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ABSTRACT

The Fisheries Agency of Japan (FAJ) conducted the second international cooperative trans-Pacific survey on wintering salmon (*Oncorhynchus* spp.) in the North Pacific Ocean aboard the R/V Kaiyo-maru from 5 January to 29 January 1996. A similar survey by FAJ was conducted aboard the Kaiyo maru in December 1992. Four Japanese scientists, one US scientist, one Canadian scientist, and one Russian scientist took part in the 1996 survey. The vessel was used to sample standard transects in the western, central, and eastern North Pacific Ocean. The objective of the survey was to elucidate the ecology and distribution of wintering salmon. A large (208 m long, 63.2 m head rope) trawl was used to catch salmon from the surface to 50 m. The survey included 22 surface trawl operations for collecting salmon and 23 oceanographic stations using a CTD system. Plankton were sampled at all trawl stations with NORPAC and bongo nets. Oceanographic and plankton data were also sampled continuously at the surface with an EPCS system. The total catch of salmon was 1,346 fish (51 sockeye, 767 chum, 439 pink, 57 coho, and 32 chinook salmon). In the western North Pacific Ocean, young (ocean age .1) chum, pink, and chinook salmon accounted for most of the catch. Immature

sockeye and chum salmon (ocean age .2 or older) occurred mainly in the central and eastern North Pacific. These results suggest that immature (including young) sockeye and chum salmon migrate eastward from the western to central North Pacific Ocean in winter. Chum, pink, and coho salmon were larger in mean fork length and higher in mean condition factor in the Gulf of Alaska than in the western North Pacific Ocean. The oceanographic data indicated that in January the thermocline is deeper and the halocline is shallower in the central and eastern North Pacific than in the western North Pacific. The EPCS survey showed that high-temperature areas generally coincided with areas of low zooplankton density.

INTRODUCTION

Scientific research activities conducted under the former International North Pacific Fisheries Commission (INPFC) provided a considerable amount of information on the ocean ecology and stocks of salmon in the North Pacific Ocean in summer. However, little is known about the winter ocean ecology of salmon, because rough weather in winter has often prevented surveys in offshore waters of the North Pacific Ocean. The Fisheries Agency of Japan (FAJ) carried out the first trans-Pacific salmon survey in the early winter (December) of 1992 using a large stern trawler, the R/V Kaiyo maru (Nagasawa et al. 1993). The results of this survey indicated : (1) the upper thermal limit of salmon habitat in winter is lower than that in summer (lower than 8℃), (2) the area of winter habitats of salmon is smaller than that in summer, and (3) stomach content weights of salmon in winter are lower than those in summer, which may indicate a shortage of food.

In 1996, FAJ conducted the first trans-Pacific salmon survey in mid-winter (January) using the R/V Kaiyo-maru. The main objective of this research was to further understand the ecology of salmon in mid-winter in the North Pacific Ocean, and to compare the results to those of previous research in the early winter (December) of 1992. The 1996 research focused on three questions: (1) where are salmon wintering habitats? (2) how do severe winter conditions affect the survival and growth of salmon? and (3) how do environmental factors (especially, primary and secondary production) change in winter? Four Japanese scientists, one U.S. scientist, one Canadian scientist, and one Russian scientist took part in this survey.

METHODS

Research Vessel, Cruise Itinerary, and Study Area

The R/V Kaiyo maru is a 2,630 gross tonnage, 93 m stern trawler that belongs to FAJ. The R/V Kaiyo maru left port in Tokyo on 4 January 1996. Trawl operations for collecting salmon were conducted at 23 stations from 8 January to 26 January 1996. The R/V Kaiyo maru arrived in port in Seattle on 29 January 29 1996. The survey area was in the western and central North Pacific Ocean and the Gulf of Alaska, from 38°-56°N, 155°E-144°W. Three north-south transects and two diagonal transects were sampled (Fig. 1).

Fishing Operations and Biological Sampling

A surface trawl ("spider net", 208-m long, 63.2 m head rope, 400 m warp, and a cod end made of 11 mm knotless mesh) was used to catch salmon. the same net was used in the December 1992 survey. The trawl fished from the surface to 50 m, and was towed at approximately 5 knots for one hour at each station. Immediately after the trawl was hauled, the catch was taken to a shipboard laboratory and sorted to species. The fork lengths (FL) and body weights (BW) of salmon were measured. Scales were taken for later age determination. Blood serum was collected from sub-samples of salmon in the catch for growth and maturity studies. The salmon collected were numbered with paper tags for subsequent identification and frozen whole at -40℃ in aluminum trays. Bycatch organisms were also sorted by species, and body lengths and weights were measured. When individuals of bycatch organisms were too numerous to count, the entire catch was weighed, and numbers were estimated from a subsample. A subsample of the bycatch was frozen at -40℃ for later examination.

When the R/V Kaiyo-maru returned to Japan, the frozen salmon were transported to the National Research Institute of Far Seas Fisheries (NRIFSF), and processed for FL, BW, sex, gonad weight, and stomach contents. Tissue samples were taken for electrophoretic analysis for stock identification and other studies. Bycatch specimens were similarly processed.

Acoustic Survey

The vertical distribution of salmon was investigated with an echo sounder (FE-1282 dual beam system). The echo sounder was used during trawl operations, while the vessel was traveling between stations.

Oceanographic Survey

Before or after trawl operations, a CTD was used to collect data on temperature, conductivity, depth, dissolved oxygen, and light intensity from the surface to 1,500 m. Seawater was collected by a bucket at surface and by a CTD Rosette sampling system at 24 depths. Seawater nutrients (NO_2+NO_3, SiO_2, PO_4) and chlorophyll a were determined within a day of sampling. Zooplankton was collected at the fishing stations. A remodelled NORPAC net and bongo nets with an attached a flow-meter were used. The nets were hauled vertically from 150 m. Zooplankton was preserved in a 10% Formalin seawater solution.

Other Surveys While Underway

Primary production was measured every morning at four sampling depths (including surface). An EPCS system monitored temperature, salinity, dissolved oxygen, chlorophyll a, and zooplankton at the surface during the cruise. An ADCP system measured and recorded vertical distribution of currents during the cruise. XBT probes to measure the vertical thermal structures were cast at every 1 degree longitude or 0.5 degree latitude.

RESULTS AND DISCUSSION

Salmon Catch and Distribution

Table 1 provides information from each tow and CTD observation on the date, location, sea surface temperature (SST; ℃), and number of salmon collected by species. Figs. 2-4 show the distribution of salmon catches by species and age (year). Total catch of salmon was 1,346 fish (51 sockeye, 767 chum, 439 pink, 57 coho, and 32 chinook salmon). Sockeye salmon occurred in the northern part of the central North Pacific Ocean and the Gulf of Alaska (Fig. 2). No sockeye salmon were found in the western North

Pacific Ocean. Many of sockeye salmon were old (ocean ages .2 and .3) and only two young sockeye (in their first winter at sea; ocean age .1) were caught in the central North Pacific Ocean.

Young chum salmon (in their first winter at sea; 0.1) were abundant in the northern part of western North Pacific Ocean (Fig. 3). In contrast, older chum salmon (0.2, 0.3, and 0.4) mainly occurred in the northern part of the central North Pacific Ocean and the Gulf of Alaska. Pink salmon were abundant in the central and western North Pacific Ocean (Fig. 4). A few pink salmon occurred in the Gulf of Alaska. Coho salmon were found in the central North Pacific and the Gulf of Alaska (Fig. 4). No coho salmon were caught in the western North Pacific Ocean. Chinook salmon were abundant in the northern part of the western North Pacific Ocean. Many of them were in their first year at sea (ocean age .1).

The results of this survey show that young chum and pink salmon (0.1) were very abundant in the northern part of the western North Pacific Ocean. Nagasawa et al. (1993) reported that there were few young chum and pink (0.1) salmon in this area in December 1992. This indicates that young chum and pink salmon may move to offshore waters from coastal waters in January.

Nagasawa et al. (1993) also reported that a few immature sockeye (older than ocean age .2) and many immature chum salmon (older than 0.2) were distributed in this area in December. On the other hand, in January 1996 few immature sockeye and chum salmon were caught in this area, and they were relatively abundant in the central North Pacific Ocean. French et al. (1976) and Neave et al. (1976) found that young sockeye (ocean age .1) and chum (0.1) salmon also did not occur in this area in early spring. These results suggest that immature (including young) sockeye and chum salmon migrate eastward from this area (the northern part of the western North Pacific Ocean) to central North Pacific Ocean in winter. Furthermore, this indicates that this area is not suitable for wintering of immature sockeye and chum salmon.

A survey in more northerly areas, including the U.S. and Russian 200-mile zones, is needed to confirm this possible eastward migration of immature sockeye and chum salmon. Sockeye (except for ocean age .1), chum, pink, and coho salmon were widely distributed in the Gulf of Alaska, which suggests that the Gulf of Alaska is a better wintering area for salmon than the northwestern North Pacific Ocean.

Biological Data and Geographic Differences in Salmon

Table 2 shows average folk length (FL; mm), body weight (BW; g), and condition factor (FL: BW/FL^{3}x10^7) by species and age. The average FLs of ocean ages .1 and .2 sockeye salmon were 429 mm and 539 mm. The average FLs of ocean ages .2 and .3 sockeye salmon are not much different from previous data reported by French et al. (1976). The average FLs of 0.1, 0.2, and 0.3 chum salmon were 234, 386, and 501 mm. These averages were considerably smaller than the averages for fish of the same ages that were reported by Salo (1991).

We divided the survey area into three sub-areas in order to evaluate geographical differences in biological characters (Fig 5). Table 3 provides average FLs, CFs, and indices of stomach content weight (ISC: Stomach content weight (g)/(body weight (g) - stomach content weight (g)) x 100) by species, age, and sub-area. Average FLs and CFs of chum, pink, and coho were larger in the Gulf of Alaska than in the western North Pacific Ocean. These results suggest that the Gulf of Alaska has better environmental or ecological conditions for wintering of salmon than the western North Pacific Ocean. We could not find any geographic differences in ISC.

Bycatch Organisms

Table 4 lists the species of salmonids and bycatch organisms collected by trawl in this survey. The abundances of bycatch animals were very low throughout the survey.

Acoustic Survey

The echo sounder often showed small spots on its recording papers in the survey. The occurrence of the spots coincided well with the abundance of salmon in trawl catches. A detailed analysis of the results of the echo sounding survey are presented in another report (Sakai et al. 1996).

Oceanographic Survey

Profiles of SST in January 1996 prepared by the Meteorological Agency of Japan presented in Figure 6. This figure includes data collected aboard the Kaiyo maru in January 1996. Vertical distribution of temperatures and salinities are summarized in Figs. 7-8. In the central and eastern North Pacific, the thermocline was deeper and the halocline was shallower than in the western North Pacific. the eastern part of the survey area and the halocline is shallower in the eastern part.

Other Survey While Underway

Surface temperatures and zooplankton densities (ppm), which were continuously recorded by the EPCS system, are summarized in Fig. 9. In general, high-temperature areas coincided with areas of low zooplankton density.

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REFERENCES

French R., H. Bilton, M. Osako, and A Hart. 1976. Distribution and origin of sockeye salmon (*Oncorhynchus nerka*) in offshore waters of the North Pacific Ocean. Bull. Int. North Pac. Fish. Comm., 34: 1-113.

Morris, J. F. T. and D. W. Welch. 1992. Data report from the Canadian high seas salmon cruise to the eastern North Pacific, February 27-March 25, 1992. Can. Data Rep. Fish Aquat. Sci., 884: 11 p.

Nagasawa, K., Y. Ueno, K. W. Myers, and D. W. Welch. 1993. Japan-U.S.-Canada cooperative survey on overwintering salmonids in the North Pacific Ocean aboard the Japanese research vessel Kaiyo-maru, November 25 to December 24, 1992. NPAFC Doc., National Research Institute of Far Seas Fisheries, Shimizu, 27 p.

Neave, F., T. Yonemori, and R. Bakkala. 1976. Distribution and origin of chum salmon in offshore waters of the North Pacific Ocean. Bull. Int. North Pac. Fish. Comm., 35: 1-79.

Sakai, J., Y. Ueno, Y. Ishida, and K. Nakayama. 1996. Vertical distribution of salmon determined by an acoustic survey in the North Pacific Ocean in the winter of 1996. (NPAFC Doc. 214.) National Research Institute of Far Seas Fisheries, 5-7-1 Orido, Shimizu, Shizuoka, 424, Japan. 13 p.

Salo, E. O. 1991. Life history of chum salmon (*Oncorhynchus keta*). In "Pacific salmon life histories" edited by C. Groot and L. Margolis. p. 231-310. UBC Press. Vancouver, BC.

Table 1. Catch of salmon in number by station (Sta.), date, latitude (Lat.), longitude (Long.), sea surface temperature (SST; ℃), and species during the January 1996 *Kaiyo-maru* survey. We could not make the trawl operations at stations 1-1 and 4-2.

St.a.	Date	LAT.	LONG.	SST	Salmon						By-catch			
					sock-eye	chum	pink	coho	chi-nook	Salmon total	squids	mycto phids	others	Total
1-1	96.01.08	3833.5N	15955.4E	11.7	-	-	-	-	-	-	-	-	-	-
1-2	96.01.09	3959.6N	16001.7E	8.8						0	4	0	19	23
1-3	96.01.10	4131.9N	15958.2E	8.0						0	261	1	3	265
1-4	96.01.10	4258.2N	15956.6E	5.9						0	890	1	2	893
1-5	96.01.11	4431.3N	15959.8E	4.5		76	127		4	207	560	0	1	561
1-6	96.01.11	4558.2N	16000.2E	4.5		471	33		3	507	3	0	0	3
2-1	96.01.12	4458.9N	16503.3E	5.5		2	36		19	57	26	0	1	27
2-2	96.01.13	4359.7N	17000.4E	8.7						0	76	34	5	115
2-3	96.01.14	4159.7N	17627.9E	10.4						0	7	10	5	22
3-1	96.01.17	4129.9N	16759.7W	9.4						0	33	0	2	35
3-2	96.01.17	4254.5N	16800.8W	8.6						0	836	12285	37	13158
3-3	96.01.18	4430.1N	16804.2W	7.8						0	1029	1	8	1038
3-4	96.01.18	4557.8N	16806.0W	7.3		41	223	17		281	0	0	0	0
3-5	96.01.19	4729.8N	16809.1W	6.1	9	3	5	15		32	20	450	0	470
3-6	96.01.19	4857.9N	16806.6W	5.3		1		5	4	10	141	1	0	142
4-1	96.01.20	4959.7N	16256.6W	5.1	1	5		3	1	10	0	0	0	0
4-2	96.01.21	5139.0N	15437.0W	4.5	-	-	-	-	-	-	-	-	-	-
4-3	96.01.22	5421.0N	14811.5W	4.5	27	32				59	0	0	0	0
5-1	96.01.23	5547.2N	14503.9W	4.7	2					2	1306	0	0	1306
5-2	96.01.23	5436.4N	14511.0W	4.5	9	2				11	11	250	1	262
5-3	96.01.24	5300.3N	14500.0W	4.6	3	20				23	2480	0	0	2480
5-4	96.01.24	5132.8N	14509.4W	5.8				1		1	2573	1669	0	4242
5-5	96.01.25	5004.4N	14458.8W	6.5		67	15	4	1	87	86	1	0	87
5-6	96.01.25	4829.0N	14447.6W	7.2		47		12		59	7	233	0	240
Total	-	-	-	-	51	767	439	57	32	1346	10349	14935	84	25368

Table 2. Average folk length (FL), body weight (BW), and condition factor (CF; BW/FL^3x10^7) by species and ocean age.

Species	Age	N	FL		BW		CF	
			Average mm	SD mm	Average mm	SD mm	Average mm	SD mm
sockeye	X.1	2	334.5	12.0	397.5	102.5	105.1	16.0
	X.2	31	428.7	33.9	889.0	209.6	110.7	5.6
	X.3	17	539.3	31.1	1996.1	419.2	125.7	6.9
	X.4	1	500.0	-	1371.0	-	109.7	-
chum	0.1	216	234.4	25.0	136.1	75.5	101.4	7.0
	0.2	75	386.0	43.9	612.6	259.2	100.9	9.4
	0.3	94	500.6	43.3	1319.6	343.3	103.0	10.1
	0.4	18	542.1	43.0	1672.7	361.7	103.6	7.8
	0.5	1	670.0	-	3755.0	-	124.8	-
pink	0.1	215	254.2	18.7	154.9	36.7	92.7	5.6
coho	X.1	57	352.9	34.1	513.9	158.2	116.1	15.7
chinook	X.1	29	281.0	14.6	304.3	52.2	135.9	6.4
	X.2	3	496.0	63.2	1670.3	655.0	132.6	4.1

Table 3. Comparison of average folk lengths (FL), condition factors (CF; BW (g) / FL $(mm)^3 * 10^7$) and indicies of stomach content weight of salmon by species and sub-region. A: western North Pacific Ocean, B: central North Pacific Ocean, C: Gulf of Alaska. When the number of individuals per a lot are less than 10, we did not show the averages.

species	ocean age	FL mm			CF (BW g /FL mm * 10^7)			Index of stomach content weight		
		A	B	C	A	B	C	A	B	C
sockeye	X.1	-	-	-	-	-	-	-	-	-
	X.2	-	-	443.3	-	-	111.3	-	-	0.95
	X.3	-	-	537.6	-	-	126.0	-	-	1.00
	X.4	-	-	-	-	-	-	-	-	-
chum	0.1	230.4	-	285.4	101.3	-	103.7	2.21	-	0.26
	0.2	-	364.7	403.4	-	95.8	105.7	-	1.34	0.20
	0.3	-	-	498.4	-	-	102.8	-	-	0.29
	0.4	-	-	536.8	-	-	104.4	-	-	0.66
pink	0.1	250.2	260.9	261.3	94.0	90.5	90.2	0.69	1.20	0.08
coho	X.1	-	337.2	389.8	-	118.0	111.4	-	1.65	2.48
chinook	X.1	280.8	-	-	136.1	-	-	1.19	-	-
	X.2	-	-	-	-	-	-	-	-	-

Table 4. List of organisms collected by trawl.

COELENTERATA

APPENDECULARIA

PISCES

Anguilliformes

Leptocephalus larvae

Salmoniforms

Bathylagidae gen. sp.

Salmonidae

Oncorhynchus nerka (Walbaum)

Oncorhynchus keta (Walbaum)

Oncorhynchus gorbuscha (Walbaum)

Oncorhynchus kisutch (Walbaum)

Oncorhynchus tschawytscha (Walbaum)

Stomiiformes

Sternoptychinae gen. sp.

Aulopiformes

Paralepididae gen. sp.

Alepisauridae

Alepisaurus ferox Lowe

Anotopteridae

Anotopterus pharao Zugmayer

Mictophiforms

Myctophidae

Tarletonbeania tayori Mead

Symbolopholus californiensis (Eigenmann and Eigenmann)

Myctophidae gen. spp.

CEPHALOPODA

Teuthoidea

Gonatidae

Gonatopsis borealis Sasaki

Gonatopsis makko Okutani and Nemoto ?

Berryteuthis anonychus Pearcy and Voss

Gonatus middendorffi

Gonatidae gen. spp.

Octopoteuthidae

Onychoteuthis borealijaponica Okada

Uidentified squid larvae

Octopoda

Japetella diphana ?

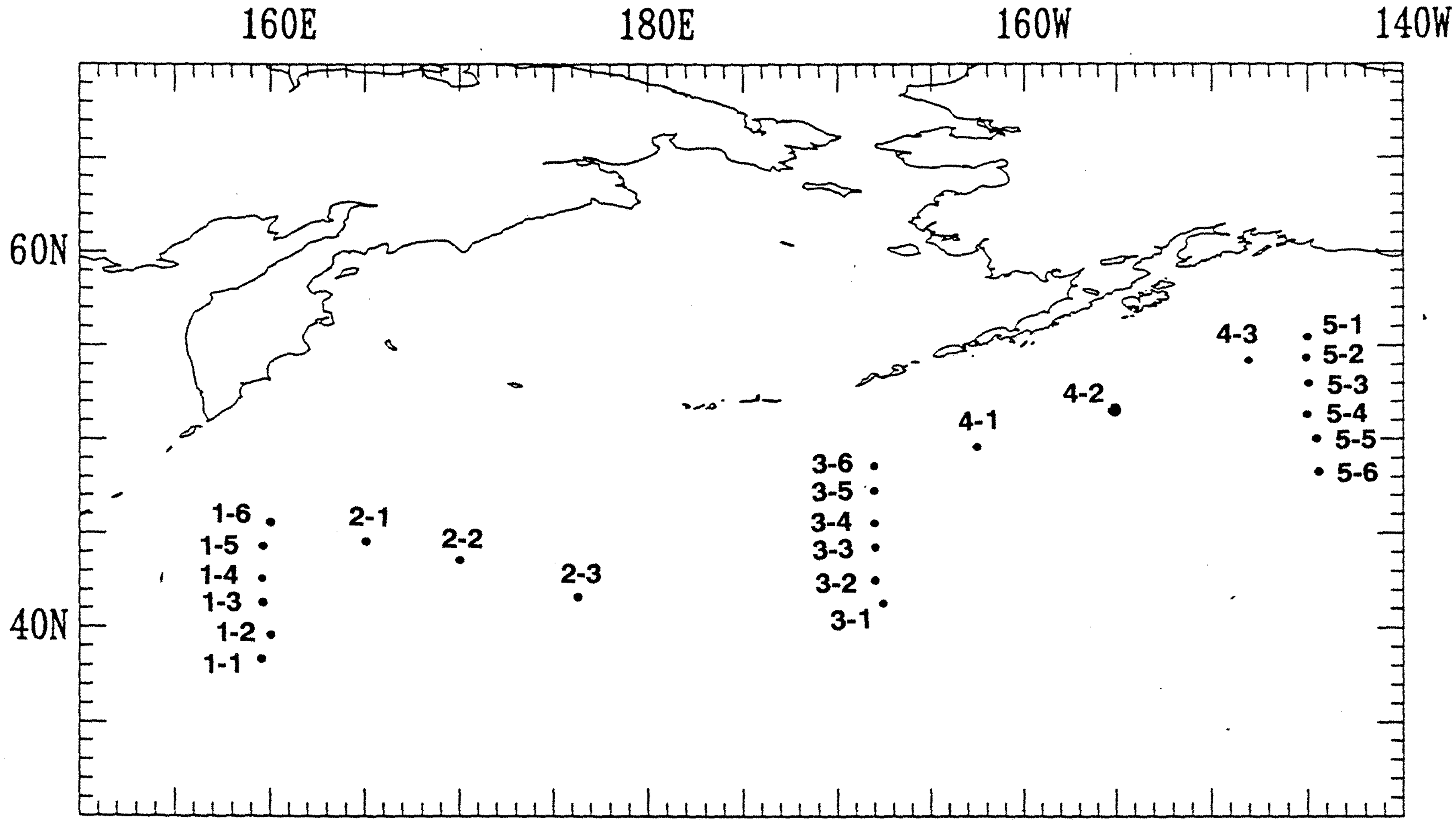

Figure 1. Research stations.

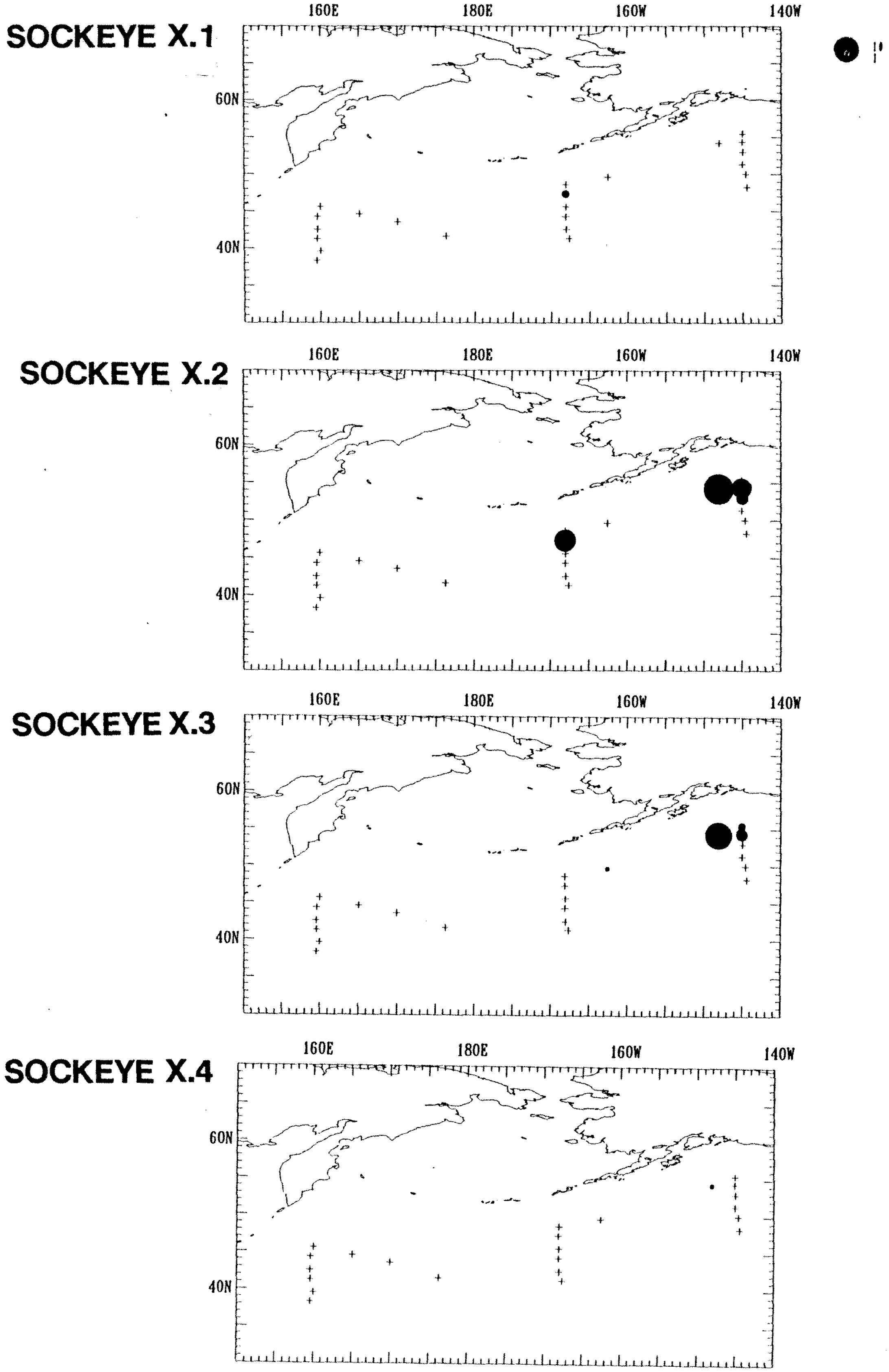

Figure 2. Distribution of sockeye salmon by age in January, 1996.

CHUM 0.1

CHUM 0.2

CHUM 0.3

CHUM 0.4

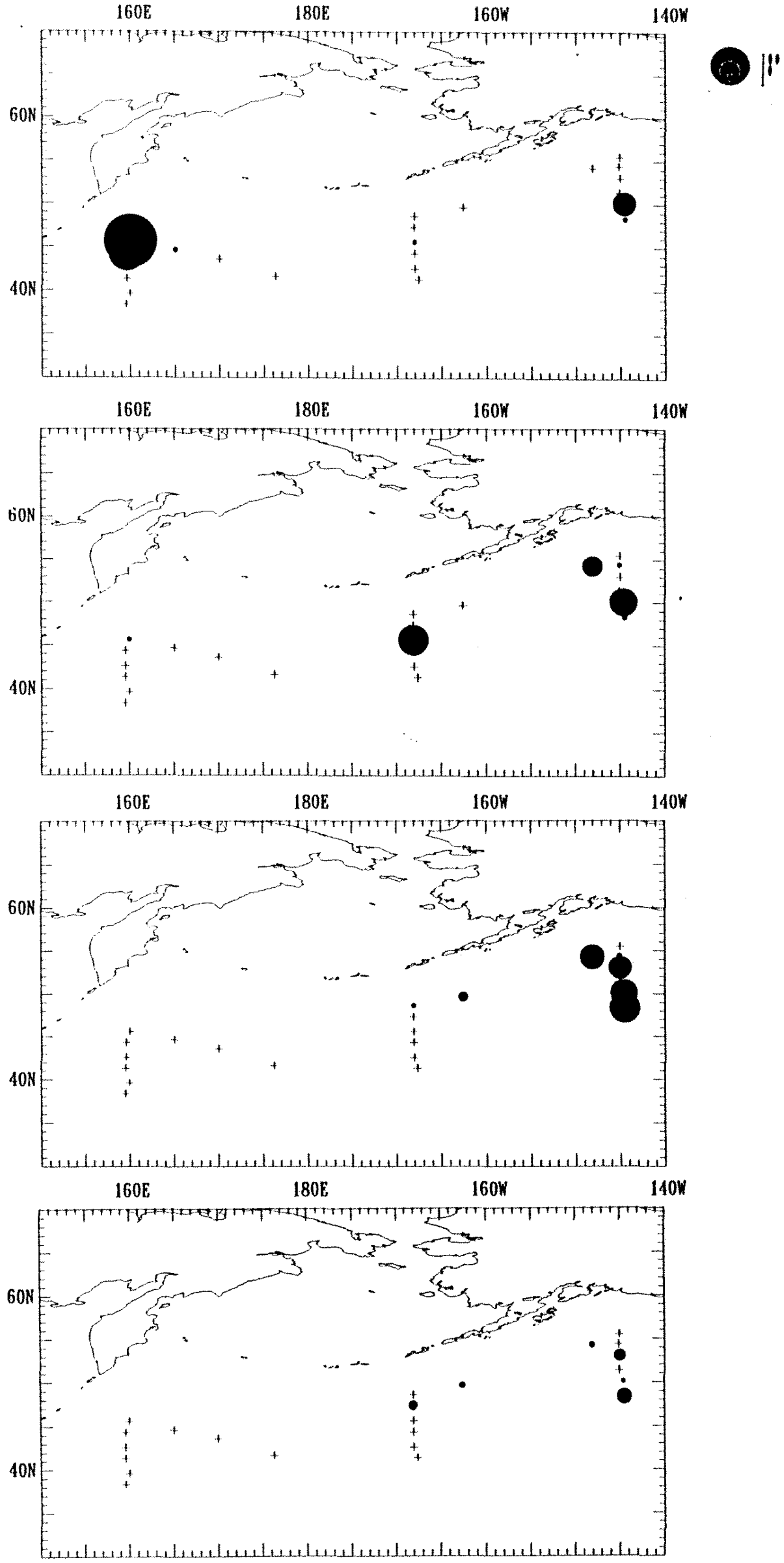

Figure 3. Distribution of chum salmon by age in January, 1996.

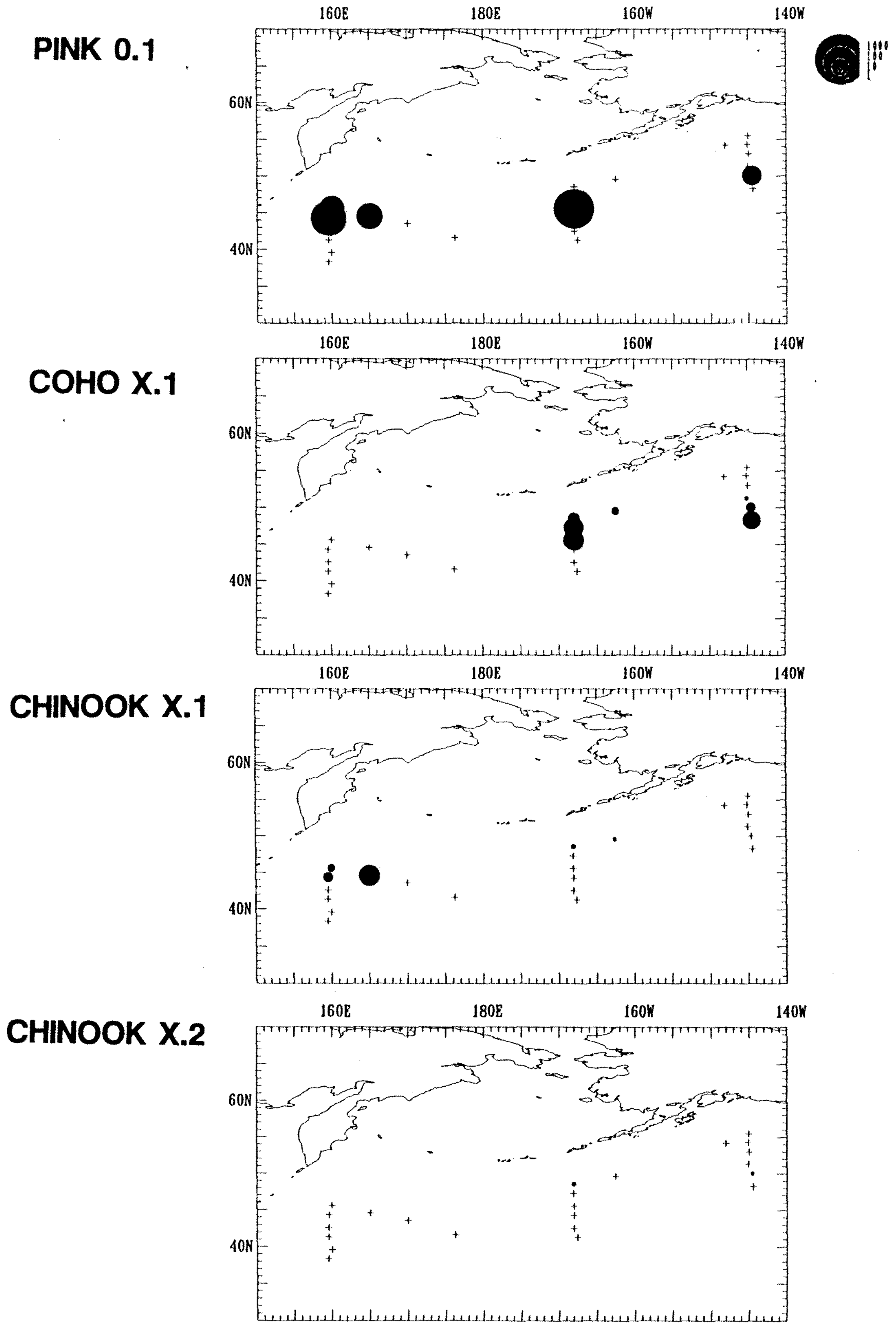

Figure 4. Distribution of pink, coho, and chinook salmon in January, 1996.

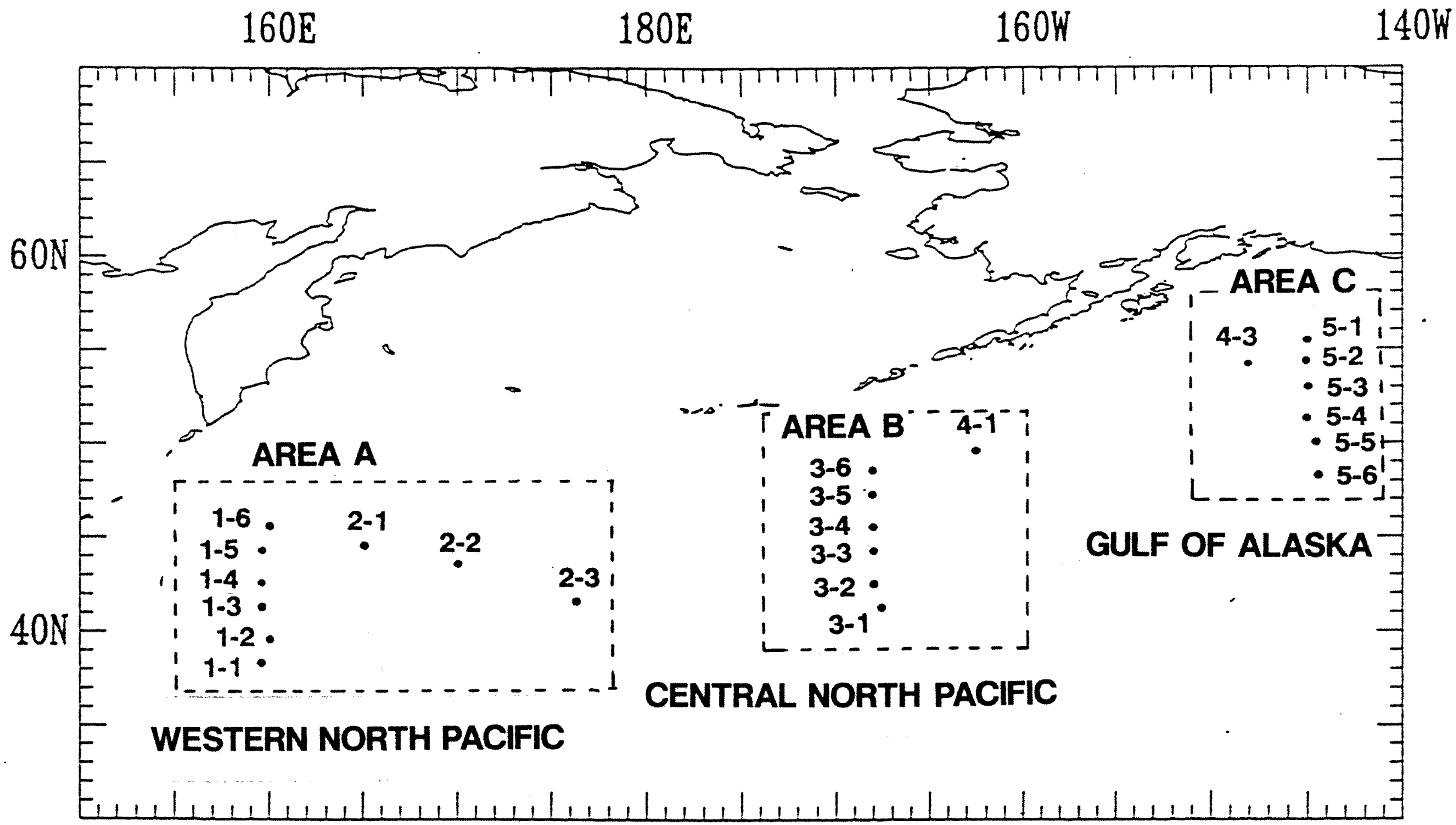

Figure 5. Sub-areas for analyses of FL, CF, and ISC of salmon.

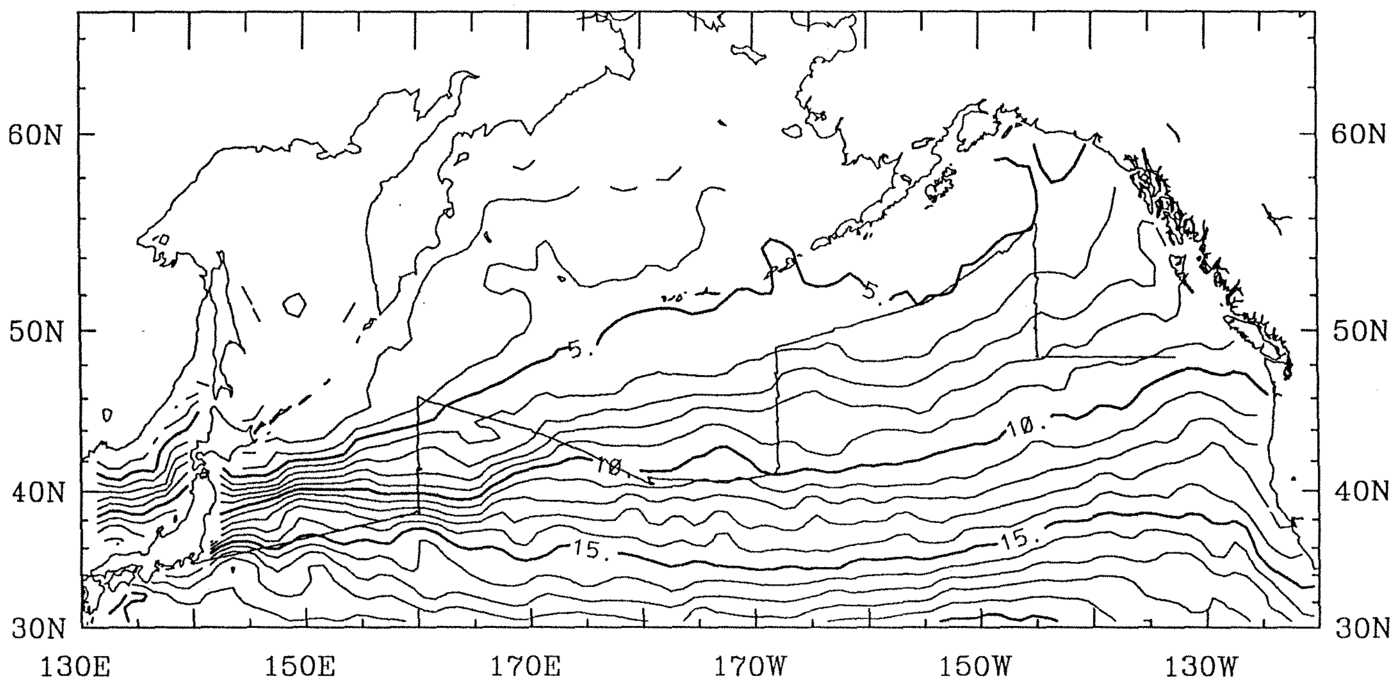

Figure 6. SST distribution in January, 1996

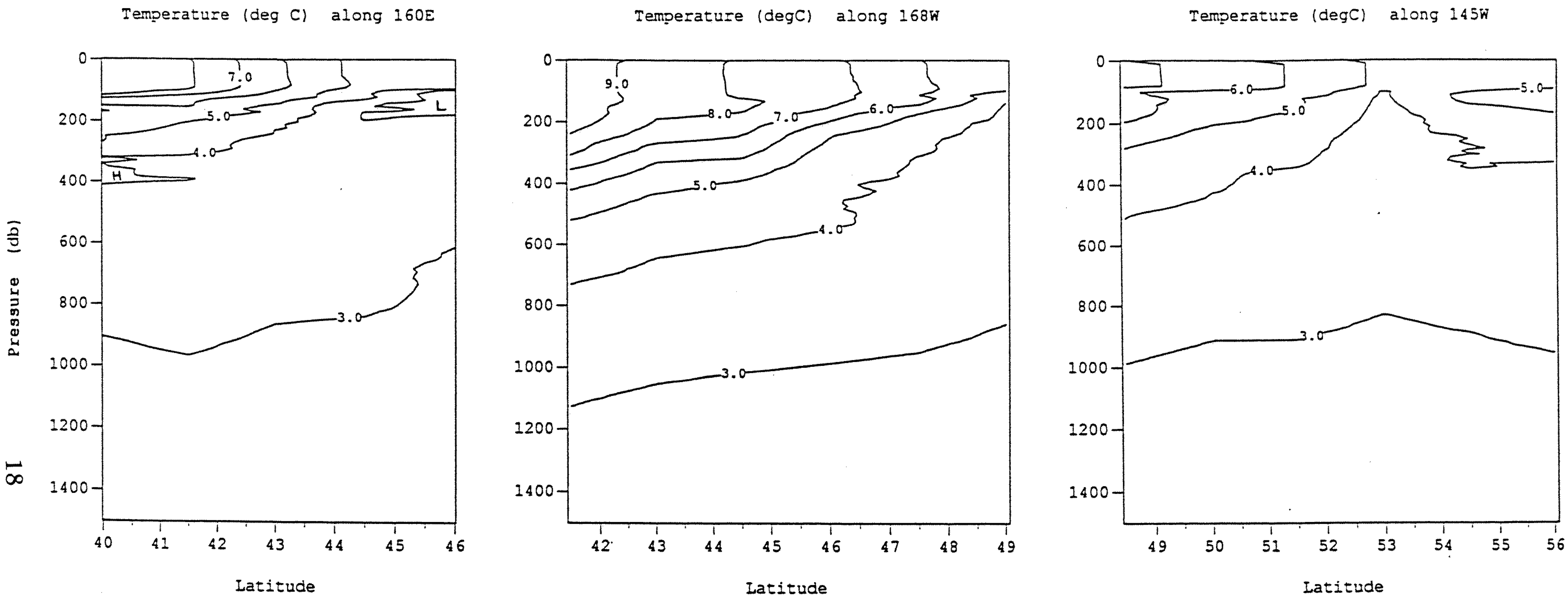

Figure 7. Vertical distribution of temperature along the north-south transects.

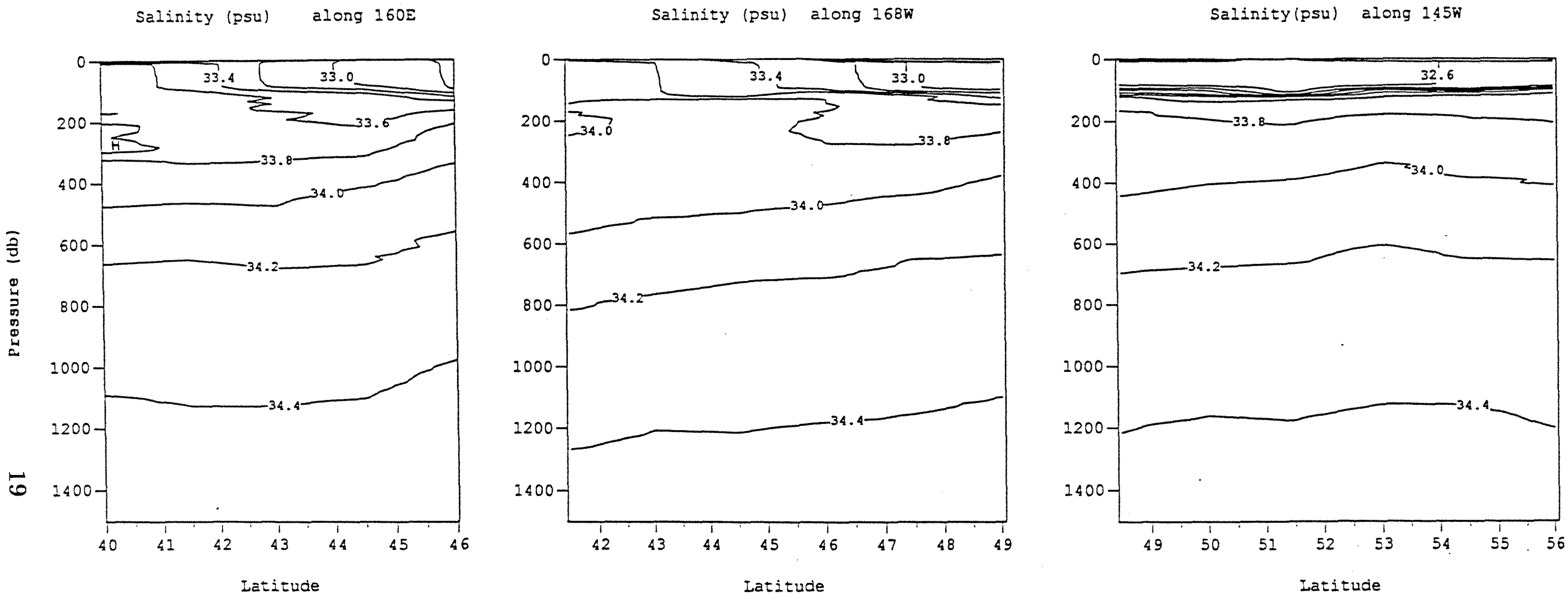

Figure 8. Vertical distribution of salinity along the north-south transects.

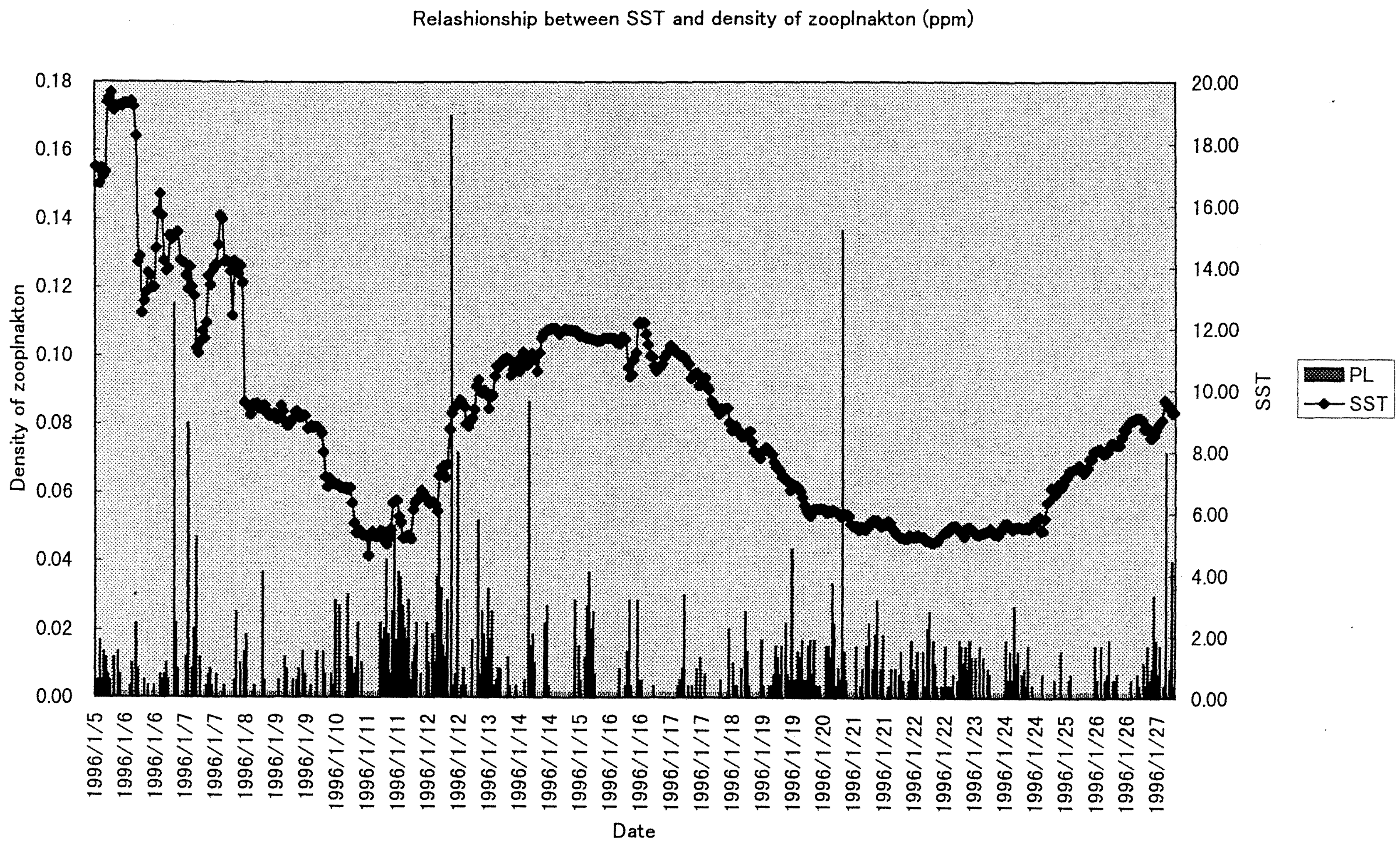

Figure 9. SST and density of zooplankton during the survey.