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International Salmon Research Aboard the R/V *Wakatake maru* in the Central North Pacific Ocean and Bering Sea during the Summer of 2009

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Abstract

An annual high-seas salmonid research cruise was conducted in the central North Pacific Ocean and Bering Sea from June 4 to July 17, 2009 onboard the Japanese research vessel, *Wakatake maru,* to investigate salmon stock condition. Research cruise activities included collection of data on oceanography, primary production, zooplankton, salmonids, and other organisms. Average sea surface temperature in the central North Pacific Ocean in 2009 was 9.3°C, which was slightly warmer by 0.1°C than the average temperature in 2008. The Subarctic Boundary was located between 42°N and 43°N, which was further north of its position in 17 of the previous 18 years. In the central Bering Sea, sea surface temperature in 2009 was 6.4°C, which was 0.2°C cooler than in 2008. At 27 experimental fishing stations, a total of 13,968 salmonids was caught by longline and gillnet: 620 fish in the central North Pacific and 13,348 fish in the central Bering Sea. In the central North Pacific, chum salmon was the most abundant species (48.5% of the salmonid catch), followed by coho (40.8%), pink (5.0%), steelhead (4.2%), sockeye (1.0%), and Chinook salmon (0.5%). In the Bering Sea, pink salmon was the most abundant species (88.2% of the salmonid catch), followed by chum (8.2%), sockeye (3.1%), Chinook (0.6%), and coho salmon(0.02%). A total of 1,499 salmonids was disk tagged during the survey, which included three sockeye, 80 chum, 17 pink, 51 coho, and two Chinook salmon, and 11 steelhead released in the central North Pacific. Seventy-eight sockeye, 207 chum, 1046 pink, and four Chinook salmon were released in the Bering Sea. A total of 64 passive integrated transponder (PIT) tags were placed on disk-tagged fish in the central North Pacific Ocean including 51 coho and two Chinook salmon, and 11 steelhead. A total of six Chinook salmon were released with water temperature and depth recording data storage tags. Snouts from ten adipose fin-clipped steelhead were collected for later potential recovery of coded-wire tags. Other salmonid research activities included sampling for total lipid content, RNA/DNA analysis, food habits analysis, and collection of steelhead and Chinook salmon genetics samples.

Introduction

The main objective of this research cruise is to monitor the stock condition of salmon (*Oncorhynchus* spp.) in the central North Pacific Ocean and Bering Sea. A decrease in body size and increase in age of chum salmon (*O. keta*) at maturity has been reported (Kaeriyama 1989; Ishida et al. 1993; Helle and Hoffman 1995; Bigler et al. 1996). A scale pattern analysis showed that Japanese chum salmon suffered growth reduction after the second year of ocean life (Kaeriyama 1998). Urawa (2000) suggested this reduction occurs in the Bering Sea, where chum salmon density increases in summer. To investigate these issues, a survey has been conducted annually in the central North Pacific Ocean and Bering Sea during summer. Routine observations have included collection of physical oceanographic data, estimates of primary production, and investigations into the relationships among zooplankton, salmonids, and higher trophic levels. This document summarizes the R/V *Wakatake maru* cruise conducted in these waters during June and July, 2009.

Methods

Research Vessel and Survey Areas

The *Wakatake maru* (666 gross tons) began the cruise when she departed Kushiro on June 4, 2009 and completed it when she returned to Kushiro on July 17, 2009. There were 27 experimental fishing stations during the cruise (Fig. 1). Nineteen fishing stations were located in the vicinity of 180° longitude from 41°N to 58°30'N latitude. In addition, eight fishing stations were located in international waters of the central Bering Sea. Oceanographic data were collected at each fishing station and additional oceanographic data were collected enroute to and from the fishing area (Table 1).

Physical Oceanography

Seawater temperature and salinity data have been collected in the same manner since 1999 (Kawana et al. 1999, Urawa et al. 2000, Fukuwaka et al. 2001, Tanaka et al. 2002, Fukuwaka et al. 2003, Morita et al. 2004, Fukuwaka et al. 2005, Fukuwaka and Watanabe 2006, Fukuwaka et al. 2007, 2008). An expendable bathythermograph (XBT), which recorded data at 1-m increments from the surface to 780 m, was used at 1°-longitude intervals on the outbound, eastward transit at 40°N, and at 1°-longitude intervals on the return leg from the Bering Sea to Kushiro (n = 58; Table 1). The conductivity, temperature, and depth sensor (CTD) was used at 5°-longitude intervals along the eastward transit, along the westward return leg, and at fishing stations (n = 41).

Primary Production

Surface seawater was collected with a bucket to sample chlorophyll at fishing stations and at 5°-longitude intervals when transiting to and returning from the fishing area (n = 33; Table 1). Water (100 ml) was filtered through a glass fiber filter (Whatman GF/F) using a vacuum pump (100-150 mm Hg). Filters containing chlorophyll-a were saturated with 6 ml of N-dimethylformaide and stored in the freezer.

Zooplankton Collection

Macro-zooplankton were sampled with a remodeled NORPAC net (0.45 m ring diameter, 1.93 m net length, 0.33 mm mesh size) at 27 fishing stations and six transit stations located at intervals of 5° longitude from 150°E to 160°E (Table 1). The net was towed vertically from 150 m to the surface. A calibrated flow meter was attached to the opening of the net in a slightly off-center position. Samples were fixed in 5% borax-buffered formalin in seawater. Samples collected by NORPAC net were collected at approximately midnight during fishing operations, or whenever the ship arrived on station for those located enroute to and from the fishing transect (Fig. 1)

Large macro-zooplankton were collected at 27 fishing stations using an Ocean Research Institute (ORI) net (1.60 m diameter, 7.5 m in overall length, 0.67 mm mesh size; Table 1). The ORI net was towed along side of the vessel at the surface at a speed of 1.5-2 knots for 10 min around 23:00 hrs. After the ORI net towing operations were completed, the NORPAC net was towed, which completed the nightly zooplankton sampling.

Fishing Operations

A gillnet and longline were used for experimental fishing operations to collect salmonids and other pelagic fish. The gillnet was used at 8 stations in the central North Pacific Ocean and 12 stations in the central Bering Sea, outside of the U.S. EEZ (Fig. 1, Table 1). The gillnet was set at 16:00 in the afternoon (Local Mean Time [LMT], GMT + 12) and retrieved at 04:00 the following morning. The gillnet configuration consisted of a variable-mesh research gillnet (C-gear: 3 tans each of 48, 55, 63, 72, 82, 93, 106, 121, 138, and 157 mm

mesh size, one tan is 50 m long) combined with panels of a commercial-mesh gillnet (A-gear: 19 tans of 115 mm mesh size, one tan is 50 m long). The longline was used at 26 fishing stations, where it was set 30 minutes before sunset and hauled 30 minutes after sunset (LMT). The longline comprised 30 hachi (overall length 3.32 km; 1 hachi is 110.68 m long with 49 hooks) and it was baited with salted Japanese anchovy (*Engraulis japonicus*).

Fish Examination

At each station, the total catch of salmonids were counted and sorted by species and mesh size (for gillnet catches) and by species for mortalities from the longline. Routine salmonid examination consisted of determining fork length (FL, mm), body weight (BW, g), sex, and gonad weight (GW, g), and collecting scale samples on a maximum of 60 individuals per species per mesh size from the research gillnet and commercial gillnet (total number of meshes = 11) and from a maximum of 60 individuals per species from longline mortalities. One scale (pink salmon *O. gorbuscha*), two scales (sockeye *O. nerka*, chum, coho *O. kisutch,* Chinook salmon *O. tshawytscha* and steelhead *O. mykiss*), and a scrape scale sample (Chinook salmon and steelhead) were collected. Scales were collected from the INPFC-preferred (International North Pacific Fisheries Commission) area on the body for age determination (Davis et al. 1990). The presence of external injuries and visceral adhesions were recorded (Nagasawa et al. 1997), and fish inspected for the presence of clipped fins. If the fish had a clipped adipose fin, the snout was removed, salted, and frozen for later potential recovery of the coded-wire tag (CWT) by researchers at NOAA NMFS, Auke Bay Laboratories (ABL).

All non-salmonid catches were identified and counted by mesh size, and from longline mortalities. Body length was determined for non-salmonid fish, squid, and other organisms, up to a maximum of 30 per species by mesh size. A few were frozen for taxonomic and ecological studies. Neon flying squid (*Ommastrephes bartramii*) samples were sent to the National Research Institute of Far Seas Fisheries, Yokohama, and birds were sent to the Graduate School of Fisheries Science, Hokkaido University, Hakodate (HU), for further examination.

Tagging Operations with Disk Tags, Data Storage Tags, and Passive Integrated Transponder Tags

Live salmonids caught in a healthy condition were briefly placed in a recovery tank immediately after removal from the longline. Tagging operations included the application of disk tags on all healthy salmonids. In addition, a few fish were also selected for injection of passive integrated transponder (PIT) tags, and for placement of data storage tags. For routine disk tagging, two disk tags, one issued by the Fisheries Agency of Japan (FAJ) and one issued by the NPAFC,. were placed on one plastic cinch strap and applied to the dorsal side of the fish, immediately anterior to the dorsal fin. The fork length was measured and two scales were collected before the fish was released to the sea.

Coho and Chinook salmon, and steelhead caught in the central North Pacific (south of the Aleutian Islands) were selected for tagging with disk tags and a PIT tag. After removal of the fish from the recovery tank, the fish was placed on its back on a supporting foam pad. The PIT tag was injected into the visceral cavity behind the stomach in the area of the pyloric caecae. The injection site on the body was located approximately halfway between the posterior end of the pectoral fin and the anterior end of the pelvic girdle, 1 to 2 mm off the ventral midline. After injection of the PIT tag, the fish's length was measured, a scale sample was collected, the fish was disk tagged, and the fish was returned to the sea.

Data storage tags (DST; Lotek model LAT 140), which record water temperature and the fish's swimming depth, were placed externally on all Chinook salmon caught in a healthy condition. The DST was placed immediately anterior to the dorsal fin using metal pins. Disk tags were placed on the metal pins on the opposite side of the fish to function as backing

plates for the DST. If the Chinook salmon was caught in the central North Pacific, it was also injected with a PIT tag.

Other Sampling and Research

To determine if salmonids or birds could be carrying a PIT tag, all steelhead, chinook and coho salmon mortalities, or live-caught during tagging operations were scanned for the presence of a PIT tag, as were seabird mortalities. Fish and birds were scanned for PIT tags using the Destron-Fearing FS2001F-ISO Reader, or Pocket Reader EX.

As a measure of salmon body condition, the lipid content was estimated for a maximum of three sockeye, chum, and pink salmon per mesh size caught in the research gillnet. Lipid content was estimated using a fish fat meter (Distell Fish Fatmeter Model 992). In addition, 15 sockeye, chum, and pink salmon were set aside, after removal of the gut, and frozen for later laboratory analysis of total lipid content. These fish represented five each of small (30~40 cm FL), medium (40~50 cm FL), and large (>50 cm FL) bodied fish.

To estimate protein synthesis in salmon, samples were collected to determine the DNA to RNA ratio present in the liver. An approximate 1-g portion of the liver was collected from five sockeye, chum, and pink salmon from each mesh size of the research gillnet up to a maximum of 50 fish each in the central North Pacific and Bering Sea.. Liver samples were stored at -30°C in sucrose solution..

Salmonid stomach samples were collected from all species of salmon and steelhead trout. These samples were collected from a maximum of 10 fish per species from longline mortalities and from a variety of gillnet mesh sizes. Stomach samples were weighed to the nearest gram before and after removal of the contents, and the weight of the stomach contents obtained by subtraction. The stomach contents were examined on board using a binocular microscope and separated into several prey categories as described by Ueno et al. (1998). The percent volume in each prey category was estimated by eye.

For genetic analysis of steelhead and chinook salmon, the axillary process was collected and stored in alcohol. These samples were obtained from mortalities from fishing gear and occasionally fin clips were removed from live fish during the tagging procedure.

Results

Physical Oceanography

The position of oceanographic domains was identified along the 180° transect according to the seawater characteristics described by Dodimead et al. (1963) and Favorite et al. (1976; Figs. 2, 3). Stations from 1 to 4 where located in the Transition Zone, an area characterized by relatively saline waters (> 34.0 psu) (Fig. 3). The vertical 34.0 psu isohaline, which characterizes the Subarctic Boundary and separates subtropical and subarctic waters, was located between 42°N (St. 4) and 43°N (St. 5). The position of the Subarctic Boundary in 2009 was 2 degees further north than observed during cruises in 1991 to 2005 and 2007 to 2008, (Davis et al. 1996, Nagasawa et al. 1997; Ueno et al. 1998, Kawana et al. 1999, Urawa et al. 2000, Fukuwaka et al. 2001, Tanaka et al. 2002, Fukuwaka et al. 2003, Morita et al. 2004, Fukuwaka et al.2005, 2007). The most northerly location of the Subarctic Boundary was observed in 2006 when the Boundary was located between 43°N and 44°N (Fukuwaka and Watanabe 2006). The southern limit of the Transition Domain is the Subarctic Boundary and the northern limit is delineated by cold water (< 4°C) below 100 m depth in the central North Pacific. The Transition Domain was located between 43°N and 47°N (between St. 5 a 9; Fig. 2). The Subarctic Current, an eastward-flowing surface current of cool, dilute waters can be identified by cold water (near 3.5°C) at approximately 125 m. This current was located between 47°N (St. 9) and 50°30'N (St. 13). Further to the north, the westward-flowing Alaska Current, identified by warm (> 4°C) and dilute (< 33.6 psu)

freshwater run-off at depths less than 100 m, was located in the vicinity of 51°30'N (St. 14).

Station 14 was located in Amchitka Pass in the Aleutian Islands, one of several locations where North Pacific waters enter the Bering Sea. Station 15 (52°30N, 180°00) was located on the relatively shallow (~300 m depth) Bowers Bank and stations north of 52°30'N (St. 16 through St. 29) were located in the central Bering Sea basin. The basin is characterized by a cold, saline surface layer (depth to approximately 200 m), which is produced by cooling and mixing during the previous winter. This year, superficial warming of the sea surface during the summer produced a shallow seasonal thermocline at approximately 30 m (Fig. 2).

In 2009, average sea surface temperature in the central North Pacific was 9.3°C, which was 0.1°C slightly warmer than the average temperature in 2008 (St. 3-13; 2009 mean = 9.3°C, 2008 mean = 9.2°C). In the central Bering Sea, average sea surface temperature in 2009 was 6.4°C, which was 0.2°C cooler than in 2008 (St. 14-29; 2009 mean= 6.4°C, 2008 mean = 6.6°C).

Salmonid Catches

A total of 13,968 salmonids was caught by longline and gillnet: 620 fish in the central North Pacific Ocean (St. 3-13) and 13,348 fish in the central Bering Sea (St. 14-29; Table 2). In the central North Pacific, chum salmon was the most abundant species (48.5% of the salmonid catch), followed by coho (40.8%), pink (5.0%), steelhead (4.2%), sockeye (1.0%), and Chinook salmon (0.5%). In the Bering Sea, pink salmon was the most abundant species (88.2% of the salmonid catch), followed by chum (8.2%), sockeye (3.1%), Chinook (0.6%), and coho salmon (0.02%).

A total of 10 fin-clipped steelhead was caught by gillnet (Table 3). Snouts from nine adipose fin-clipped steelhead, and one adipose and ventral fin-clipped steelhead were collected for later potential retrieval of CWTs. Nine steelhead observed with clipped adipose fins were tagged and released.

Non-Salmonid Catches

Pacific pomfret (*Brama japonica*: n = 995) was particularly abundant in the catch (Table 2). In addition, 265 neon flying squid, 151 Pacific saury (*Cololabis saira*), 71 smalleye squaretail (*Tetragonurus cuvieri*), 67 eight-armed squid (*Gonatopsis borealis*), 64 boreal clubhook squid (*Onychoteuthis borealijaponicus*), 21 Atka mackerel (*Pleurogrammus monopterygius*), 13 salmon shark (*Lamna ditropis*), 5 spiny dogfish (*Squalus acanthias*), 4 Pacific lamprey (*Entosphenus tridentatus*), 19 other fishes from a mixture of species, 108 seabirds, one Dall's porpoise (*Phocoenoides dalli*) one northern fur seal (*Callorhinus ursinus*), and one short-finned pilot whale (Globicephala macrorhynchus) were caught.

Trends in Mean Fish Size at Age

Preliminary data on mean length (FL, mm) at age for salmon caught in the research mesh gillnet (C-gear) were plotted for the period 1991 to 2009 for the central North Pacific and Bering Sea. Size data for sockeye salmon in the central North Pacific had been available from ocean age-1 and -2 fish regularly since 1998 (Fig. 4). In the Bering Sea, trends indicate since 2001 the size of ocean age -1 sockeye and ocean age -1 chum salmon has increased. The size of ocean age-3 sockeye and ocean age-3 and -4 chum salmon has been stable since 2004. Generally, the size of pink salmon in the central North Pacific has increased since 1999 (Fig. 5). In the central Bering Sea portion of the survey, catches of pink salmon are higher in odd-numbered years because odd-year runs of pink salmon predominate in this area in summer (e.g., Fukuwaka et al. 2008). Although the catch of pink salmon was higher in 2009, the average size of maturing pink salmon was not observed to be much different than in 2008, when the abundance was much lower. The size of maturing coho salmon in the central North Pacific has generally decreased since 2001. Size of ocean age-1, Chinook salmon in the Bering Sea has remained relatively stable since 2001, while ocean age-2 and -3 Chinook

salmon has been variable since that time (Fig. 6). In the central North Pacific, the mean size of ocean age-1 steelhead has increased since 2006, however, the mean size of ocean age-2 and 3 steelhead decreased in 2009.

Tagging Operations

A total of 1,499 salmonids was disk tagged during the survey. In the central North Pacific (St. 3-13), 164 disk tags were placed on fish, including three sockeye, 80 chum, 17 pink, 51 coho, and two Chinook salmon, and 11 steelhead. In the Bering Sea (St. 14-30), 1,335 disk tags were placed on salmon including 78 sockeye, 207 chum, 1,046 pink, and 4 Chinook salmon.

A total of 64 PIT tags were placed on disk-tagged fish in the central North Pacific Ocean. Fifty-one coho and two Chinook salmon, and 11 steelhead were tagged with PIT tags. These two Chinook salmon were also tagged with DSTs. In addition, four more DSTs were put on Chinook salmon in the Bering Sea.

Other Sampling and Research

Salmonids and seabirds (short tailed shearwater, horned and crested puffin, common murre, northern fulmar, and kittiwake) were scanned for identification of PIT tags including 251 coho and 79 Chinook salmon, 26 steelhead, and 108 seabirds, . However, no PIT tags were detected.

Samples for lipid content and RNA/DNA studies were obtained. Fish fat meter measurements were collected from 672 salmonids (171 sockeye, 251 chum, and 250 pink salmon). Round samples for lipid content analysis were collected from 15 sockeye, 20 chum, and 15 pink salmon. Liver samples for RNA/DNA analysis were collected from 55 sockeye, 79 chum, and 60 pink salmon.

A total of 663 samples for salmonid food habits was collected. This total included samples collected from 113 sockeye, 192 chum, 204 pink, 66 coho, 73 Chinook salmon, and 15 steelhead, which were examined on board the ship.

Fin clips for genetic analysis were obtained from 26 steelhead and 77 Chinook salmon.

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Table 1. Research activities conducted at each station during the *Wakatake maru* cruise in 2009.

NO	ST	Date			Latitude		Longitude			XBT	CTD	Primary	NORPAC	ORI	BONGO	Gillnet	Longline	Remarks
1	T-1	2009	6	5	40	0	150	0	E	○	○	○	○					flowmeter calibration
2	T-2	2009	6	5	40	0	151	0	E	○								
3	T-3	2009	6	5	40	0	152	0	E	○								
4	T-4	2009	6	6	40	0	153	0	E	○								
5	T-5	2009	6	6	40	0	154	0	E	○								
6	T-6	2009	6	6	40	0	155	0	E	○	○	○	○					
7	T-7	2009	6	6	40	0	156	0	E	○								
8	T-8	2009	6	6	40	0	157	0	E	○								
9	T-9	2009	6	6	40	0	158	0	E	○								
10	T-10	2009	6	7	40	0	159	0	E	○								
11	T-11	2009	6	7	40	0	160	0	E	○	○	○	○					
12	T-12	2009	6	7	40	0	161	0	E	○								
13	T-13	2009	6	7	40	0	162	0	E	○								
14	T-14	2009	6	7	40	0	163	0	E	○								
15	T-15	2009	6	7	40	0	164	0	E	○								
16	T-16	2009	6	8	40	0	165	0	E	○	○	○						
17	T-17	2009	6	8	40	0	166	0	E	○								
18	T-18	2009	6	8	40	0	167	0	E	○								
19	T-19	2009	6	8	40	0	168	0	E	○								t
20	T-20	2009	6	8	40	0	169	0	E	○								
21	T-21	2009	6	8	40	0	170	0	E	○	○	○						
22	T-22	2009	6	9	40	0	171	0	E	○								
23	T-23	2009	6	9	40	0	172	0	E	○								
24	T-24	2009	6	9	40	0	173	0	E	○								
25	T-25	2009	6	9	40	0	174	0	E	○								
26	T-26	2009	6	9	40	0	175	0	E	○	○	○						
27	T-27	2009	6	9	40	0	176	0	E	○								
28	T-28	2009	6	9	39	45	177	0	E	○								
29	T-29	2009	6	10	39	30	178	0	E	○								
30	T-30	2009	6	10	39	15	179	0	E	○								
31	ST-1	2009	6	10	39	0	180	0		○	○	○						
32	ST-2	2009	6	10	40	0	180	0			○	○						
33	ST-3	2009	6	12	41	0	180	0			○	○	○	○		○	○	t
34	ST-4	2009	6	13	42	0	180	0			○	○	○	○		○	○	
35	ST-5	2009	6	14	43	0	180	0			○	○	○	○		○	○	
36	ST-6	2009	6	15	44	0	180	0			○	○	○	○		○	○	
37	ST-7	2009	6	18	45	0	180	0			○	○	○	○		○	○	
38	ST-8	2009	6	19	46	0	180	0			○	○	○	○		○	○	
39	ST-9	2009	6	20	47	0	180	0			○	○	○	○		○	○	
40	ST-10	2009	6	21	47	30	180	0			○	○	○	○		○	○	
41	ST-11	2009	6	21	48	30	180	0			○	○	○	○			○	
42	ST-12	2009	6	22	49	30	180	0			○	○	○	○			○	
43	ST-13	2009	6	23	50	30	180	0			○	○	○	○			○	
44	ST-14	2009	6	24	51	30	180	0			○	○	○	○			○	
45	ST-15	2009	6	25	52	30	180	0			○	○	○	○			○	
46	ST-16	2009	6	26	53	30	180	0			○	○	○	○			○	
47	ST-17	2009	6	27	54	30	180	0			○	○	○	○			○	
48	ST-18	2009	6	29	55	30	180	0			○	○	○	○		○	○	
49	ST-19	2009	6	30	56	30	180	0			○	○	○	○		○	○	
50	ST-20	2009	7	1	57	30	180	0			○	○	○	○		○	○	
51	ST-21	2009	7	2	58	30	180	0			○	○	○	○		○	○	
52	ST-22	2009	7	3	57	30	179	0	W		○		○	○		○	○	
53	ST-23	2009	7	4	57	30	178	0	W		○		○	○		○	○	
54	ST-24	2009	7	5	56	30	178	0	W		○		○	○		○	○	
55	ST-25	2009	7	6	56	30	179	0	W		○		○	○		○	○	
56	ST-26	2009	7	7	56	30	179	0	E		○		○	○		○	○	
57	ST-27	2009	7	8	56	30	178	0	E		○		○	○		○	○	
58	ST-28	2009	7	10	56	30	177	0	E		○		○	○		○		Longline operation cancelled
59	ST-29	2009	7	9	57	30	177	0	E		○		○	○		○	○	
60	T-50	2009	7	10	56	0	176	0	E	○								
61	T-51	2009	7	10	55	30	175	0	E	○	○	○						
62	T-52	2009	7	10	55	0	174	0	E	○								
63	T-53	2009	7	10	54	30	173	0	E	○								
64	T-54	2009	7	11	54	0	172	0	E	○								
65	T-55	2009	7	11	53	30	171	0	E	○								
66	T-56	2009	7	11	53	0	170	0	E	○	○	○						
67	T-57	2009	7	11	52	20	169	0	E	○								
68	T-58	2009	7	11	51	40	168	0	E	○								
69	T-59	2009	7	11	51	10	167	0	E	○								

Table 1. (continued)

NO	ST	Date			Latitude		Longitude			XBT	CTD	Primary	NORPAC	ORI	BONGO	Gillnet	Longline	Remarks
70	T-60	2009	7	12	50	40	166	0	E	○								
71	T-61	2009	7	12	50	0	165	0	E	○	○	○						
72	T-62	2009	7	12	49	20	164	0	E	○								
73	T-63	2009	7	12	48	40	163	0	E	○								
74	T-64	2009	7	12	48	0	162	0	E	○								
75	T-65	2009	7	13	47	30	161	0	E	○								
76	T-66	2009	7	13	46	50	160	0	E	○	○	○	○					
77	T-67	2009	7	13	46	10	159	0	E	○								
78	T-68	2009	7	13	45	30	158	0	E	○								
79	T-69	2009	7	13	44	50	157	0	E	○								
80	T-70	2009	7	14	44	10	156	0	E	○								
81	T-71	2009	7	14	43	30	155	0	E	○	○	○	○					
82	T-72	2009	7	14	42	50	154	0	E	○								
83	T-73	2009	7	14	42	10	153	0	E	○								
84	T-74	2009	7	15	41	20	152	0	E	○								
85	T-75	2009	7	15	40	40	151	0	E	○								
86	T-76	2009	7	15	40	0	150	0	E	○	○	○	○					flowmeter calibration

Table 2. Salmonids, other fishes, and squid catches at each station with sea surface temperature (SST, °C) during the summer research cruise of the *Wakatake maru*, 2009. B-gear, surface longline; C-gear, salmon research gillnet (mesh sizes = 48, 55, 63, 72, 82, 93, 106, 121, 138 and 157 mm); A-gear, commercial gillnet (mesh size = 115 mm). The number of salmonids tagged with disk tags and released is listed for each station.

St	Date	Lat	Long	SST	Gear	No. unit	Sock-eye	Chum	Pink	Coho	Chi-nook	Masu	Steel-head	Dolly Varden	Salmo-nid total	Neon flying squid	Eight-armed squid	Hook-armed squid	Pacific lamprey	Salmon shark	Spiny dog-fish	Dagger tooth	Pacific saury	Pacific pom-fret	Atka macke-rel	Square tail	Other fishes	Sea birds	Dall's porpoi-se
3	6/12/09	4100	18000	14.2	B	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	351	0	0	0	0	0
					C	30	0	0	0	0	0	0	0	0	0	31	0	2	0	3	0	0	7	149	0	21	6	0	0
					A	19	0	0	0	0	0	0	0	0	0	43	0	0	0	4	0	0	0	202	0	1	2	0	0
					Total		0	0	0	0	0	0	0	0	0	74	0	2	0	7	0	0	7	702	0	22	8	0	0
					Rel.		0	0	0	0	0	0	0	0	0														
4	6/13/09	4200	18000	12.8	B	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	126	0	0	0	0	0
					C	30	0	0	0	0	0	0	0	0	0	118	0	6	0	3	0	0	0	20	0	4	4	0	0
					A	19	0	0	0	0	0	0	0	0	0	65	0	0	0	0	1	0	0	24	0	0	4	1	0
					Total		0	0	0	0	0	0	0	0	0	183	0	6	0	3	1	0	0	170	0	4	8	1	0
					Rel.		0	0	0	0	0	0	0	0	0														
5	6/14/09	4300	18000	10.3	B	30	0	2	0	0	0	0	0	0	2	0	1	1	0	0	0	0	0	54	0	0	0	0	0
					C	30	0	1	0	1	0	0	0	0	2	1	4	37	0	2	0	0	144	17	0	4	0	0	0
					A	19	0	0	0	3	0	0	0	0	3	7	0	0	0	2	0	0	0	13	0	0	0	0	0
					Total		0	3	0	4	0	0	0	0	7	8	5	38	0	4	0	0	144	84	0	4	0	0	0
					Rel.		0	2	0	0	0	0	0	0	2														
6	6/15/09	4400	18000	9.6	B	30	0	4	0	2	0	0	2	0	8	0	0	0	0	0	0	0	0	10	0	0	0	0	0
					C	30	0	2	0	4	0	0	0	0	6	0	3	10	0	1	0	0	0	16	0	0	0	1	0
					A	19	0	0	0	2	0	0	3	0	5	0	0	1	0	0	1	0	0	6	0	0	0	0	0
					Total		0	6	0	8	0	0	5	0	19	0	3	11	0	1	1	0	0	32	0	0	0	1	0
					Rel.		0	4	0	1	0	0	1	0	6														
7	6/18/09	4500	18000	8.4	B	30	0	9	1	20	0	0	5	0	35	0	0	0	0	0	0	0	0	1	0	0	0	0	0
					C	30	0	17	1	16	0	0	1	0	35	0	9	5	0	0	1	0	0	5	0	1	0	0	0
					A	19	0	2	0	27	0	0	2	0	31	0	0	0	0	0	0	0	0	1	0	0	1	0	1
					Total		0	28	2	63	0	0	8	0	101	0	9	5	0	0	1	0	0	7	0	1	1	0	1
					Rel.		0	9	1	16	0	0	5	0	31														

Table 2. (continued)

St	Date	Lat	Long	SST	Gear	No. unit	Sock-eye	Chum	Pink	Coho	Chi-nook	Masu	Steel-head	Dolly Varden	Salmo-nid total	Neon flying squid	Eight-armed squid	Hook-armed squid	Pacific lamprey	Salmon shark	Spiny dog-fish	Dagge tooth	Pacific saury	Pacific pom-fret	Atka macke-rel	Square -tail	Other fishes	Sea-birds	Dall's porpoi-se
8	6/19/09	4600	18000	8.6	B	30	0	18	0	13	0	0	3	0	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					C	30	0	53	0	18	0	0	2	0	73	0	23	2	0	0	0	0	0	0	0	39	0	2	0
					A	19	0	5	0	48	1	0	2	0	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					Total		0	76	0	79	1	0	7	0	163	0	23	2	0	0	0	0	0	0	0	39	0	2	0
					Rel.		0	18	0	11	0	0	3	0	32														
9	6/20/09	4700	18000	7.2	B	30	0	1	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					C	30	0	40	4	6	0	0	0	0	50	0	4	0	0	0	0	0	0	0	0	1	0	0	0
					A	19	0	2	2	13	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	1	0	0
					Total		0	43	7	19	0	0	0	0	69	0	4	0	0	0	0	0	0	0	0	1	1	0	0
					Rel.		0	1	1	0	0	0	0	0	2														
10	6/21/09	4730	18000	6.8	B	30	1	27	1	14	2	0	1	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					C	30	3	85	2	28	0	0	1	0	119	0	12	0	0	0	2	0	0	0	0	0	0	1	0
					A	19	0	9	3	25	0	0	3	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					Total		4	121	6	67	2	0	5	0	205	0	12	0	0	0	2	0	0	0	0	0	0	1	0
					Rel.		1	24	1	11	2	0	1	0	40														
11	6/21/09	4830	18000	7.0	B	30	0	3	2	6	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					Rel.		0	3	1	5	0	0	0	0	9														
12	6/22/09	4930	18000	6.8	B	30	0	3	4	7	0	0	1	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					Rel.		0	3	3	7	0	0	1	0	14														
13	6/23/09	5030	18000	6.8	B	30	2	18	10	0	0	0	0	0	30	0	2	0	0	0	0	0	0	0	0	0	0	0	0
					Rel.		2	16	10	0	0	0	0	0	28														
14	6/24/09	5130	18000	4.6	B	30	0	2	4	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	1	0	0	0	0
					Rel.		0	2	4	0	0	0	0	0	6														
15	6/25/09	5230	18000	5.2	B	30	11	16	57	0	1	0	0	0	85	0	0	0	0	0	0	0	0	0	16	0	0	0	0
					Rel.		11	13	52	0	1	0	0	0	77														
16	6/26/09	5330	18000	5.9	B	30	19	40	81	0	0	0	0	0	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					Rel.		18	30	56	0	0	0	0	0	104														
17	6/27/09	5430	18000	6.1	B	30	4	46	186	0	0	0	0	0	236	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					Rel.		4	37	151	0	0	0	0	0	192														

Table 2. (continued)

St	Date	Lat	Long	SST	Gear	No. unit	Sock-eye	Chum	Pink	Coho	Chi-nook	Masu	Steel-head	Dolly Varden	Salmo-nid total	Neon flying squid	Eight-armed squid	Hook-armed squid	Pacific lamprey	Salmon shark	Spiny dog-fish	Dagg-er tooth	Pacific saury	Pacific pom-fret	Atka macke-rel	Square -tail	Other fishes	Sea-birds	Dall's porpoi-se
18	6/29/09	5530	18000	6.2	B	30	4	6	28	0	0	0	0	0	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					C	30	13	13	734	0	1	0	0	0	761	0	0	0	0	0	0	0	0	0	0	0	0	2	0
					A	19	8	22	561	0	0	0	0	0	591	0	0	0	0	0	0	0	0	0	0	0	0	7	0
					Total		25	41	132 3	0	1	0	0	0	1390	0	0	0	0	0	0	0	0	0	0	0	0	9	0
					Rel.		4	5	23	0	0	0	0	0	32														
19	6/30/09	5630	18000	6.0	B	30	3	5	114	0	0	0	0	0	122	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					C	30	10	13	658	0	0	0	0	0	681	0	6	0	0	0	0	0	0	0	0	0	0	3	0
					A	19	6	13	676	0	1	0	0	0	696	0	0	0	0	0	0	0	0	0	0	0	0	8	0
					Total		19	31	144 8	0	1	0	0	0	1499	0	6	0	0	0	0	0	0	0	0	0	0	11	0
					Rel.		3	4	92	0	0	0	0	0	99														
20	7/01/09	5730	18000	7.0	B	30	3	10	198	0	0	0	0	0	211	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					C	30	24	16	456	0	6	0	0	0	502	0	1	0	0	0	0	0	0	0	0	0	0	19	0
					A	19	12	15	430	0	4	0	0	0	461	0	0	0	0	0	0	0	0	0	0	0	0	7	0
					Total		39	41	108 4	0	10	0	0	0	1174	0	1	0	0	0	0	0	0	0	0	0	0	26	0
					Rel.		3	9	176	0	0	0	0	0	188														
21	7/02/09	5830	18000	7.0	B	30	8	4	112	0	1	0	0	0	125	0	0	0	0	0	0	0	0	0	0	0	0	1	0
					C	30	22	30	601	0	33	0	0	0	686	0	0	0	0	0	0	0	0	0	0	0	0	16	0
					A	19	18	35	856	0	2	0	0	0	911	0	0	0	1	0	0	0	0	0	0	0	1	3	0
					Total		48	69	156 9	0	36	0	0	0	1722	0	0	0	1	0	0	0	0	0	0	0	1	20	0
					Rel.		8	4	96	0	1	0	0	0	109														
22	7/03/09	5730	17900W	6.8	B	30	1	9	44	0	1	0	0	0	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					C	30	10	11	355	0	6	0	0	0	382	0	0	0	1	0	0	0	0	0	0	0	0	1	0
					A	19	10	15	436	0	0	0	0	0	461	0	0	0	0	0	0	0	0	0	0	0	0	3	0
					Total		21	35	835	0	7	0	0	0	898	0	0	0	1	0	0	0	0	0	0	0	0	4	0
					Rel.		1	9	42	0	0	0	0	0	52														
23	7/04/09	5730	17800W	6.7	B	30	5	14	67	0	0	0	0	0	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					C	30	19	29	426	0	4	0	0	0	478	0	0	0	0	0	0	0	0	0	0	0	0	3	0
					A	19	19	30	426	0	1	0	0	0	476	0	0	0	0	0	0	0	0	0	0	0	0	3	0
					Total		43	73	919	0	5	0	0	0	1040	0	0	0	0	0	0	0	0	0	0	0	0	6	0
					Rel.		5	12	60	0	0	0	0	0	77														

Table 2. (continued)

St	Date	Lat	Long	SST	Gear	No. unit	Sock-eye	Chum	Pink	Coho	Chi-nook	Masu	Steel-head	Dolly Varden	Salmo-nid total	Neon flying squid	Eight-armed squid	Hook-armed squid	Pacific lamprey	Salmon shark	Spiny dog-fish	Dagge tooth	Pacific saury	Pacific pom-fret	Atka macker-el	Square -tail	Other fishes	Sea-birds	Dall's Porpoi-se
24	7/05/09	5630	17800W	6.8	B	30	3	10	35	0	0	0	0	0	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					C	30	10	53	269	0	2	0	0	0	334	0	0	0	1	0	0	0	0	0	0	0	0	3	0
					A	19	13	77	249	1	2	0	0	0	342	0	0	0	1	0	0	0	0	0	0	0	0	7	0
					Total		26	140	553	1	4	0	0	0	724	0	0	0	2	0	0	0	0	0	0	0	0	10	0
					Rel.		3	8	28	0	0	0	0	0	39														
25	7/06/09	5630	17900W	6.8	B	30	3	28	47	0	1	0	0	0	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					C	30	12	17	313	0	4	0	0	0	346	0	0	0	0	0	0	0	0	0	1	0	0	0	0
					A	19	6	18	464	1	3	0	0	0	492	0	0	0	0	0	0	0	0	0	0	0	1	0	0
					Total		21	63	824	1	8	0	0	0	917	0	0	0	0	0	0	0	0	0	1	0	0	1	0
					Rel.		2	20	47	0	1	0	0	0	70														
26	7/07/09	5630	17900E	6.7	B	30	8	21	167	0	0	0	0	0	196	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					C	30	27	72	467	0	2	0	0	0	568	0	0	0	0	0	0	0	0	0	1	0	0	6	0
					A	19	9	30	477	0	0	0	0	0	516	0	0	0	0	0	0	0	0	0	0	0	0	5	0
					Total		44	123	1111	0	2	0	0	0	1280	0	0	0	0	0	0	0	0	0	1	0	0	11	0
					Rel.		8	21	146	0	0	0	0	0	175														
27	7/08/09	5630	17800E	6.6	B	30	5	15	22	0	0	0	0	0	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					C	30	21	54	240	0	0	0	0	0	315	0	1	0	0	0	0	0	0	0	1	0	0	1	0
					A	19	6	26	297	0	0	0	0	0	329	0	0	0	0	1	0	0	0	0	0	0	0	0	0
					Total		32	95	559	0	0	0	0	0	686	0	1	0	0	1	0	0	0	0	1	0	0	1	0
					Rel.		4	14	19	0	0	0	0	0	37														
29	7/09/09	5730	17700E	6.3	B	30	10	28	108	0	1	0	0	0	147	0	0	0	0	0	0	0	0	0	0	0	0	1	0
					C	30	11	60	120	0	0	0	0	0	191	0	1	0	0	0	0	0	0	0	0	0	0	0	0
					A	19	7	53	123	0	0	0	0	0	183	0	0	0	0	0	0	0	0	0	0	0	0	1	0
					Total		28	141	351	0	1	0	0	0	521	0	1	0	0	0	0	0	0	0	0	0	0	2	0
					Rel.		4	19	54	0	1	0	0	0	78														
28	7/10/09	5630	17700E	6.3	C	30	21	100	434	0	0	0	0	0	555	0	0	0	0	0	0	0	0	0	1	0	0	2	0
					A	19	8	34	433	0	0	0	0	0	475	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					Total		29	134	867	0	0	0	0	0	1030	0	0	0	0	0	0	0	0	0	1	0	0	2	0
	Total				B	780	90	339	1289	62	7	0	12	0	1799	0	3	1	0	0	0	0	0	542	17	0	0	2	0
					C	600	203	666	5080	73	58	0	4	0	6084	150	64	62	2	6	3	0	151	207	4	70	10	60	0
					A	380	122	386	5433	120	14	0	10	0	6085	115	0	1	2	7	2	0	0	246	0	1	9	46	1
					Total		415	1391	11802	255	79	0	26	0	13968	265	67	64	4	13	5	0	151	995	21	71	19	108	1
					Rel.		81	287	1063	51	6	0	11	0	1499														

Table 3. Steelhead were observed with clipped fins during the summer cruise of the R/V *Wakatake maru* in 2009. Live fish caught on the longline were tagged and released. Attributes of fin-clipped fish included, fork length, body weight, sex, gonad weight, clipped fin, sample number, and tag numbers, if released. Gear: A = commercial-mesh gillnet; C = research-mesh gillnet followed by mesh size (mm); and B = surface longline. Clipped fin: Ad = adipose fin, RV = right ventral fin, LV = left ventral fin. Dash – = no data. Disk tags begin with "KK" or "NA," PIT tags begin with the code "1BF12."

	Location				Fork length	Body weight		Gonad weight	Clipped		
Date	Lat.	Long.	Gear	Species	(mm)	(g)	Sex	(g)	fin	Sample #	Tag # if released
6/15/09	44°00'N	180°00'	A115	steelhead	580	2060	M	2	Ad	8-3	
6/15/09	44°00'N	180°00'	A115	steelhead	620	2370	M	5	Ad	8-4	
6/15/09	44°00'N	180°00'	A115	steelhead	675	2720	F	13	Ad	8-5	
6/17/09	45°00'N	180°00'	B	steelhead	544	-	-	-	Ad	1-7-1#15	KK3015 NA2515 BF1279072
6/17/09	45°00'N	180°00'	B	steelhead	591	-	-	-	Ad	1-7-1#16	KK3016 NA2516 1BF127A6A1
6/17/09	45°00'N	180°00'	B	steelhead	520	-	-	-	Ad	1-7-1#17	KK3017 NA2517 1BF1270772
6/17/09	45°00'N	180°00'	B	steelhead	658	-	-	-	Ad	1-7-1#18	KK3018 NA2518 1BF126F576
6/17/09	45°00'N	180°00'	B	steelhead	565	-	-	-	Ad	1-7-1#29	KK3029 NA2529 1BF126EC00
6/18/09	46°00'N	180°00'	B	steelhead	569	-	-	-	Ad	1-8-1#14	KK3044 NA2544 1BF126FB6D
6/18/09	46°00'N	180°00'	B	steelhead	629	-	-	-	Ad	1-8-1#22	KK3052 NA2552 1BF127069A
6/18/09	46°00'N	180°00'	B	steelhead	718	-	-	-	Ad	1-8-2#6	KK3066 NA2566 1BF127B3DA
6/18/09	45°00'N	180°00'	A115	steelhead	563	1610	F	3	Ad, LV,RV	10-29	
6/18/09	45°00'N	180°00'	A115	steelhead	564	1700	M	2	Ad	10-30	
6/18/09	45°00'N	180°00'	C106	steelhead	562	1760	M	2	Ad	13-9	
6/19/09	46°00'N	180°00'	C093	steelhead	695	3070	M	5	Ad	19-18	
6/21/09	47°30'N	180°00'	C138	steelhead	716	3510	M	10	Ad	44-1	
6/21/09	47°30'N	180°00'	A115	steelhead	665	2700	F	22	Ad	51-14	
6/21/09	47°30'N	180°00'	A115	steelhead	579	1810	F	2	Ad	51-15	
6/22/09	49°00'N	180°00'	B	steelhead	562	-	-	-	Ad	1-12-1#13	KK3133 NA2633 1BF126FB73

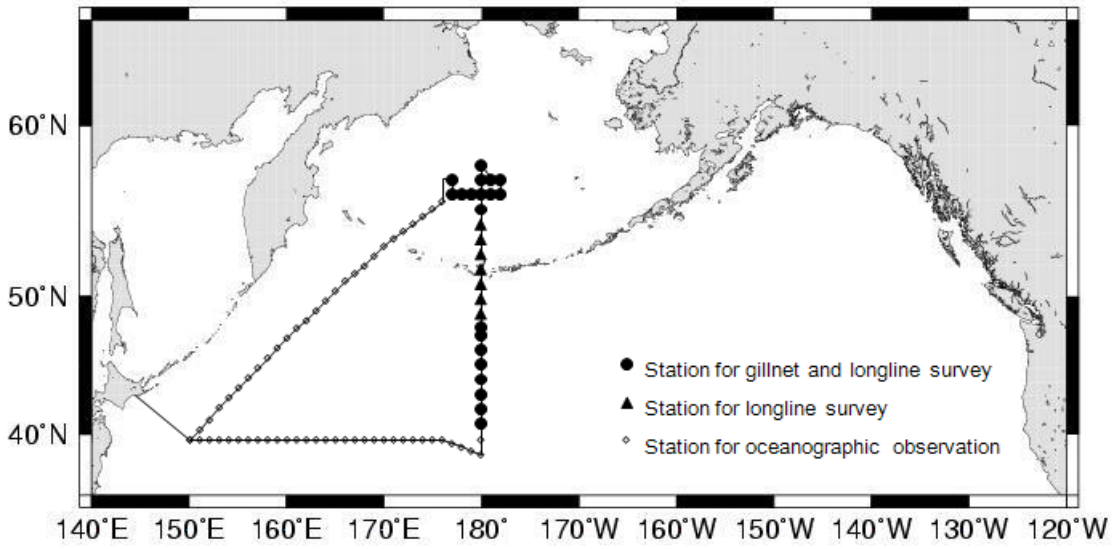

Fig. 1. Survey area of the R/V *Wakatake maru* salmon research cruise, summer 2009.

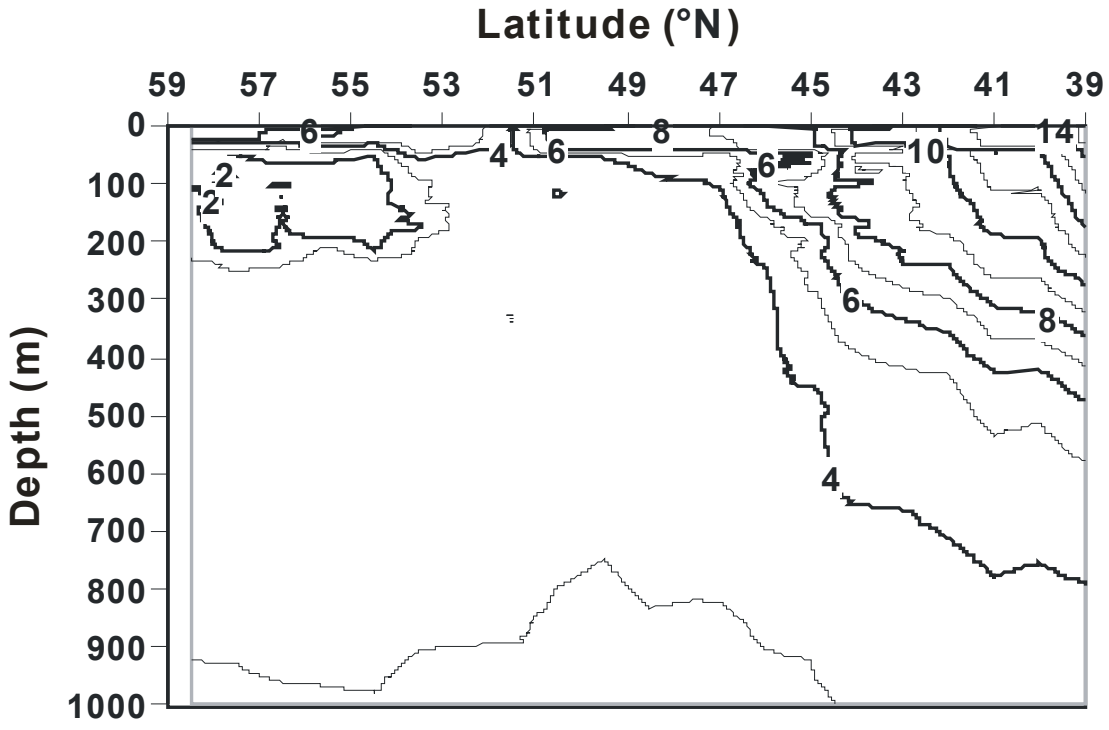

Fig. 2. Vertical section of water temperature (°C) along the 180° transect of the *Wakatake maru* cruise, 2009.

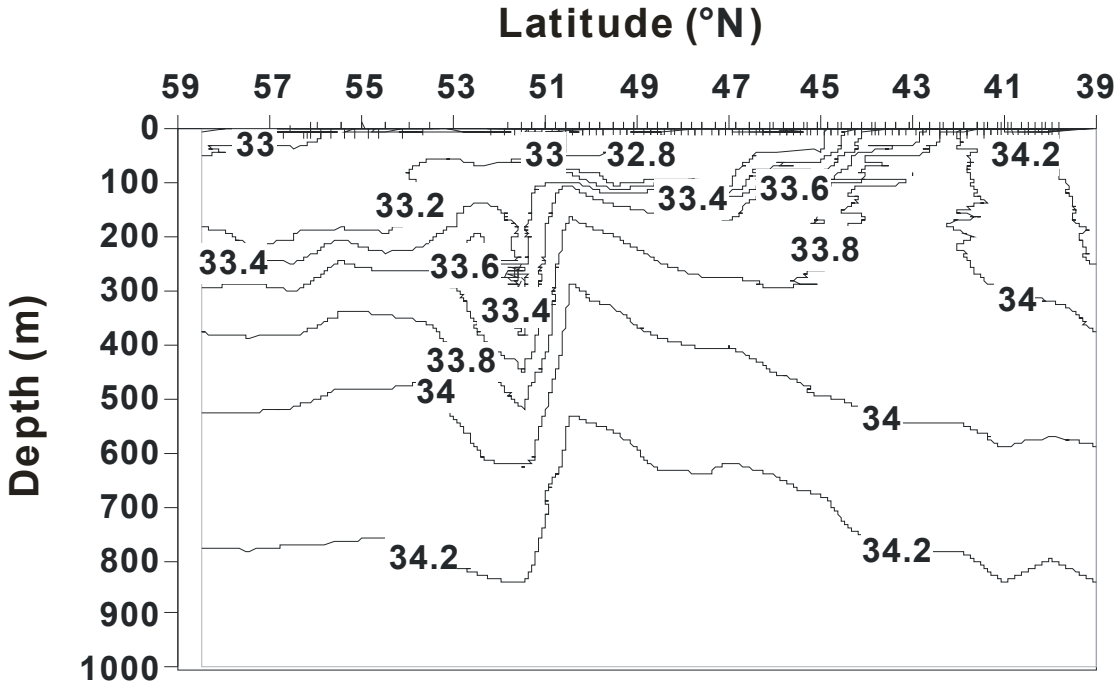

Fig. 3. Vertical section of salinity (psu) along the 180° transect of the *Wakatake maru* cruise, 2009.

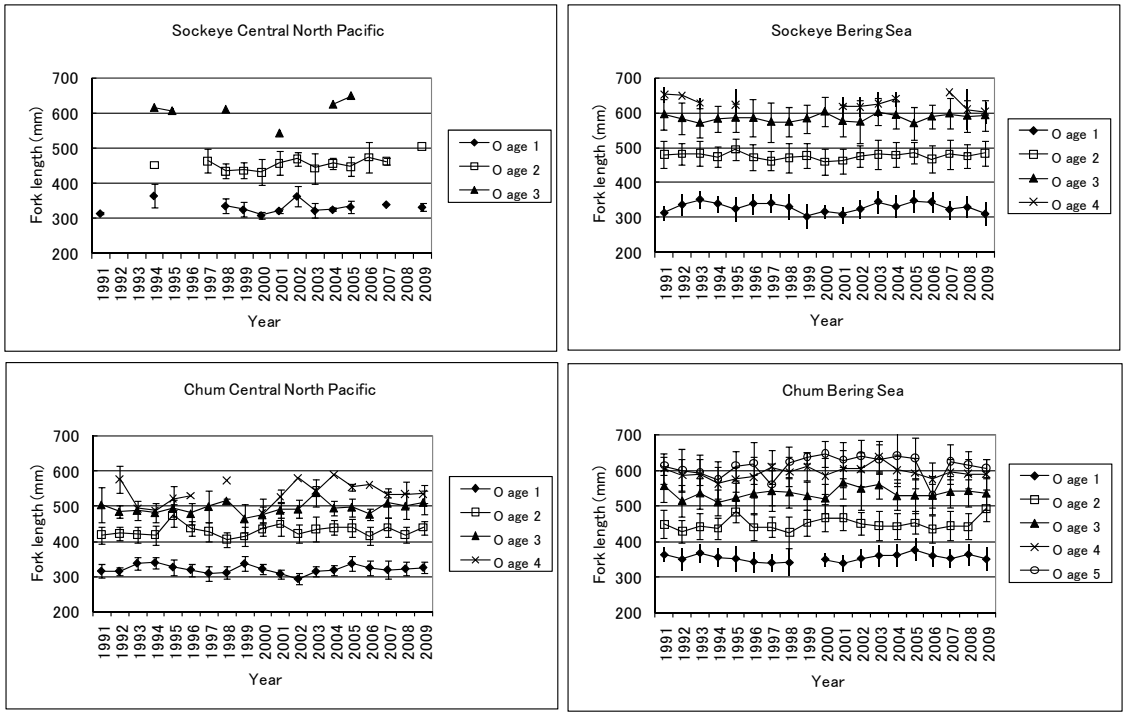

Fig. 4. Mean fork length (+/- one standard deviation) at ocean age by year for sockeye and chum salmon caught in the research-mesh gillnet (C-gear), 1991-2009. Fish were caught in the central North Pacific and Bering Sea.

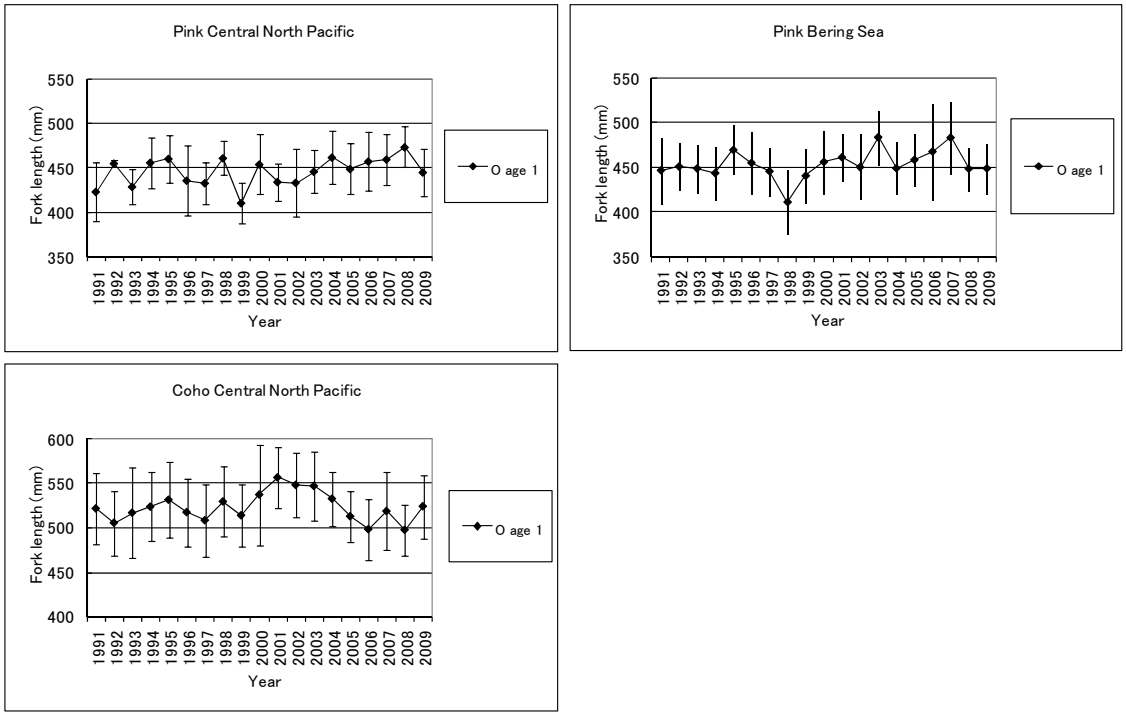

Fig. 5. Mean fork length (+/- one standard deviation) at ocean age by year for pink and coho salmon caught in the research-mesh gillnet (C-gear), 1991-2009. Fish were caught in the central North Pacific and Bering Sea.

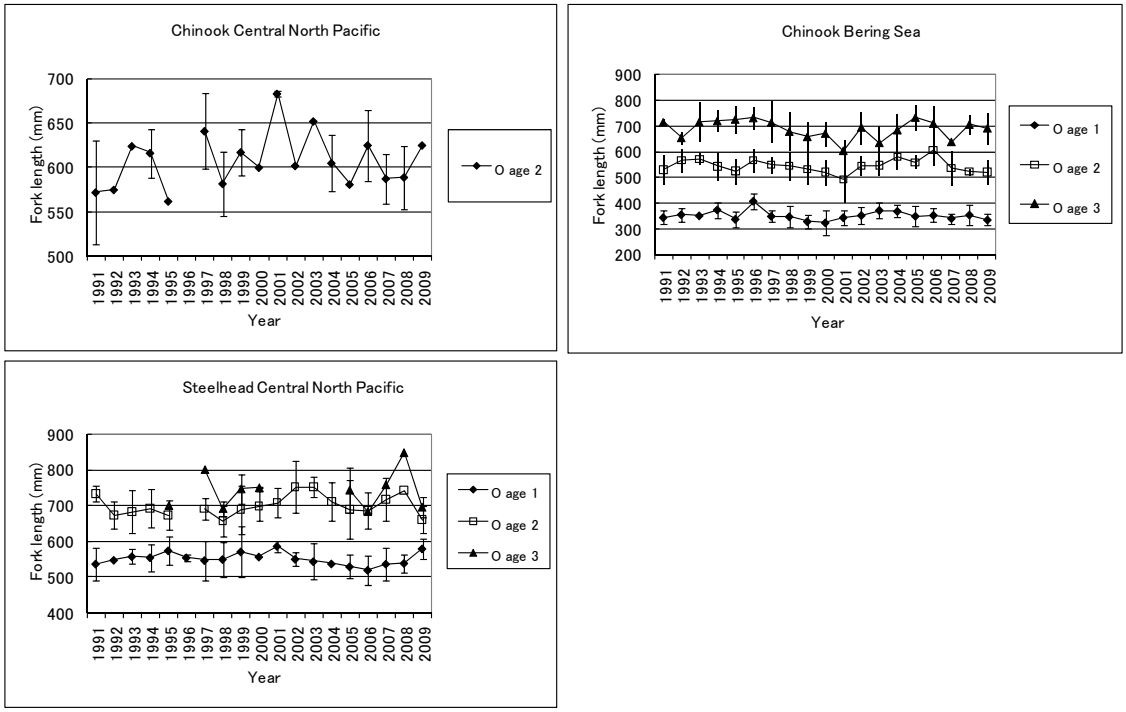

Fig. 6. Mean fork length (+/- one standard deviation) at ocean age by year for Chinook salmon and steelhead caught in the research-mesh gillnet (C-gear), 1991-2009. Fish were caught in the central North Pacific and Bering Sea.