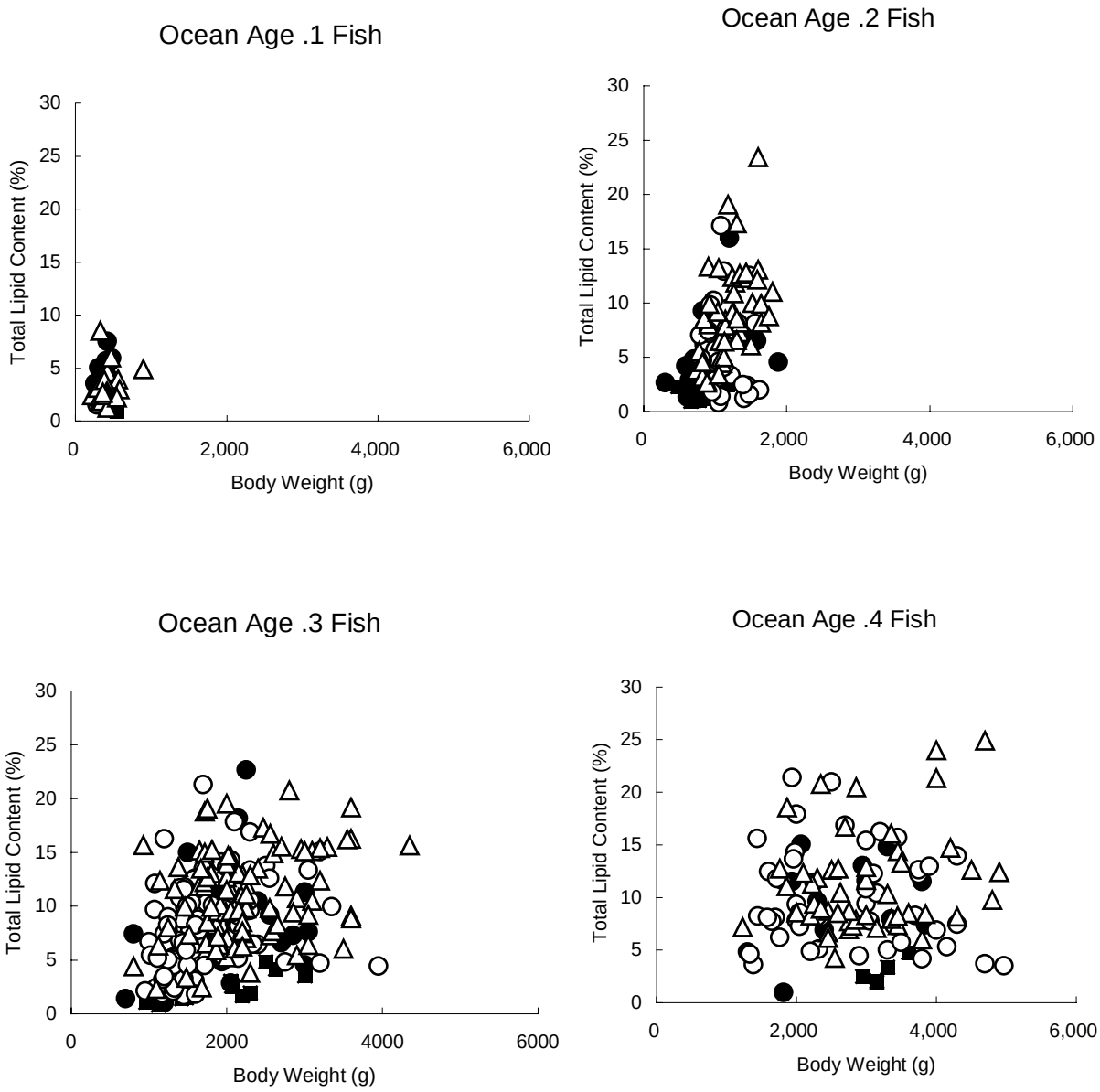

Fig. 4. Relationship between total lipid content in white muscle and body weight in chum salmon caught in the central North Pacific Ocean and Bering Sea in June and July 1993 (solid squares), 1998 (open squares), 1999 (solid circle), 2000 (open circle) and 2001 (open triangles) by ocean age.