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Distribution and Biological Characters of Pink (*Oncorhynchus gorbuscha*) and Masu Salmon (*O. masou*) in the Sea of Japan

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Abstract.– Distribution and biological characters of pink (*Oncorhynchus gorbuscha*) and masu salmon (*O. masou*) in the Sea of Japan in spring were summarized based on the data obtained from the research cruises carried out from 1993 to 1999. Though pink salmon showed higher CPUEs within the 8-13°C SST range, they were caught even in lower temperature around 5°C. In contrast, masu salmon were caught only in 8-14°C SST range waters. The body size of pink salmon excluding the result in 1997 were larger in the odd years and smaller in the even years. Though the sex ratio of pink salmon were almost even, about 70% of total catch were female in masu salmon. From the results of age determination, 64% of masu salmon were identified as age 1.1 fish and 36% were age 2.1.

Key words: pink salmon, masu salmon, distribution, Sea of Japan

Introduction

Pink (*Oncorhynchus gorbuscha*) and masu salmon (*O. masou*) are the dominant salmon species in the Sea of Japan. Both species spend one winter in the ocean after their seaward migration. After wintering, masu salmon return to their natal river from spring to summer (Tanaka 1965, Machidori and Kato 1984), and pink salmon return from summer to autumn. Pink salmon are distributed not only in the Sea of Japan, but also over a broad area of the North Pacific Ocean and Bering Sea, and they are more abundant than other Pacific salmon species. On the other hand, masu salmon are distributed only in the western North Pacific Ocean, where their abundance low compared to pink salmon (Kato 1971; Kaeriyama 1985). In the Sea of Japan, pink and masu salmon are important fishery and biological resources. The Sea of Japan is not very wide, but complex oceanographic structures formed by Tsushima warm current from southwest and Liman cold current from northeast affect distribution and ecology of salmon in this region (Shimomura et al. 1962).

We use data obtained from Japan-Russia cooperative research in 1993-1999 to clarify the recent distribution and biological characteristics of pink and masu salmon in the Sea of Japan.

Materials and Methods

The dates of the research cruises, the number of gill net operations, and the total number of tans of gillnet gear used are summarized in Table 1. The locations of experimental fishing operations are shown in Figure 1. Research was conducted from mid to late April, except in 1997 and 1998. Research was conducted in mid February in 1997 and from late April to early May in 1998. There were only three gillnet operations in 1997 due to severe ocean conditions, and because of the long cruise period there were 15 operations in 1998. In other years, there were 8-11 gillnet operations. The total amount of gillnet gear (50 m/tan) used varied in proportion to the number of operations, from 765 tans in 1998 to 148 tans in 1997 (Table 1). Gillnets were usually 49 tans in total length, including 30 tans of research net (10 different

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stretched-mesh sizes from 47 to 157 mm, 3 tans each) connected to 10 and 9 tans of 93-mm mesh commercial net at each end of the net. However, a 50-tan net set (30 tans of research gillnet and 10 tans of commercial gillnet at each end) was used in 1993, and two kinds of small mesh gillnet (26 mm and 35 mm, one tan each) were added to the 49-tan gillnet in 1998. A longline was also used during the survey. Because the number of fish caught by longline was small, only gillnet data were used for pink salmon analyses. Results were expressed as catch per unit effort (CPUE), calculated with following formula: CPUE (fish/tan) = number of fish caught in the each operation/number of all gillnets, expressed in tan, used in the operation. Details of experimental gillnet fishing are shown in Appendix 1. After each fishing operation, fork length (FL in mm), body weight (BW in g), and gonad weight (GW) of fish were measured, sex was recorded, and scales collected from defined area (INPFC 1963, p. 115) were examined for age determination of masu salmon. To increase sample number of masu salmon for analysis of length, weight, and sex ratio, seven specimens caught by longline (3 fish in 1993, 4 fish in 1996) were added. Condition factor (CF) and gonad somatic index (GSI) were calculated with following formulae: $CF = (BW/FL^3) \times 10^9$, $GSI = (GW/BW) \times 100$.

Sea surface temperature (SST) was recorded before each fishing operation. In addition, 8 and 12°C isothermal curves of SST during each research cruise were obtained from "Gyokaikyo sokuho" supplied by the Japan Fisheries Information Service Center (Ikenohata, Tokyo 110-0008).

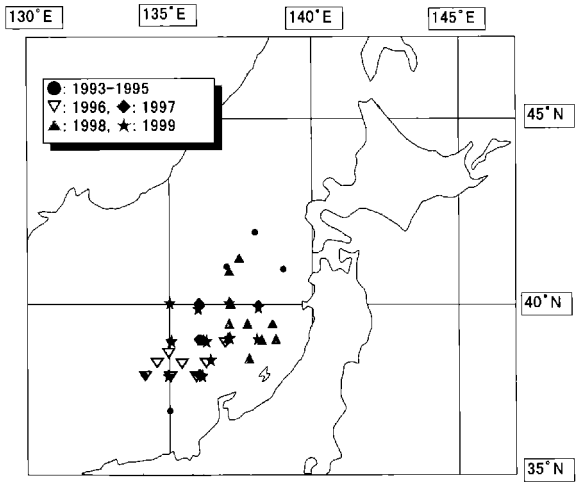

Fig. 1. Map showing the locations of gillnet sampling in 1993-1999.

Results

Salmon distribution and ocean conditions

Pink salmon were caught at almost all stations in 1993-1995, although there were no or few pink salmon caught in northern waters with SSTs colder than 8°C (Fig. 2). Operations were conducted only south of 39°N in 1996, and the density of pink salmon was relatively high. High CPUEs of pink salmon were also recorded in 1999, even though operations were limited to the area between 39-40°N. Although pink salmon were distributed at lower SSTs in a wide area of 8-12°C SST water in 1996, many fish were caught in a narrow area of 8-12°C SST water in 1998 and 1999. As previously mentioned, ocean conditions in mid February 1997 were severe, and the distribution of pink salmon could not be clearly determined. Some pink salmon, however, were distributed in waters around 8°C SST in the central Sea of Japan in February 1997.

Generally, masu salmon were caught in smaller numbers than pink salmon, and showed large annual fluctuation: 124 fish in 1998, four in 1995, and only one in 1997 (Table 2). Excluding the data in 1995 and 1997, when few masu salmon were caught, masu salmon

Table 1. Outline of spring salmon research cruises in the Sea of Japan from 1993 to 1999.

Year	Name of R/V	Period of cruise		Number of gillnet	
		from	to	operation	total (tan)
1993	*Hokuho*	Apr. 14	Apr. 27	10	500
1994	*Hokuho*	Apr. 14	Apr. 28	10	490
1995	*Wakatake*	Apr. 19	Apr. 30	9	441
1996	*Wakatake*	Apr. 16	Apr. 27	8	392
1997	*Kanki,38*	Feb. 9	Feb. 23	3	148
1998	*Wakatake*	Apr. 18	May 8	15	765
1999	*Wakatake*	Apr. 15	Apr. 28	11	539
Total				66	3,275

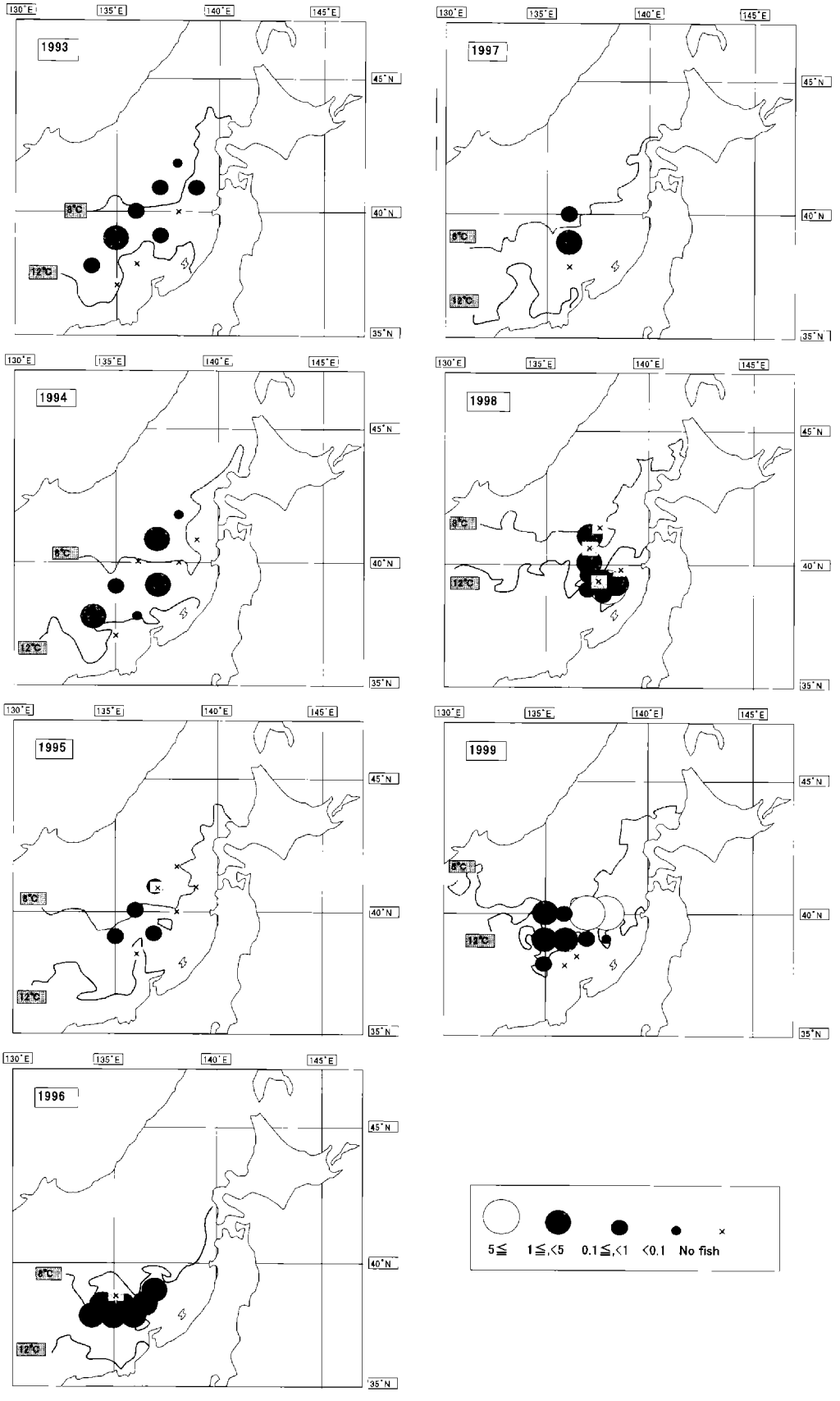

Fig. 2. CPUE (number of fish per tan of gillnets) distribution of pink salmon in the springs of 1993-1999.

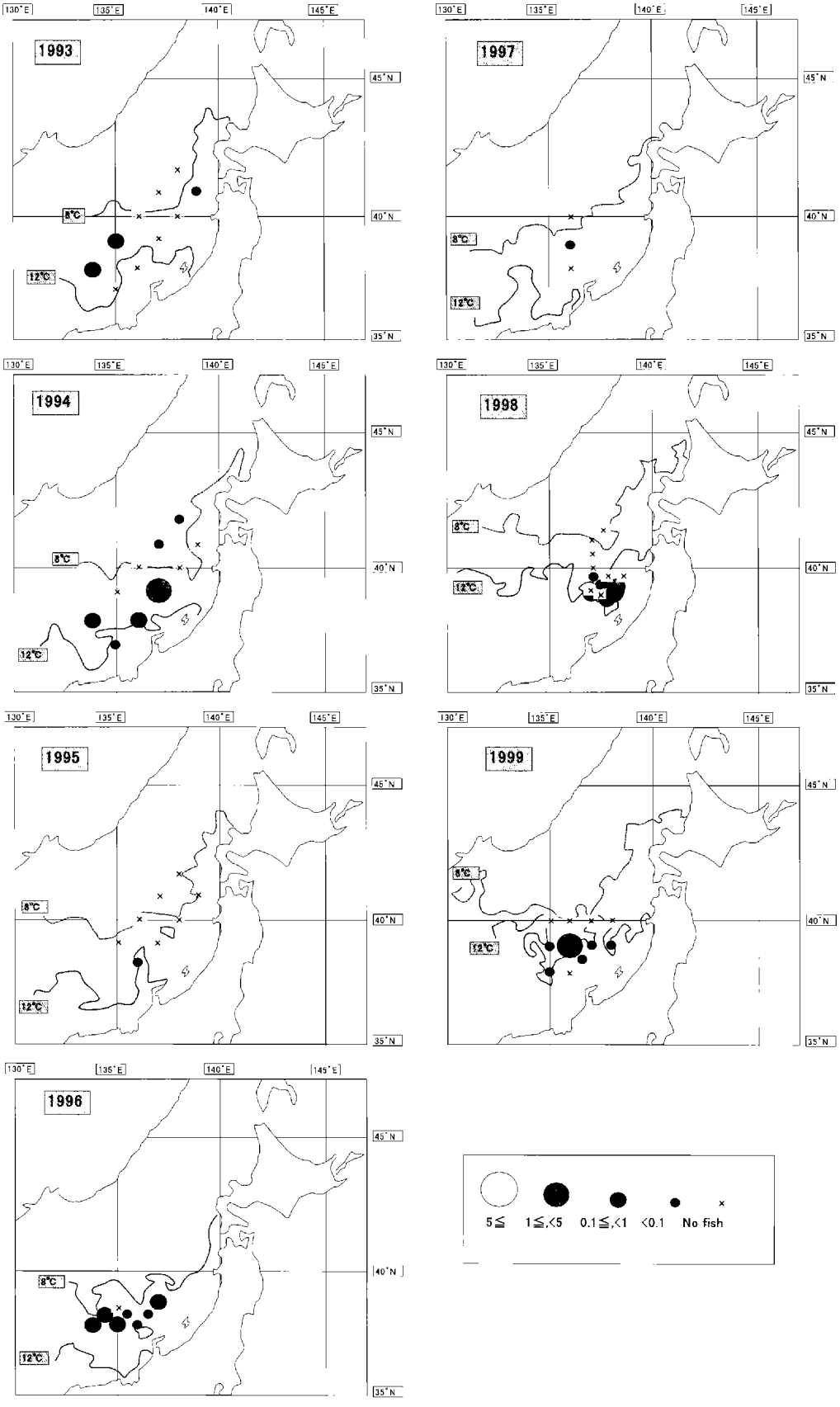

Fig. 3. CPUE (number of fish per tan of gillnets) distribution of masu salmon in the springs of 1993-1999.

Table 2. Number and CPUE of fish obtained in the Sea of Japan by drift gillnets.

Year	Number of fish			CPUE (catch/tan)			Pink/masu
	pink	masu	chum	pink	masu	chum	ratio
1993	181	19	0	0.362	0.038	0	9.5
1994	307	20	1	0.627	0.041	0.002	15.4
1995	114	4	0	0.259	0.009	0	28.5
1996	598	35	0	1.526	0.089	0	17.1
1997	98	1	0	0.662	0.007	0	98.0
1998	644	124	3	0.842	0.162	0.004	5.2
1999	1,464	15	5	2.716	0.028	0.009	97.6
Total	3,406	218	9	1.040	0.067	0.003	15.6

were caught at higher water temperature locations. In 1998 and 1999 masu salmon were not caught at stations north of 40°N, although pink salmon were distributed at these stations. Density of masu salmon was high at stations south of 40°N (Fig. 3). Masu salmon are caught only at relatively high temperatures (8.5-14°C), and are not caught at SSTs under 8.5°C (Fig. 4). Similar to masu salmon, CPUEs of pink salmon were higher at 8-13°C SSTs, but CPUEs of more than 2 fish per tan were recorded at lower SSTs (4-7°C). High CPUEs (more than 5 fish per tan) were recorded three times, and occurred at SSTs of 12-13°C. Thus, masu salmon were distributed in relatively warm waters, and pink salmon were distributed not only in these warm waters but also in colder waters.

Biological characters of pink and masu salmon

In 1997, the number of pink salmon caught was small, and their body size was small because of the early (mid February) sampling period (Table 3). Body size in odd years was large (average FL over 400 mm, BW range 750- 950 g, and CF around 12), except for the fish caught in 1997. In even years, body size was small (average FL 360-390 mm, BW range 500-700 g, and CF around 11). The sex ratio was almost even (51.2% female, 48.8% male).

Female masu salmon were the dominant (70.3%, Table 4). There was no clear correlation between FL and CF for either sex (Fig.5). GSIs of males were consistently lower than 1% over the entire range of BWs. Large females over 2,000 g had GSIs of 3-4%, and GSIs of smaller females ranged from 1% to 5%. For male fish there was no clear correlation between CF and GSI, but there was a clear positive correlation for female fish (Fig. 5).

Among 151 from total of 222 masu salmon (including 7 fish caught by longline, and excluding 71 fish with regenerated scales), 37 out of 108 females and 17 out of 43 males were age 2.1 fish (35.8% of the total) (Table 5).

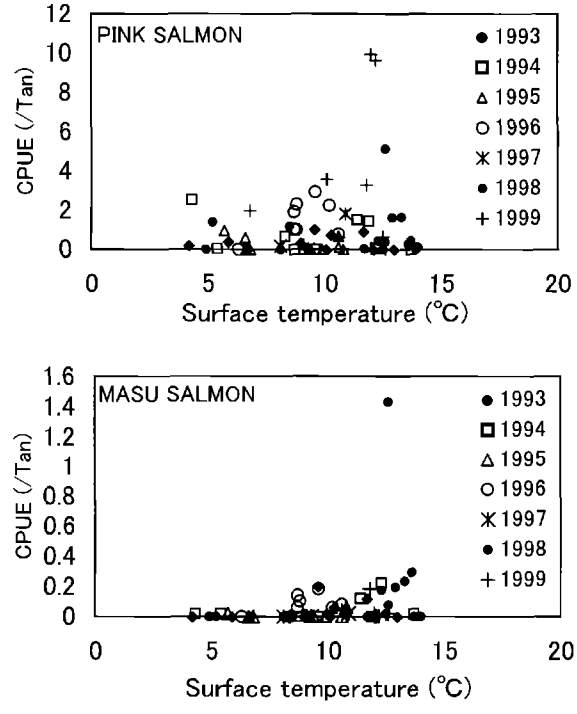

Fig. 4. Relations between sea surface temperature (SST) and CPUE (number of fish per tan of gillnets) of pink and masu salmon.

Discussion

In the Japan Sea pink and masu salmon were distributed over a wide range of SSTs (4.2-13.7°C for pink salmon, 4.3-13.6°C for masu salmon). The abundances of masu salmon, however, were higher at warmer temperatures (≧8°C). This differed from previous informa-

Table 3. Average fork length (FL), body weight (BW), condition factor (CF), and gonad somatic index (GSI) of pink salmon caught in the sea of Japan. N, number of samples; F, female; M, male.

Year	Sex	N	FL (mm)	BW (g)	CF	GSI (%)
1993	F	98	398	759	11.90	1.49
	M	65	405	806	11.93	0.55
1994	F	120	370	598	11.69	1.29
	M	162	381	658	11.66	0.42
1995	F	54	414	881	12.31	1.66
	M	46	422	940	12.36	0.48
1996	F	276	362	519	10.79	1.57
	M	298	374	574	10.68	0.57
1997	F	49	307	318	10.96	0.83
	M	42	315	352	11.03	0.09
1998	F	276	369	568	11.10	1.88
	M	287	387	692	11.50	0.66
1999	F	387	418	907	12.34	1.85
	M	303	409	863	12.21	0.60

Table 4. Average fork length (FL), body weight (BW), condition factor (CF), gonad somatic index (GSI) and sex ratio of masu salmon caught in the sea of Japan. N, number of samples; F, female; M, male.

Year	Sex	N	FL (mm)	BW (g)	CF	GSI (%)	Sex ratio (%)
1993	F	14	424	971	12.5	2.12	63.6
	M	8	409	853	12.3	0.52	36.4
1994	F	11	448	1,388	14.7	2.08	55.0
	M	9	448	1,300	13.5	0.29	45.0
1995	F	3	415	1,070	14.7	2.37	75.0
	M	1	470	1,610	15.5	0.50	25.0
1996	F	27	421	948	12.5	2.05	69.2
	M	12	424	1,045	12.6	0.52	30.8
1997	F	0	–	–	–	–	0
	M	1	311	374	12.4	0.11	100
1998	F	95	453	1,563	16.2	2.83	77.2
	M	28	466	1,762	16.3	0.59	22.8
1999	F	6	415	1,028	14.2	2.76	46.2
	M	7	440	1,214	14.2	0.39	53.8

tion that pink salmon were distributed at higher temperatures and in more southern waters than masu salmon (Shimomura et al. 1962). Takagi et al. (1982), however, reported that the SST distribution of pink salmon ranged from 3℃ to 15℃, and that the most favorable temperature range was 4-11℃. Machidori and Kato (1984) suggested that masu salmon were distributed at SSTs higher than 7-8℃ in the Sea of Japan. These historical data support our results. Azuma (Abstracts for the 1994 Annual Meeting of the Japanese Society of Fisheries Science, p. 106) concluded that in the Sea of Japan pink salmon distribution depends on prey distribution, and masu salmon distribution depends more on salinity and water temperature than on prey distribution. Thus, distributions of pink and masu salmon may be affected not only by water tem-

perature, but also by prey density, salinity, and other factors (Machidori and Kato 1984). In addition, long term fluctuations have been observed in SST anomalies in the Sea of Japan. Hirai (1995) reported that SSTs decreased in the first half of 1960s, and that low temperatures continued until the 1980s. In the 1990s Sea of Japan waters shifted again to relatively high temperatures. In 1993-1997, the position of 8°C water along 135°E was located around 40°N; however, the position of 8°C water moved northward in 1998, resulting in warmer conditions in 1998. To clarify the mechanisms affecting salmon distribution and abundance of pink and masu salmon in the Sea of Japan, water temperature, salinity, prey abundance, and other phenomena influenced by changes in oceanographic structure should be investigated. Pink salmon were not caught during the mid-winter research cruise in February 1997, although previous surveys showed a high abundance of pink salmon in southern waters of the Sea of Japan in February (Hiyama and Markovtsev 1993). Only three fishing operations were conducted in 1997, but our results indicated that pink salmon might migrate to waters south of our fishing stations at 38-40°N.

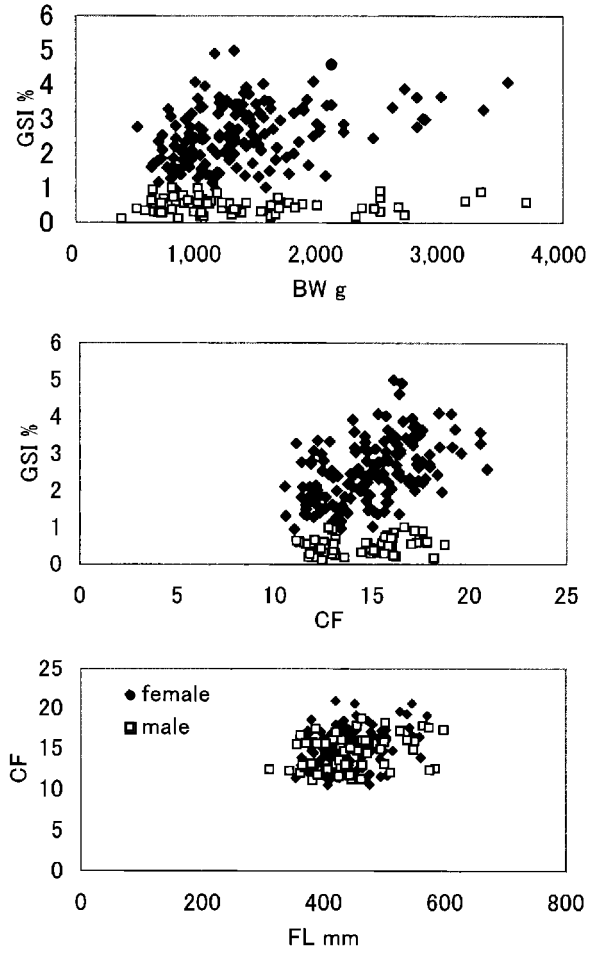

Fig. 5. Relationships between body weight (BW) and gonad somatic index (GSI), condition factor (CF) and GSI, and fork length (FL) and CF, of masu salmon.

Table 5. Age compositions of masu salmon caught in the Sea of Japan in 1993-1999.

	Age		
	1.1	2.1	Total
Female	71 (65.7)*	37 (34.3)	108 (100)
Male	26 (60.5)	17 (39.5)	43 (100)
Total	97 (64.2)	54 (35.8)	151 (100)

*Number (%)

Body size of pink salmon was negatively correlated with stock abundance (Takagi et al. 1982). The abundance of maturing pink salmon stocks in the Sea of Japan changed from an even- to an odd-year dominance cycle in 1962, and recently the even-year stock has become abundant again. Except for 1999, we observed higher CPUEs and smaller body sizes in even years (Tables 2 and 3). In addition, data from March-May surveys in 1978-1991 showed a negative correlation between CF and stock abundance (Hiyama et al. 1998). Pink salmon CFs in our study ranged from 10.5 to 12.5, which were within the range shown by Hiyama et al. (1998). This correlation may be useful for stock assessment in the future, if stock abundance could be estimated from the condition factor. The average body sizes of masu salmon (443 mm in FL, 1,360 g in BW) were slightly larger and the sex ratio was almost the same as in an earlier survey from mid to late April 1962-1972 (421-436 mm in FL, 1,093-1,227 g in BW, 66.3% female / 33.7% male; Machidori and Kato 1984).

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References

Hiyama, Y., S. Hasegawa, and F. Kato 1998. Density dependent effects on body weight of the pink salmon in the Japan Sea. Bull. Japan Sea Natl. Fish. Res. Inst., 48: 17-25.

Hiyama, Y., and V. G. Markovtsev 1993. Pink salmon, *Oncorhynchus gorbuscha*, in the southern open water

of the Japan Sea in February 1991. Bull. Japan Sea Natl. Fish. Res. Inst., 43: 125-128.
INPFC. 1963. Annual Report 1961. Int. North Pac. Fish. Comm. p. 167.
Kaeriyama, M. 1985. Adaptation and differentiation of *Oncorhynchus*. Aquabiology, 7: 426-432. (In Japanese.)
Kato, M. 1971. Sex ratio, fecundity and migration of the masu salmon, *Oncorhynchus masou* (Brevoort), during the marine life. Bull. Japan Sea Natl. Fish. Res. Inst., 23: 55-67. (In Japanese with English summary.)
Machidori, S., and F. Kato. 1984. Spawning populations and marine life of masu salmon (*Oncorhynchus masou*). Int. North Pac. Fish. Comm. Bull., 43: 1-138.
Shimomura, T. 1962. Review of pink salmon at present. The study of fishing ground the polar front in the Sea of Japan, 3rd year (1961). Japan Sea Regional Fisheries Research Laboratory. p. 76-78. (In Japanese.)
Takagi, K., K. V. Aro, A. C. Harrt, and M. B. Dell. 1982. Distribution and origin of pink salmon (*Oncorhynchus gorbuscha*) in offshore waters of the North Pacific. Int. North Pac. Fish. Comm Bull., 40: 1-195.
Tanaka, S. 1965. Salmon of the North Pacific Ocean part IX. Coho, chinook, and masu salmon in offshore waters. 3. A review of the biological information on masu salmon (*Oncorhynchus masou*). Int. North Pac. Fish. Comm. Bull., 16: 75-135.

日本海のカラフトマスおよびサクラマスの分布と生物学的特徴

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1993年から1999年までに行った日本海での日ロ共同のサケ・マス調査結果に基づき，カラフトマスとサクラマスの分布と生物学的特徴について総括し，過去の知見との比較検討を行った．カラフトマスは表面水温が8-13℃で比較的高いCPUEを示したが，5℃前後の低い水温においても漁獲がみられた．これに対し，サクラマスはカラフトマス同様8-14℃の範囲で漁獲されていたが，それ以外の水温帯での漁獲はみられなかった．カラフトマスの体サイズは越冬時期の2月に調査を行った1997年を除き，奇数年に大きく，偶数年に小さい値を示した．カラフトマスの性比はほぼ1:1であった．サクラマスは採捕されたうちの約70%がメスで占められており，年齢査定の結果1.1年魚は64%，2.1年魚は36%であった．

Appendix 1. Data of experimental gillnet fishing in the Sea of Japan from 1993 to 1999.

Year	Month	Date	Location		SST	No. of gill	Catch number		CPUE	
			N	E	°C	net (tan)	pink	masu	pink	masu
1993	4	16	42°00′	138°00′	6.7	50	1	0	0.020	0.000
		17	41°00′	139°00′	10.3	50	37	3	0.740	0.060
		18	40°00′	138°00′	10.1	50	0	0	0.000	0.000
		19	41°00′	137°00′	4.2	50	10	0	0.200	0.000
		20	40°00′	136°00′	5.9	50	20	0	0.400	0.000
		21	39°00′	137°00′	9.0	50	16	0	0.320	0.000
		22	38°00′	135°59′	12.1	50	0	0	0.000	0.000
		23	39°00′	135°00′	9.6	50	51	10	1.020	0.200
		24	38°11′	134°02′	11.7	50	46	6	0.920	0.120
		25	36°55′	135°05′	13.0	50	0	0	0.000	0.000
1994	4	17	42°00′	138°00′	5.4	49	2	1	0.041	0.020
		18	41°00′	139°00′	8.7	49	0	0	0.000	0.000
		19	40°00′	138°00′	9.1	49	0	0	0.000	0.000
		20	41°00′	137°00′	4.3	49	124	1	2.531	0.020
		21	40°00′	136°00′	9.6	49	0	0	0.000	0.000
		22	39°00′	137°00′	11.9	49	71	0	1.499	0.000
		23	38°00′	136°00′	12.3	49	3	11	0.061	0.244
		24	39°00′	135°00′	8.3	49	33	0	0.673	0.000
		25	38°00′	134°00′	11.4	49	74	6	1.510	0.122
		25	36°55′	135°05′	13.7	49	0	1	0.000	0.020
1995	4	21	38°00′	136°00′	10.8	49	0	3	0.000	0.061
		22	39°00′	135°00′	10.6	49	5	0	0.102	0.000
		23	40°00′	136°00′	6.6	49	29	0	0.592	0.000
		24	39°00′	137°00′	10.6	49	33	0	0.673	0.000
		25	40°00′	138°00′	9.9	49	0	0	0.000	0.000
		26	41°00′	137°00′	5.7	49	47	1	0.959	0.020
		27	42°00′	138°00′	6.8	49	0	0	0.000	0.000
		28	41°00′	139°00′	9.4	49	0	0	0.000	0.000
		29	41°00′	137°00′	6.6	49	0	0	0.000	0.000
1996	4	18	38°00′	136°00′	10.2	49	110	3	2.245	0.061
		20	38°00′	134°00′	8.7	49	50	7	1.020	0.143
		21	38°45′	135°45′	6.3	49	0	0	0.000	0.000
		22	39°00′	137°00′	8.8	49	113	5	2.306	0.102
		23	38°30′	136°30′	8.7	49	94	3	1.918	0.061
		24	38°00′	135°00′	9.6	49	144	9	2.939	0.184
		25	38°30′	134°30′	8.8	49	49	5	1.000	0.102
		26	38°30′	135°30′	10.6	49	38	4	0.776	0.082
1997	2	11	40°00′	136°06′	8.1	50	9	0	0.180	0.000
		14	39°00′	136°00′	10.9	49	89	1	1.816	0.020
		15	38°00′	136°00′	9.3	49	0	0	0.000	0.000

Appendix 1. (continued)

Year	Month	Date	Location		SST	No. of gill	Catch number		CPUE	
			N	E	°C	net (tan)	pink	masu	pink	masu
1998	4	20	41°20′	137°10′	4.9	51	0	0	0.000	0.000
		21	41°01′	137°01′	5.2	51	71	0	1.392	0.000
		22	40°30′	137°00′	8.1	51	0	0	0.000	0.000
		23	40°00′	137°00′	8.5	51	60	0	1.176	0.000
		24	39°30′	137°00′	12.6	51	20	4	0.392	0.078
		25	39°00′	137°00′	13.6	51	14	15	0.275	0.294
		26	39°17′	137°25′	12.5	51	0	1	0.000	0.020
		27	38°30′	137°30′	12.3	51	22	9	0.431	0.176
		30	39°10′	138°21′	12.9	51	82	10	1.608	0.196
	5	1	39°00′	138°00′	12.6	51	261	73	5.118	1.431
		2	39°00′	137°10′	13.7	51	22	0	0.431	0.000
		4	39°00′	137°00′	11.7	51	2	0	0.039	0.000
		5	39°00′	136°00′	13.3	51	84	12	1.647	0.235
		6	39°30′	137°30′	14.0	51	6	0	0.118	0.000
		7	39°30′	138°30′	13.9	51	0	0	0.000	0.000
1999	4	17	38°00′	135°01′	10.6	49	29	2	0.592	0.041
		18	39°00′	135°00′	10.1	49	175	1	3.571	0.020
		19	40°00′	135°00′	6.8	49	96	0	1.959	0.000
		20	40°00′	136°00′	9.1	49	11	0	0.224	0.000
		21	39°00′	136°01′	11.8	49	161	9	3.286	0.184
		22	38°00′	136°00′	12.1	49	0	0	0.000	0.000
		23	38°30′	136°30′	12.6	49	0	1	0.000	0.020
		24	39°00′	137°00′	12.5	49	31	1	0.633	0.020
		25	40°00′	137°00′	12.0	49	486	0	9.918	0.000
		27	40°00′	138°00′	12.2	49	472	0	9.633	0.000
		28	39°00′	138°00′	12.0	49	3	1	0.061	0.020
Total						3,275	3,406	219	1.040	0.067