

Japan-Russia-U.S. Cooperative Survey
on Overwintering Salmonids
in the Western and Central North Pacific Ocean
and Bering Sea aboard the *Kaiyo Maru*,
3 February-2 March, 1998

by

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Submitted to the
NORTH PACIFIC ANADROMOUS FISH COMMISSION
by
JAPAN, RUSSIA, AND THE UNITED STATES OF AMERICA
October 1998

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:

Ishida, Y., Y. Ueno, A. Shiimoto, T. Watanabe, T. Azumaya, M.V. Koval,
and N. D. Davis. 1998. Japan-Russia-U.S. cooperative survey on
overwintering salmonids in the western and central North Pacific Ocean
and Bering Sea aboard the *Kaiyo Maru*; 3 February-2 March, 1998.
(NPAFC Doc.329). National Research Institute of Far Seas Fisheries,
Japan, Japan. 18 p.

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ABSTRACT

A Japan-Russia-U.S. cooperative overwintering salmonid survey was conducted on board the Japanese research vessel *Kaiyo maru* in the western (165°E) and central (180°) North Pacific Ocean and Bering Sea (180°) from 3 February to 2 March 1998, to clarify information on the offshore distribution of Pacific salmon (*Oncorhynchus* spp.) and the relation of oceanographic conditions and salmonid distributions. This was the third overwintering salmonid survey conducted on board the *Kaiyo maru*. The first two surveys were trans-Pacific cruises (Nov.-Dec. 1992 and Jan. 1996), however, this cruise was the first wintertime salmon research cruise in the central Bering Sea since 1963. Salmon were caught at 14 of 19 trawl stations. A total of 2,383 salmonids was collected. Chum salmon were the most abundant (N=1,436, 60.3%), followed by pink (N=843, 35.4%), sockeye (N=49, 2.1%), chinook (N=31, 1.3%), and coho salmon (N=24, 1.0%). No steelhead were caught. The majority of the catch (66%) occurred at one station in the western North Pacific Ocean, where there were relatively large catches of chum and pink salmon. Most of the salmon catch in February 1998 was distributed in a narrow band from 42°-45°N in the western North Pacific Ocean (at 165°E), where sea surface temperatures were 3.9°-5.0°C, and from 43°-46°N in the central North Pacific Ocean (at 180°), where sea surface temperatures were 5.2-6.7°C. Chinook salmon was the only species caught in the Bering Sea. The narrow band of salmon distribution in the western and central North Pacific may be limited to the Subarctic Boundary in the south and to the northern extent of the transition domain in the north.

INTRODUCTION

Interest in wintertime salmon (*Oncorhynchus* spp.) distribution, growth, and survival has increased during the 1990s, as concerns regarding carrying capacity of salmon in the North Pacific Ocean and climate change, have focused on the winter season as a critical time, when the combined effects of temperature and feeding conditions may decrease salmon growth and survival. To investigate the overwintering habitats of high-seas salmon, the *Kaiyo maru* has conducted two previous wintertime surveys in the North Pacific Ocean. In November-December 1992 and January 1996, trans-Pacific surveys with trawling operations were conducted aboard the *Kaiyo maru* in the western (157°E in 1992 and 160°E in 1996), central (179°W in 1992, 168°W in 1996), and eastern (145°W in 1992 and 1996) North Pacific Ocean (Nagasawa et al. 1994, Ueno et al. 1997). Those surveys indicated that salmon were caught in relatively cool surface waters (<7.5°C), and that salmon were found in a rather narrow band of north to south distribution. In February-March 1998, the *Kaiyo maru* conducted a third survey in the western (165°E) and central (180°) North Pacific Ocean. The survey included trawl operations in the Bering Sea basin, which were the first to sample salmon in the central Bering sea since 1963. Our primary purpose was to investigate whether salmon distribution in the February was limited to a narrow area with low sea surface temperature, as was observed in December (1992) and January (1996). In this report, we present information on methods used during this survey and some preliminary results of the fishing operations.

METHODS

Survey area

The *Kaiyo maru*, a 93-m stern trawler, departed Tokyo, Japan, on 3 February 1998 and proceeded to the transect at 165°E, where we conducted fishing operations and made oceanographic observations from 7 to 12 February. The survey along the 180° transect (Bering Sea and North Pacific) was conducted from 15 February to 22 February, and the *Kaiyo maru* returned to Japan at Shimizu Port on 2 March 1998 (Fig. 1).

Oceanographic sampling

The oceanographic sampling aboard the *Kaiyo maru* followed the methods used on previous cruises in 1992 and 1996 (Nagasawa et al. 1994, Ueno et al. 1997). The primary oceanographic tool was the CTD octopus, which includes a deep-sea CTD sensor and rosette of niskin water collecting bottles. The CTD operation was a 0 to 1500 m cast, and water samples were collected from 23 depths. Surface water collection was done using a bucket. The variables measured by the CTD octopus included temperature, salinity, depth, DO, and fluorescence (chlorophyll-a). Analysis of water samples

provided confirmation of CTD salinity, DO, and chlorophyll-a values, and information on nutrient concentrations (NO_2+NO_3 , PO_4 , SiO_2) at depth. At fishing stations, and while transiting between stations XBTs and XCTDs were used to gather oceanographic data and for intercalibration with the CTD.

Phytoplankton sampling

Along the 165°E transect, the rate of primary production was determined in a manner similar to the experiments carried out on previous *Kaiyo maru* salmon cruises. The depth of light penetration of 100% (surface), 30%, 10%, and 1% light intensities was determined with a quantum and depth sensor, and water samples at those depths were collected using a Go-Flo sampler. Phytoplankton were incubated with ^{13}C for six hours in a water bath on deck. The water was filtered and the filters frozen at -80°C for later analysis by mass spectrophotometry. Additional water samples were collected at 0, 10, 30, 50, 100 and 200 m to determine the quantity of various phyto-pigments. For continuous monitoring of plankton while underway, the *Kaiyo maru* has an EPSC (electronic plankton counting and sizing system) device that records time, location, water temperature, salinity, DO, chlorophyll-a, and plankton particle count every minute.

Zooplankton sampling

Zooplankton were collected using a remodeled Norpac net (Motoda, 1994) towed from 0-150 m and fitted with a flow meter. Zooplankton collections during previous cruises included collection by both Norpac and bongo nets, however the bongo net collection was not continued in the 1998 cruise.

Sampling the catch

Salmon were caught with the same mid-water spider net trawl, using fishing methods similar to those used in the two previous salmon cruises. The trawl was towed at the surface for one hr, and typically fished with a 50-m vertical by 70-m horizontal opening. The codend was lined with 13-mm mesh, and the trawl was capable of catching juvenile, immature, and maturing salmon.

The salmon catch was sorted by species. For up to 60 salmon per species, the fork length (FL; mm) and body weight (BW; g) were measured, a scale sample was collected, and the fish individually labeled. As noted previously, scales from the preferred area for scale sampling (International North Pacific Fisheries Commission) were not usually present on the fish because the scales were worn off by abrasion in the net. Scales were collected where they could be found, usually from areas on the body protected by covering fins, such as the pectoral fins. Most scales were non-preferred, making freshwater age determination difficult. Therefore, only the ocean ages will be presented in this report. In cases where more than 60 fish per species were caught, as occurred at a couple of stations where chum or pink salmon

were particularly abundant, the fish were counted and the total weight measured.

To analyze steroid hormones and insulin-like growth factor-1, blood samples were collected from the caudal vein using vacutainer blood collection tubes, and centrifuged at 3000 rpm for 15 minutes. The separated serum was pipetted into cryotubes and frozen at -80°C.

After measuring the fish and collecting scale and blood samples, small salmon were wrapped in plastic and frozen. Large salmon were frozen uncovered and later water-glazed. The fish were frozen flat on trays in the ship's freezer at -40°C.

The non-salmonid catch was identified and sorted by species. Up to 30 individuals of each species of fish or squid were measured for length and the total weight of the 30 individuals was measured. If more than 30 per species were caught, then the remainder of the catch for that species was weighed. A subsample of each species of fish and squid was frozen for later confirmation of species identification. Jellyfish were measured for total weight.

RESULTS AND DISCUSSION

Oceanographic conditions

The Subarctic Boundary, defined as a vertical 34 psu isohaline from the surface to 200-400 m (Dodimead et al. 1963), was found between St. 1 and St. 2 (41° N and 42° N) along the 165° E transect, but not found along the 180° transect. The northern extent of the transition domain, indicated by the <4 °C isotherm at depths below 100 m (Favorite et al. 1976), was located at 45° N along 165° E transect and at 46-47° N along 180° transect.

Salmon catch and distribution

The total catch of salmon was 2,383 fish: 49 sockeye (*O. nerka*; 2.1% of the total catch), 1436 chum (*O. keta*; 60.3%), 843 pink (*O. gorbuscha*; 35.4%), 24 coho (*O. kisutch*; 1.0%), and 31 chinook (*O. tshawytscha*; 1.3%) salmon (Table 1). No steelhead (*O. mykiss*) were caught. Most of the salmon (66%) were caught at one station (St. 4), where chum and pink salmon were abundant.

Most of the salmon catch was distributed in a narrow band from 42°-45°N, in the western North Pacific Ocean (at 165°E), where sea surface temperatures were 5.0°-3.9°C. In the central North Pacific Ocean (at 180°), salmon were caught between 43-46°N, where sea surface temperatures were 5.2-6.7°C (Fig. 4, Table 1). The narrow band of salmon distribution in the western and central North Pacific may correspond to the Subarctic Boundary in the south and the northern extent of the transition domain in the north. Although the southern edge of this band was not clearly delineated at 180° because we were catching salmon at our southern-most station on this transect (Table 1).

Salmon were caught at temperatures from 1.3°C to 6.7°C. Chinook salmon were caught at a wide range of water temperatures from 1.3°C to 6.2°C. Coho salmon were caught in warmer waters (5.2-6.7°C). Sockeye, chum, and pink salmon were caught at sea surface temperatures between 2.7° and 6.7°C (Fig. 5, Table 1).

Sockeye salmon

Sockeye salmon were caught in the western and central North Pacific Ocean, where sea surface temperature were 3.3-6.2°C. They were caught in colder waters as compared with other species. Sockeye salmon were mainly ocean age 1 fish (FL=249-360 mm) and ocean age 2 fish (FL=350-440 mm), and only few ocean age 3 fish (FL>500 mm) were caught (Fig. 6). During previous *Kaiyo maru* cruises, sockeye salmon were not caught in the western North Pacific at 157°E and 160°E in November-December and January. In the central North Pacific, sockeye salmon abundance was slightly larger in February than in November-December and January (Nagasawa et al. 1994, Ueno et al. 1997). During this cruise, sockeye salmon were not caught in the Bering Sea. This was an unexpected result because a previous gillnet survey in January-February 1963 caught sockeye salmon in the Bering Sea (French and McAlister 1970). The mean sea surface temperature in the central Bering Sea was 0.9°C cooler in 1998 than the value recorded during the 1963 cruise when sockeye salmon were caught in the same vicinity in the Bering Sea (French and Mason 1964).

Chum salmon

Ocean age 1 chum salmon (FL=200-340 mm) were caught mainly in the western North Pacific, where sea surface temperature were 4-6°C. No chum salmon were caught in the Bering Sea. Ocean age 2 fish (FL=310-440 mm) were caught in the central North Pacific, where sea surface temperature were warmer than 5.5°C. A few ocean age 3 chum salmon (FL> 430 mm) were caught in the western and central North Pacific (Fig. 7). The chum salmon caught along the 160°E transect by the *Kaiyo maru* in 1996 consisted of Russian (65%) and Japanese (29%) chum stocks, while chum stocks originating from Russia, Japan, and Alaska intermingle in the central North Pacific (Urawa and Ueno 1997).

Pink salmon

Pink salmon caught were all ocean age 1 fish. Their fork length ranged from 200 to 340 mm. They were caught in the western and central North Pacific, where sea surface temperatures were 2.8-6.7°C. No pink salmon were caught in the Bering Sea (Fig. 8). By December, pink salmon had not yet moved east to 157°E, however, pink salmon were abundant in January at 160°E and in February at 165°E (Nagasawa et al. 1994, Ueno et al. 1997).

Coho salmon

Coho salmon were not caught in the western North Pacific Ocean and the Bering Sea during this cruise. A total of 24 coho salmon (FL=290-350 mm) was caught in the central North Pacific, where sea surface temperature were 5.2-6.7°C (Fig. 8). These coho were caught from 45°54'N to the southernmost station at 43°31'N. The location of these catches was further south than those in December (46°-48°N) and January (46°-50°N) in the central North Pacific (Nagasawa et al. 1994; Ueno et al. 1997).

Chinook salmon

A total of 31 chinook salmon was caught in the western and central North Pacific and Bering Sea, where sea surface temperature were 1.3-6.2°C. Most chinook caught were ocean age 1 fish (FL=240-330 mm), and a few ocean age 2 (FL=370-460 mm) and ocean age 3 (FL=580 mm) fish were caught in the central North Pacific (Fig. 9).

Non-salmonid catch

The non-salmonid catch included fish, squid, and jellyfish (Table 3). Myctophids were tentatively identified as *Tarletonbeania taylori*, *Diaphus theta*, and *Stenobranchius leucopsarus*. Other fishes included three-spine sticklebacks, *Gasterosteus aculeatus*, the prowfish, *Zaprora silenus*, and the lumpfish, *Aptocyclus ventricosus*. In addition, larval forms of leptocephalus and Stichaeidae were caught. The squids were tentatively identified as *Gonotopsis borealis*, *Berryteuthis anonychus*, *Gonatus middendorffii*, *Moroteuthis robustus*, and unidentified Gonatidae. Jellyfish was not identified because of damage by the trawl. No marine mammals or birds were caught by the trawl during the survey.

ACKNOWLEDGMENTS

We thank Captain K. Yamanaka, and the officers and crew of the *Kaiyo maru* for their hard work and kind help during this cruise. Funding for the U.S. portion of this work was provided by the Auke Bay Laboratory, Alaska Fisheries Science Center, U.S. National Marine Fisheries Service (NOAA Contract No. 50ABNF700003).

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Table 1. Numbers of salmonids and other animals caught by the mid-water trawl in the western and central North Pacific and the Bering Sea in February, 1998.
Others and total by-catches do not include numbers of jelly fish.

Station Name	Year	Month	Days	Time	Lat	Long.	Towing Direction	Warp (m)	Towing velocity (knot)	SST (°C)	Sock-eye	Chum	Pink	Coho	Chinook	Total salmonid	Lantern fishies	Squids	Others	Total by-catch
1	98	2	7	10:42	40 30 N	165 0 E	50	410	6.2	9.2									1	1
2	98	2	9	8:14	42 15 N	165 0 E	125	400	4.6	5.0	1	2	282		2	287			0	0
3	98	2	9	15:56	43 8 N	165 0 E	270	400	5.6	4.7	16	48	45		5	114	87	99	0	186
4	98	2	10	8:05	45 0 N	165 0 E	215	400	6.2	3.9	8	1109	462		2	1581	0	0	0	0
5	98	2	10	15:37	46 15 N	165 0 E	180	400	5.6	2.8		3	1		1	5	84	415	97	596
6	98	2	11	7:38	47 59 N	164 59 E	160	400	5.8	2.7		2				2	0	245	52	297
7	98	2	11	15:31	49 6 N	164 49 E	130	400	6.1	2.7						0	0	11	5	16
8	98	2	12	7:47	51 0 N	165 0 E	180	395	5.8	2.2						0	0	138	62	200
9	98	2	13	8:52	53 1 N	171 43 E	175	400	5.8	3.4	2	2			1	5	0	1	3	4
10-A	98	2	15	7:47	58 30 N	179 59 E	220	395	5.8	1.3					5	5	0	101	0	101
10-B	98	2	15	9:53	58 21 N	179 47 E	205	880	5.0	1.6					3	3	0	1334	52	1386
11	98	2	15	15:30	57 27 N	179 59 E	270	395	6.0	1.5						0	0	744	0	744
12	98	2	16	7:37	55 30 N	179 58 E	270	400	6.2	2.2						0	0	172	193	365
13	98	2	16	14:48	54 9 N	179 58 E	270	400	5.8	2.6					4	4	0	230	0	230
14	98	2	18	7:10	52 30 N	179 56 E	90	395	6.3	3.0						0	0	980	0	980
15	98	2	19	7:49	49 29 N	179 59 W	180	400	4.6	3.3	1				1	2	0	565	0	565
16	98	2	19	14:32	48 11 N	179 59 W	185	405	4.3	3.4					1	1	0	2236	0	2236
17	98	2	20	14:10	45 54 N	179 56 W	107	405	5.2	5.2	19	8	8	11	5	51	0	81	0	81
18	98	2	21	8:05	45 0 N	179 58 W	45	400	4.8	6.2	2	200	20	9	1	232	0	0	0	0
19	98	2	22	8:03	43 31 N	180 0 E	330	405	6.4	6.7		62	25	4		91	0	6	0	6
Total											49	1436	843	24	31	2383	171	7358	465	7994

Table 2. Species of fishes and other animals caught by the mid-water trawl in the western and central North Pacific and the Bering Sea in February, 1998.

Family (Order)	Scientific name	English Name	Number of collected
Class Osteichthyes			
Elopiformes	-	(Leptocephalus type)	5
Salmonidae	<i>Oncorhynchus keta</i>	chum salmon	1436
Salmonidae	<i>Oncorhynchus nerka</i>	sockeye salmon	49
Salmonidae	<i>Oncorhynchus gorbuscha</i>	pink salmon	843
Salmonidae	<i>Oncorhynchus tshawytscha</i>	Chinook salmon	31
Salmonidae	<i>Oncorhynchus kisutch</i>	coho salmon	24
Myctophidae	<i>Tarletonbeania taylori</i>	North Pacific lanternfish	42
Myctophidae	<i>Stenobrachius leucopsarus</i>	Small-finned lanternfish	1
Myctophidae	<i>Diaphus theta</i>	"Todo hadaka" (in Japanese)	128
Gasterosteidae	<i>Gasterosteus aculeatus</i>	Three-spined stickleback	149
Cyclopteridae	<i>Aptocyclus ventricosus</i>	Smooth lumpsucker	53
Zaproridae	<i>Zaprora silenus</i>	Prowfish	2
Stichaeidae	Stichaeidae sp.	Pricklebacks	256
Class Thaliacea			
Unidentified sulps	-	-	-
Class Cephalopoda			
Gonatidae	Gonatidae sp.	Gonate squids	7306
Enoploteuthidae	<i>Gonatus middendorffi</i>	Shortarm gonate squid	50
Gonatidae	<i>Gonatopsis borealis</i>	Boreopacific gonate squid	1
Unidentified squid	-	(large pelagic species)	1
Others			
Phylum Coelentrata	-	Unidentified jelly fishes	-

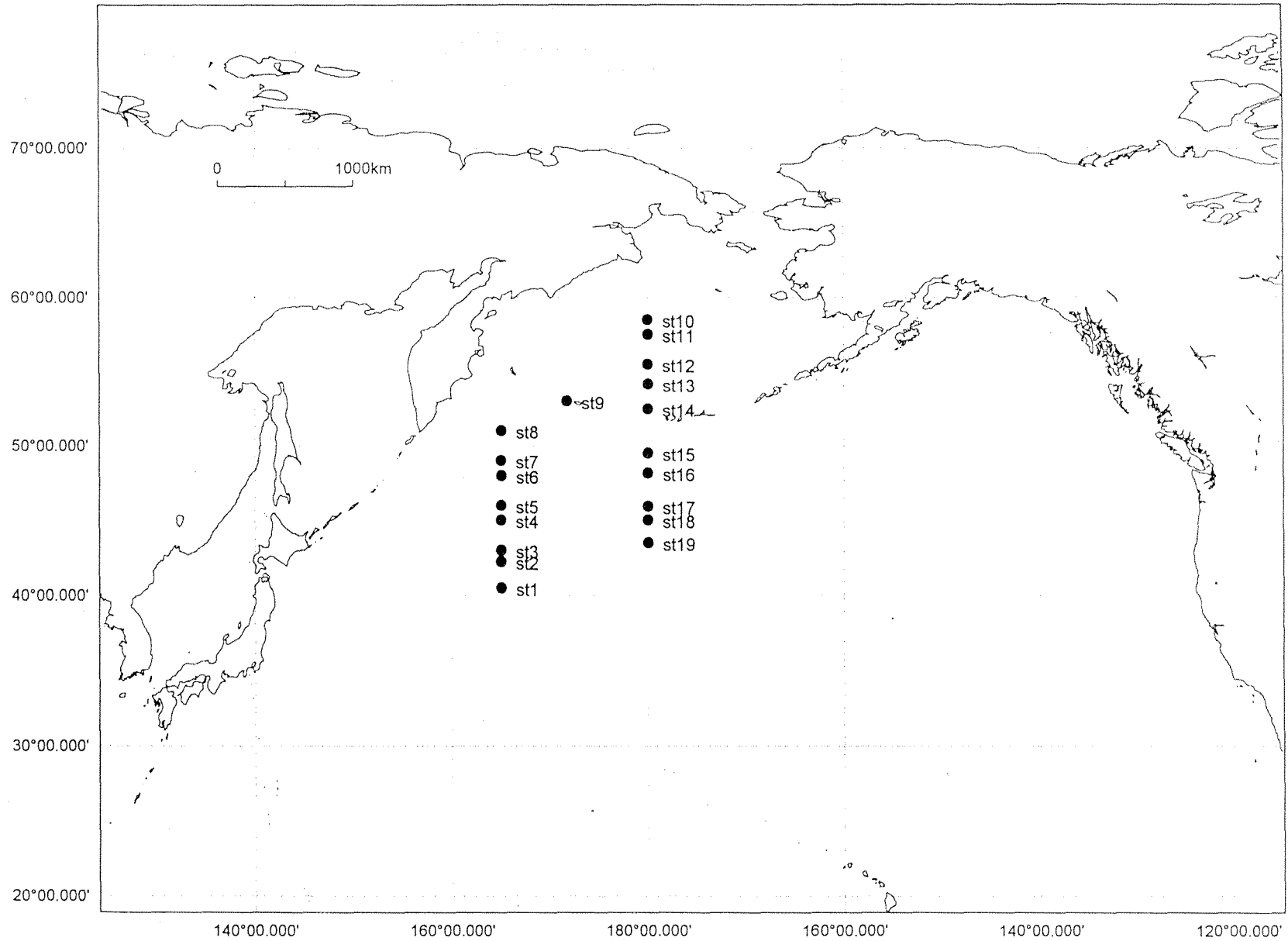
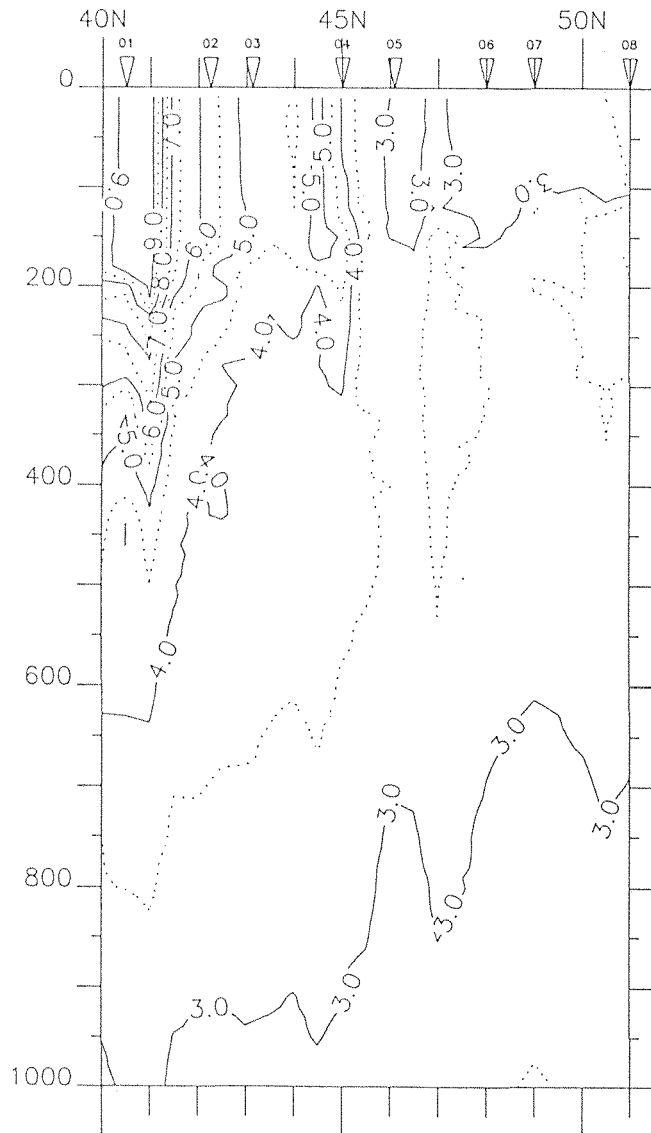


Fig. 1. Map of the North Pacific Ocean showing the location of fishing stations for salmonids and cruise track of the *Kaiyo maru*, February 1998.

XCTD TEMPERATURE SECTION 165E



XCTD TEMPERATURE SECTION 180

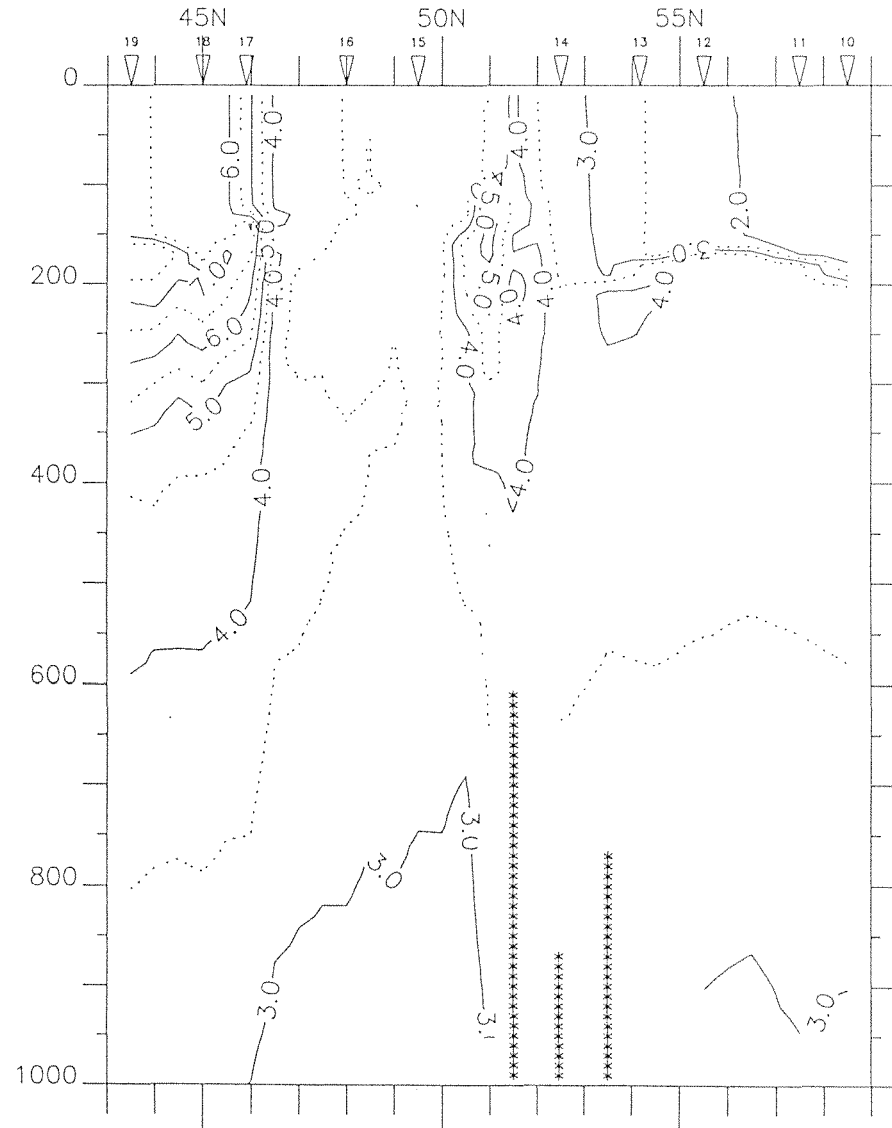


Fig. 2. Vertical profile of sea temperature (°C) along the transects at 165°E and 180° in February, 1998.

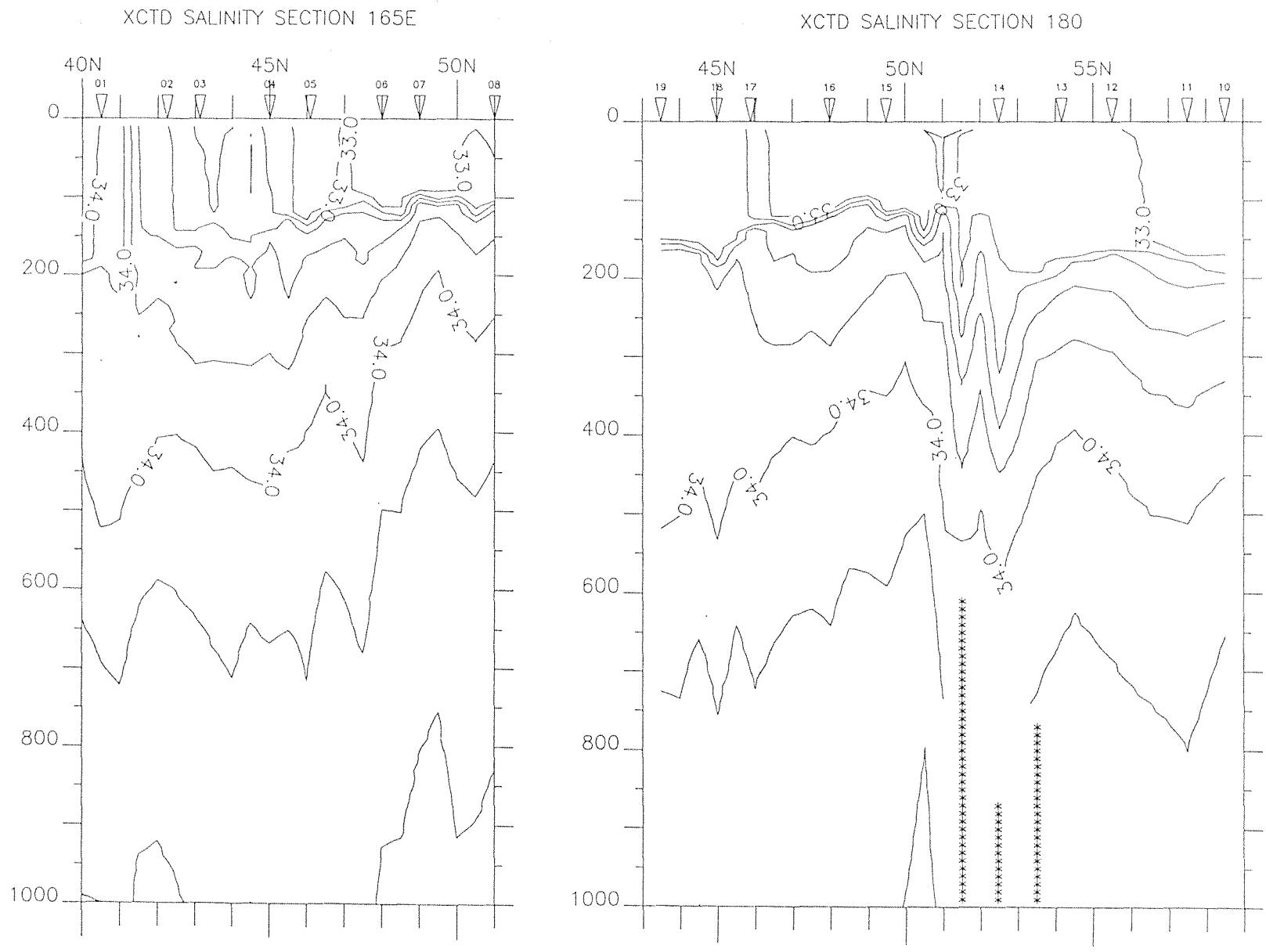


Fig. 3. Vertical profile of salinity (psu) along the transects at 165° E and 180° in February, 1998.

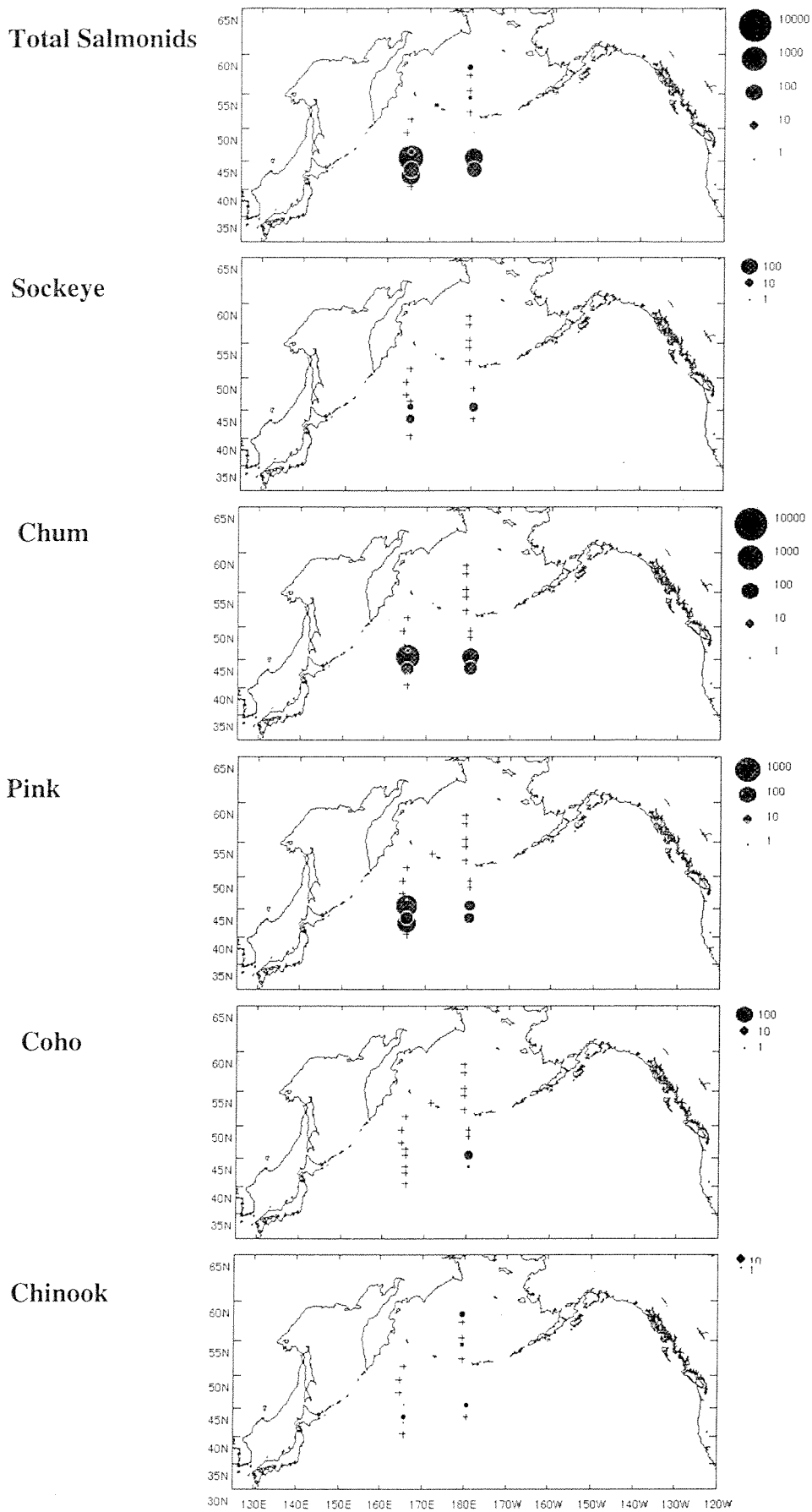


Fig. 4. The CPUE (number of fish caught by the trawl net per hour) of salmonids caught in the western and central North Pacific and Bering Sea in February, 1998.

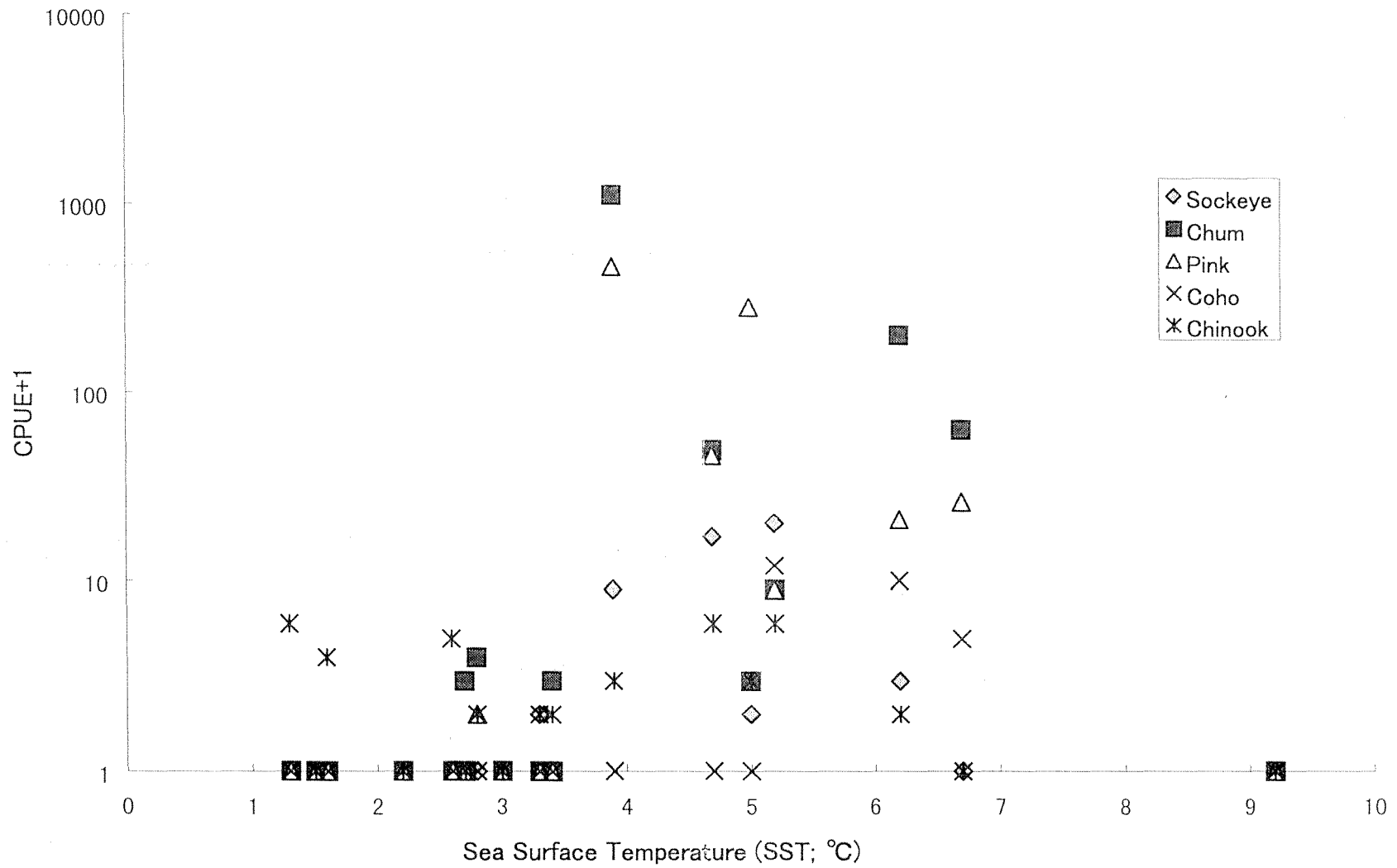


Fig 5. Relationship between sea surface temperatures and CPUE (numbers of salmon caught by the trawl net per hour) by the *Kaiyo maru* in February, 1998.

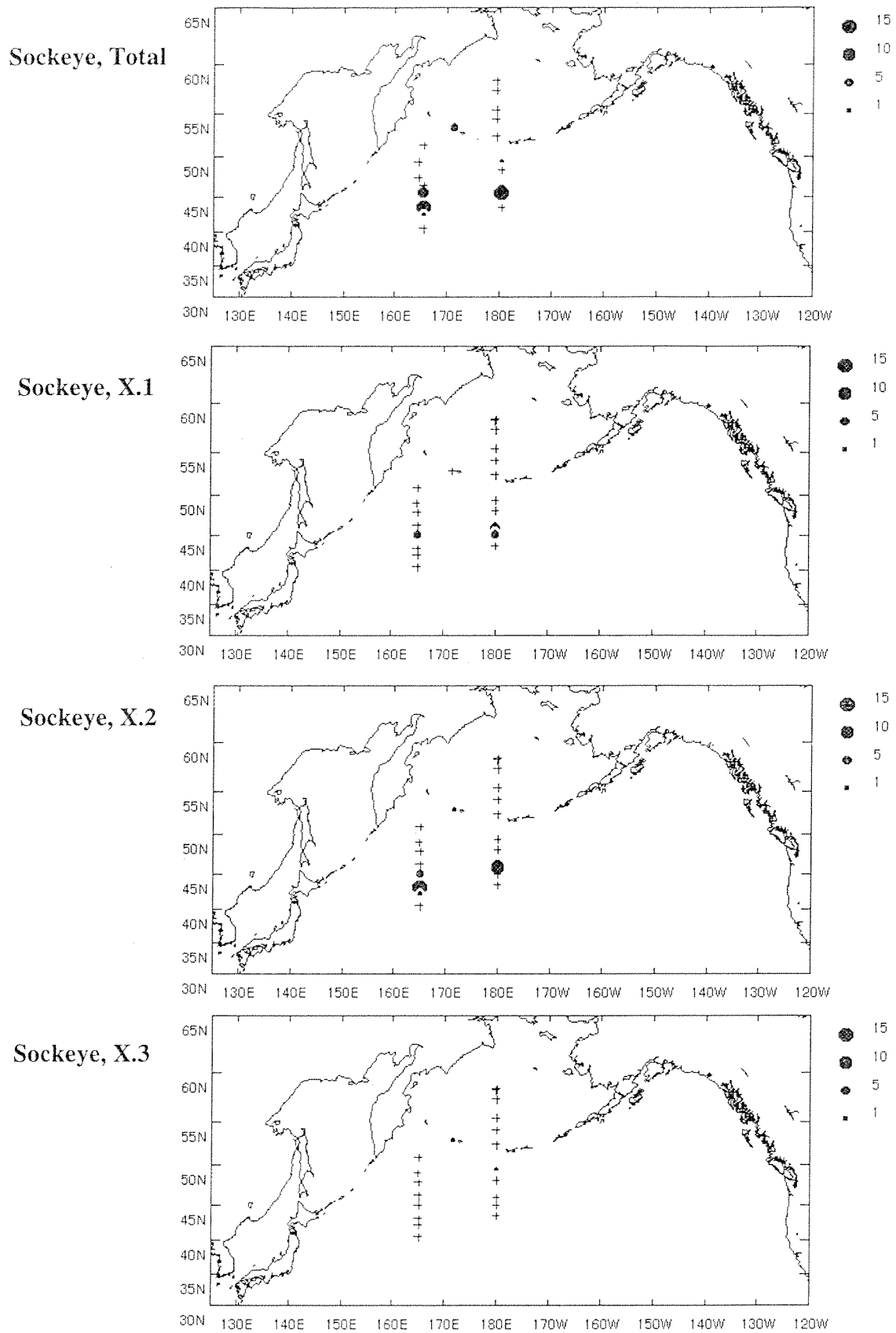


Fig. 6. The CPUE (number of fish caught by the trawl net per hour) of sockeye salmon caught in the western and central North Pacific and Bering Sea in February, 1998.

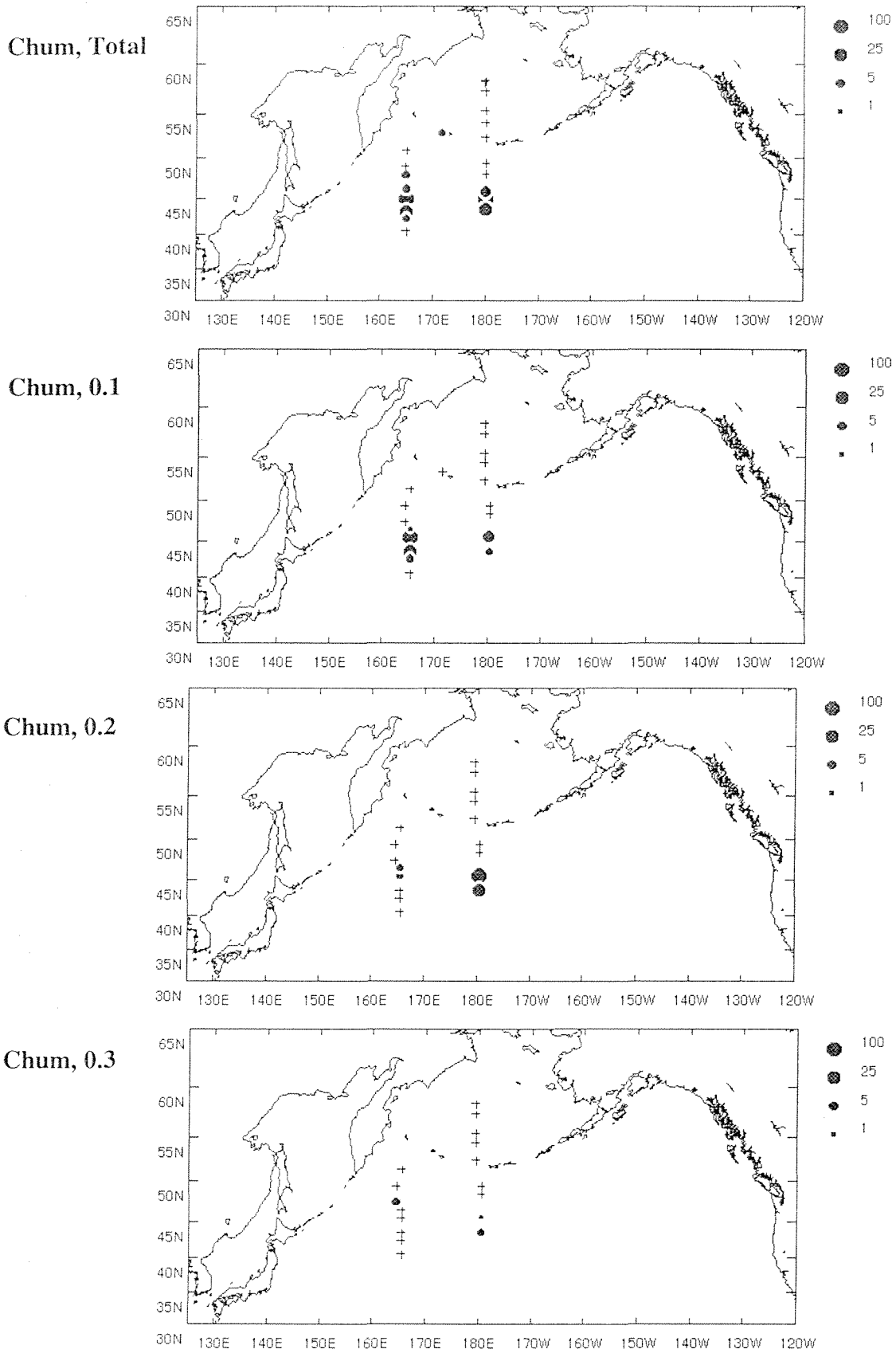
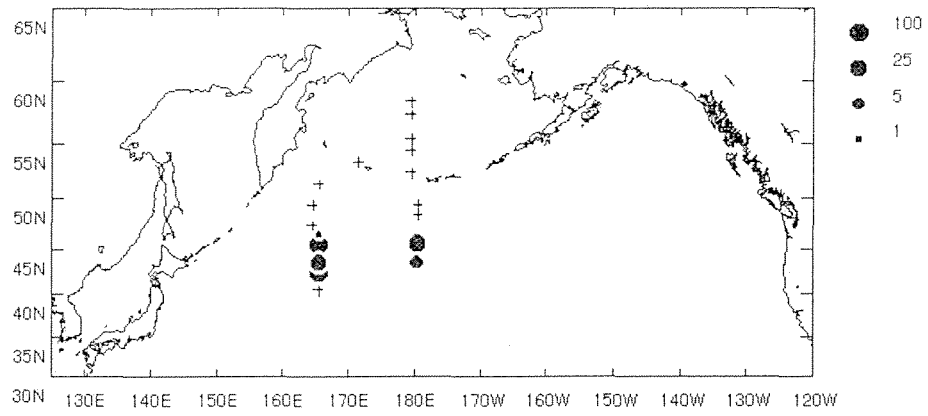


Fig. 7. The CPUE (number of fish caught by the trawl net per hour) of chum salmon caught in the western and central North Pacific and Bering Sea in February, 1998.

Pink



Coho

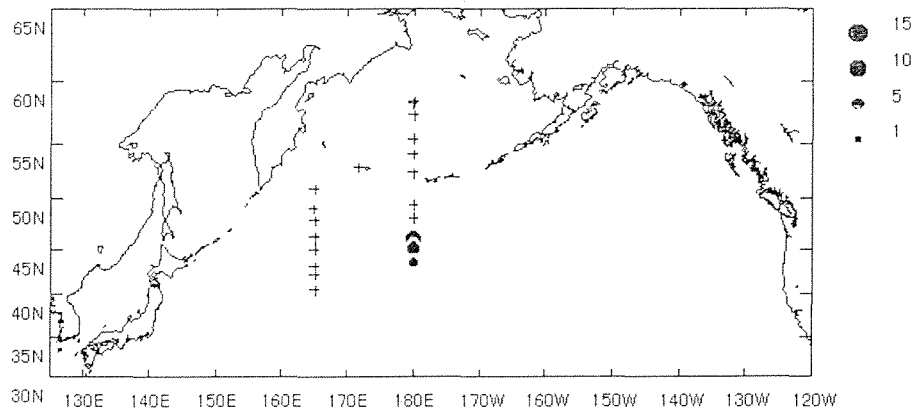
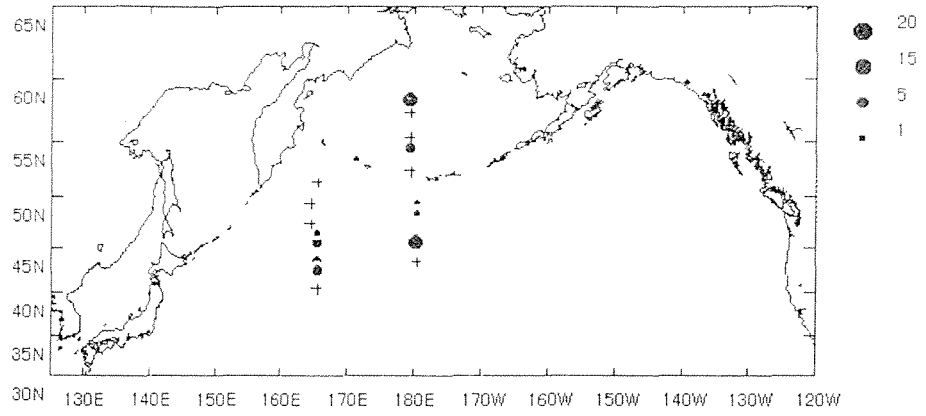
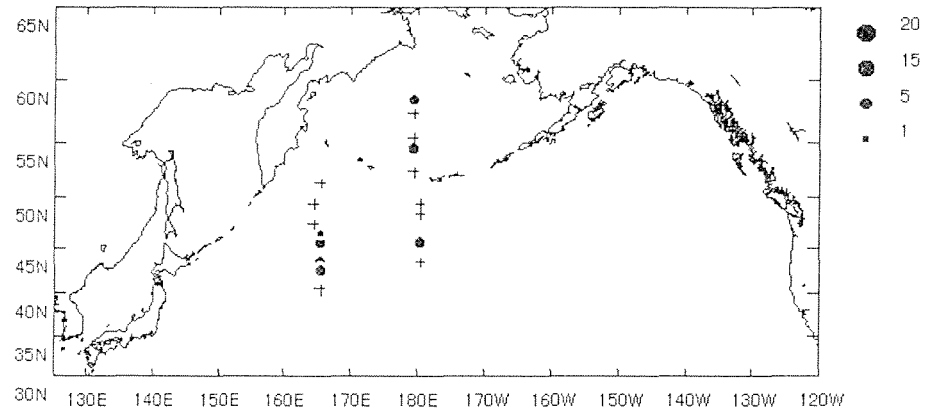


Fig. 8. The CPUE (number of fish caught by the trawl net per hour) of pink and coho salmon caught in the western and central North Pacific and Bering Sea in February, 1998.

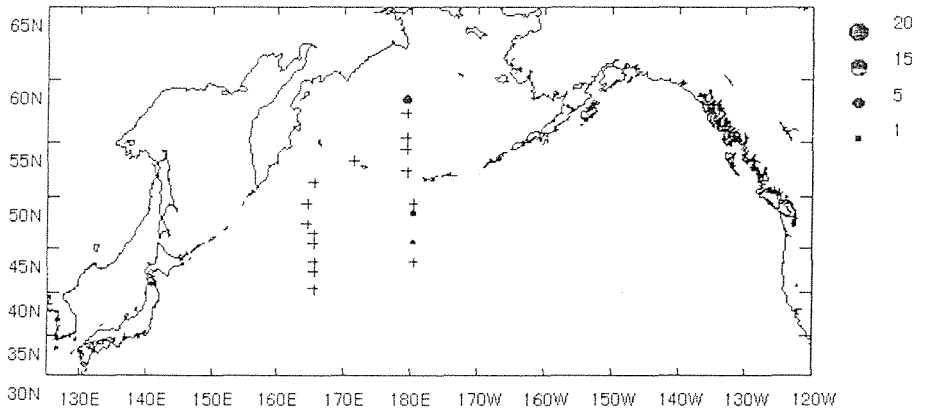
Chinook, Total



Chinook, X.1



Chinook, X.2



Chinook, X.3

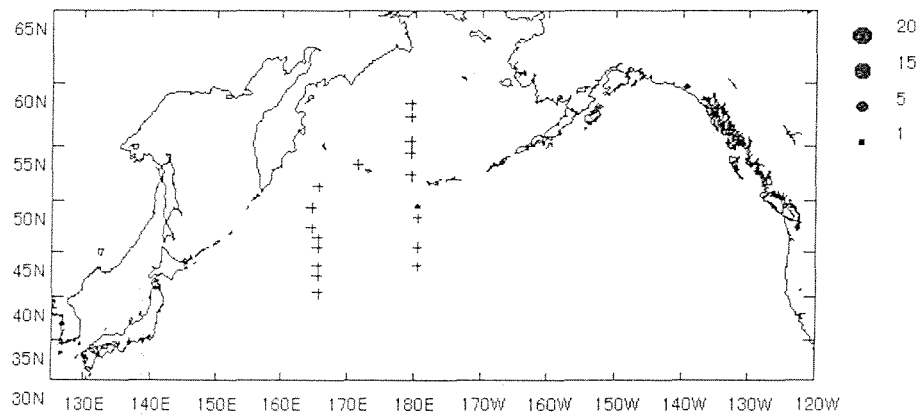


Fig. 9. The CPUE (number of fish caught by the trawl net per hour) of chinook salmon caught in the western and central North Pacific and Bering Sea in February, 1998.