

**International Salmon Research Aboard the R/V *Wakatake maru* in
the Central North Pacific Ocean and Bering Sea during the Summer
of 2006**

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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 6 to July 20, 2006 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 temperatures in the North Pacific were 2.0°C warmer than in 2005. The Subarctic Boundary was located between 43°N (St. 5) and 44°N (St. 6), which was further north than in previous years. In the Bering Sea, sea surface temperatures in 2006 were 0.7°C cooler than in 2005. A few days of fishing were lost midway through the cruise for medical reasons. Therefore, 17 experimental fishing stations were surveyed, fewer than surveyed in previous years. A total of 3,872 salmonids was caught by longline and gillnet: 878 fish in the central North Pacific Ocean (St. 3-13) and 2,994 fish in the central Bering Sea (St. 14-26; Table 2). In the North Pacific Ocean, coho salmon was the most abundant species (43.8% of the salmonid catch), followed by chum (37.9%), steelhead (6.2%), sockeye (5.1%), pink (4.1%) and chinook salmon (2.8%). In the Bering Sea, chum salmon was the most abundant species (74.5% of the salmonid catch), followed by sockeye (19.2%), pink (2.4%), chinook (2.4%), Dolly Varden (1.1%), coho (0.4%), and steelhead (0.03%). Twenty-three snouts of 24 adipose-fin clipped salmonids (all steelhead) were collected for later retrieval of CWT tags, and one adipose-fin clipped steelhead was double-tagged with disk tags and released. A total of 789 disk tags were placed on salmonids during the survey, which included 30 sockeye, 160 chum, 7 pink, 124 coho, 3 chinook salmon, and 4 steelhead released in the central North Pacific and 41 sockeye, 368 chum, 8 pink, 1 coho, 7 chinook salmon and 6 Dolly Varden released in the Bering Sea.

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 recent 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) estimated that 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 2006.

Methods

Research Vessel and Survey Areas

The *Wakatake maru* (666 gross tons) began the cruise when she departed Kushiro on June 6, 2006 and completed it when she returned to Kushiro on July 20, 2006. Midway through, however, the ship returned to Kushiro to take a crewman there for medical reasons. Afterwards, the ship returned to the Bering Sea to resume the survey (Fig. 1). Because of the diversion of the *Wakatake maru* to Kushiro, a total of 17 experimental fishing stations was surveyed, fewer than surveyed in previous years. Sixteen fishing stations were located in the vicinity of 180° longitude from 41°N to 51°30'N and from 55°30'N to 58°30'N latitude. In addition, one fishing station was located in the international waters of the central Bering Sea at 56°30'N, 179°00'E. Oceanographic data were collected at each fishing station and between stations. 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). 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°-latitude intervals between fishing stations (n = 47). The conductivity, temperature, and depth sensor (CTD) was used at 5°-longitude intervals along the eastward transit and at fishing stations (n = 31). The XCTD (expendable CTD) was used at 1°-longitude intervals on the leg between Kushiro and the Bering Sea (n = 27). The CTD and XCTD record data in 1-m intervals from the surface to approximately 1000 m. In addition, an ARGO float, which collects temperature, salinity, and current data autonomously, was cast at seven stations along 180° longitude at the request of the Institute of Observational Research for Global Change, Japan Agency for Marine-Earth Science and Technology.

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=30; 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 soaked with 6 ml of N-dimethylformamide 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 17 fishing stations and 6 transit stations located at intervals of 5° longitude from 150°E to 160°E. 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 position slightly off-center. Samples were fixed in 5% borax-buffered formalin in seawater.

Large macro-zooplankton were collected at 17 fishing stations using an Ocean Research Institute (ORI) net (1.60 m diameter, 7.5 m in overall length, 0.67 mm mesh size). 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. Samples were fixed in 5% borax-buffered formalin in seawater.

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 5 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 17 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

Salmonids, except for Dolly Varden (*Salvelinus malma*), were processed soon after removal from the fishing gear. For each mesh size, the catch was sorted and counted by species. Biological data were collected from a maximum of 60 individuals of each species from each mesh size (gillnet operation, mesh sizes = 11) and from a maximum of 60 individuals per species from longline mortalities. The biological data included fork length (FL, mm), body weight (BW, g), sex, and gonad weight (GW, g). One scale (pink salmon *O. gorbuscha*), two scales (sockeye *O. nerka*, chum, coho *O. kisutch*, and chinook salmon *O. tshawytscha*), or a scrape scale sample (steelhead *O. mykiss*) 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 on salmon and visceral adhesions in sockeye salmon and other species were recorded (Nagasawa et al. 1997). Salmonids were inspected for the presence of clipped fins. If the fish had a clipped adipose fin, the snout was removed, salted, and frozen for later recovery of the CWT. Dolly Varden were measured for fork length and body weight, and the round sample was frozen and stored for further examination in the laboratory.

All non-salmonid catches were identified and counted by mesh size. Body lengths were measured for non-salmonid fish, squid, and other organisms, and a few were frozen for taxonomic and ecological studies. Neon flying squid (*Ommastrephes bartramii*) 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, for further examination.

Other Sampling and Research

Stomach samples were collected from all species of salmon and steelhead trout. These samples were collected from three fish per species from longline mortalities and from each of five mesh sizes of the research-mesh gillnet (55, 72, 93, 121, and 157 mm) and from the commercial-mesh gillnet (115 mm). Samples were frozen and stored for later examination.

Scales were collected from all measured chum salmon caught by research-mesh gillnet. Dried chum salmon scales were sent to the National Salmon Resources Center (NASREC), Sapporo, for stock identification using DNA.

Both sagittal otoliths were collected from all measured chum salmon caught by the research-mesh gillnet to detect thermal marks on the otolith. Dried otoliths were sent to NASREC for further examination.

To investigate lipid contents of chum and pink salmon, gutted fish were collected from gillnet catches and sent to NASREC for further examination.

Disk Tags

Live salmonids caught in a healthy condition were put into a recovery tank soon after removal from the longline. Fish were tagged with two disk tags; one issued by the Fisheries Agency of Japan (FAJ) and one issued by the University of Washington (UW). Both disk tags were placed on one plastic cinch strap and applied to the fish anterior to the dorsal fin. The fork length was measured and two scales were collected before the fish was released to the sea.

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 1-5 were located in the Transition Zone, an area characterized by relatively saline waters (> 34.0 psu) (Fig. 3). A vertical 34.0 psu isohaline characterizes the Subarctic Boundary, which separates subtropical and subarctic waters. The Boundary was located between 43°N (St. 5) and 44°N (St. 6). In 2006, the Subarctic Boundary was located further north than during previous cruises. Specifically, the Boundary was located between 40°N and 41°N in 1997, 1998, 2000, and 2003-2005, and between 39°N and 40°N in 1991-1996, 1999, and 2001-2002 (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). The southern limit of the Transition Domain is the Subarctic Boundary and 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 46°30'N (between St. 5 and T-38; 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 46°30'N (T-38) and 50°30'N (St. 13). Further to the north, at 50°30'N (Station 13), the westward-flowing Alaska Current was observed. Fed by freshwater run-off, this current has warm (> 4°C) and dilute (< 33.6 psu) waters at depths less than 100 m.

Station 14 was located in Amchitka Pass in the Aleutian Islands, one of several locations where North Pacific waters enter the Bering Sea. Stations north of 52°00'N (St. 18 through St. 26) were located in the Bering Sea. The central Bering Sea 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 relatively deep seasonal thermocline at 30 to 50 m (Fig. 2).

In 2006, average sea surface temperatures in the North Pacific were 2.0°C warmer than in 2005 (St. 3-13; 2006 mean = 9.6°C, 2005 mean = 7.6°C). In the Bering Sea, sea surface temperatures in 2006 (St. 14-26; mean = 6.8°C) were 0.7°C cooler than in 2005 (St. 14-28; mean = 7.5°C).

Salmonid Catches

A total of 3,872 salmonids was caught by longline and gillnet: 878 fish in the central North Pacific Ocean (St. 3-13) and 2,994 fish in the central Bering Sea (St. 14-26; Table 2). In the North Pacific Ocean, coho salmon was the most abundant species (43.8% of the salmonid catch), followed by chum (37.9%), steelhead (6.2%), sockeye (5.1%), pink (4.1%) and chinook salmon (2.8%). In the Bering Sea, chum salmon was the most abundant species (74.5% of the salmonid catch), followed by sockeye (19.2%), pink (2.4%), chinook (2.4%), Dolly Varden (1.1%), coho (0.4%), and steelhead (0.03%).

Non-Salmonid Catches

Pacific pomfret (*Brama japonica*: n = 1089), neon flying squid (n = 271), and Pacific saury (*Cololabis saira*: n = 157) were particularly abundant in the catch (Table 2). In addition, 48 eight-armed squid (*Gonatopsis borealis*), 34 boreal clubhook squid (*Onychoteuthis borealijaponicus*), 24 square tail (*Tetragonurus cuvieri*), 19 spiny dogfish (*Squalus acanthias*), 13 Atka mackerel (*Pleurogrammus monopterygius*), seven salmon shark (*Lamna ditropis*), three blue shark (*Prionace glauca*), three medusafish (*Icichthys lockingtoni*), two albacore (*Thunnus alalunga*), one longnose lancetfish (*Alepisaurus ferox*), and one robust hooked squid (*Moroteuthis robusta*) were caught.

Trends in Mean Fish Size at Age

Preliminary data on mean length (FL, mm) at age for salmon caught in research mesh gillnet (C-gear) were plotted for the period 1991 to 2006 for the central North Pacific Bering Sea to investigate trends in mean fish size. Size data for sockeye in the central North Pacific has been available from ocean age-1 and -2 fish regularly since 1998, which may indicate a shift in distribution of these ages of sockeye salmon to this area after 1997 (Fig. 4). In the Bering Sea, trends indicate that the size of ocean age -1 and -2 sockeye and ocean age -1 chum salmon have increased since 2001, but decreased in 2006 from the previous year. Ocean age-3 sockeye and ocean age-3 and -4 chum salmon have decreased since 2003. The size of pink salmon in both areas has stabled around 450 mm in fork length (Fig. 5). The size of maturing coho salmon in the central North Pacific has generally decreased since 2001. Trends of ocean age-2 and -3 chinook salmon size have increased since 2003 in the Bering Sea (Fig. 6). In the central North Pacific, mean size of steelhead ocean age-2 and -3s have decreased since 2002.

Sampling

A total of 24 adipose-fin clipped salmonids (all steelhead) were caught by longline and gillnet (Table 3). Twenty-three snouts from these fish were collected for later retrieval of CWTs. One adipose-fin clipped steelhead was double-tagged with disk tags and released.

During the cruise, a total of 496 samples of stomach contents was collected. This total included samples collected from 88 sockeye, 167 chum, 59 pink, 99 coho, and 43 chinook salmon, and 40 steelhead.

A total of 951 scale samples was collected from chum salmon in the central North Pacific (n = 103) and Bering Sea (n = 848) for genetic stock identification. A total of 950 pairs of sagittal otoliths was collected from chum salmon in the central North Pacific (n = 103) and Bering Sea (n = 847) to detect the presence of thermal marks.

A total of 270 gutted fish was collected from 62 chum and 9 pink salmon in the central North Pacific and from 138 chum and 61 pink salmon in the Bering Sea for lipid content analysis.

Disk Tags

A total of 789 salmonids were disk tagged during the survey. In the central North Pacific (St. 3-13), 266 disk tags were placed on fish, including 30 sockeye, 160 chum, 7 pink, 124 coho, and 3 chinook salmon, and 4 steelhead. In the Bering Sea (St. 14-26) a total of 431 disk tags were placed on salmon including 41 sockeye, 368 chum, 8 pink, 1 coho, 7 chinook salmon, and 6 Dolly Varden.

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Table 1. Research activities conducted at each station during the *Wakatake maru* cruise in 2006.

NO	ST	Date		Latitude		Longitude		XBT	XCTD	CTD	Primary	NORPAC	ORI	Gillnet	Longline	Remarks
1	T-1	2006	6	8	40	0	150	0	E	o		o				
2	T-2	2006	6	8	40	0	151	0	E	o						
3	T-3	2006	6	9	40	0	152	0	E	o						
4	T-4	2006	6	9	40	0	153	0	E	o						
5	T-5	2006	6	9	40	0	154	0	E	o						
6	T-6	2006	6	9	40	0	155	0	E	o		o	o			
7	T-7	2006	6	9	40	0	156	0	E	o						
8	T-8	2006	6	9	40	0	157	0	E	o						
9	T-9	2006	6	10	40	0	158	0	E	o						
10	T-10	2006	6	10	40	0	159	0	E	o						
11	T-11	2006	6	10	40	0	160	0	E	o		o	o			
12	T-12	2006	6	10	40	0	161	0	E	o						
13	T-13	2006	6	10	40	0	162	0	E	o						
14	T-14	2006	6	10	40	0	163	0	E	o						
15	T-15	2006	6	11	40	0	164	0	E	o						
16	T-16	2006	6	11	40	0	165	0	E	o		o	o			
17	T-17	2006	6	11	40	0	166	0	E	o						
18	T-18	2006	6	11	40	0	167	0	E	o						
19	T-19	2006	6	11	40	0	168	0	E	o						
20	T-20	2006	6	11	40	0	169	0	E	o						
21	T-21	2006	6	11	40	0	170	0	E	o		o	o			
22	T-22	2006	6	12	40	0	171	0	E	o						
23	T-23	2006	6	12	40	0	172	0	E	o						
24	T-24	2006	6	12	40	0	173	0	E	o						
25	T-25	2006	6	12	40	0	174	0	E	o						
26	T-26	2006	6	12	40	0	175	0	E	o		o	o			
27	T-27	2006	6	12	40	0	176	0	E	o						
28	T-28	2006	6	13	39	45	177	0	E	o						
29	T-29	2006	6	13	39	30	178	0	E	o						
30	T-30	2006	6	13	39	15	179	0	E	o						
31	ST-1	2006	6	13	39	0	180	0		o		o	o			ARGO Float cast
32	T-31	2006	6	13	39	30	180	0		o						
33	ST-2	2006	6	13	40	0	180	0			o	o				ARGO Float cast
34	T-32	2006	6	14	40	30	180	0		o						
35	ST-3	2006	6	14	41	0	180	0			o	o	o	o	o	ARGO Float cast
36	T-33	2006	6	15	41	30	180	0		o						
37	ST-4	2006	6	15	42	0	180	0			o	o	o	o	o	ARGO Float cast
38	T-34	2006	6	16	42	30	180	0		o						
39	ST-5	2006	6	16	43	0	180	0			o	o	o	o	o	ARGO Float cast
40	T-35	2006	6	17	43	30	180	0		o						
41	ST-6	2006	6	17	44	0	180	0			o	o	o	o	o	ARGO Float cast
42	T-36	2006	6	18	44	30	180	0		o						
43	ST-7	2006	6	18	45	0	180	0			o	o	o	o	o	ARGO Float cast
44	T-37	2006	6	19	45	30	180	0		o						
45	ST-8	2006	6	19	46	0	180	0			o	o	o	o	o	
46	T-38	2006	6	20	46	30	180	0		o						
47	ST-9	2006	6	20	47	0	180	0			o	o	o	o	o	
48	ST-10	2006	6	21	47	30	180	0			o	o	o	o	o	
49	T-39	2006	6	22	48	0	180	0		o						
50	ST-11	2006	6	22	48	30	180	0			o	o	o	o	o	
51	T-40	2006	6	23	49	0	180	0		o						
52	ST-12	2006	6	23	49	30	180	0			o	o	o	o	o	
53	T-41	2006	6	24	50	0	180	0		o						

54	ST-13	2006	6	24	50	30	180	0				o	o	o	o		o	
55	T-42	2006	6	25	51	0	180	0		o								
56	ST-14	2006	6	25	51	30	180	0				o	o	o	o		o	
57	T-43	2006	6	26	52	0	179	40	W	o								
58	T-76	2006	7	3	40	0	150	0	E		o	o	o	o				
59	T-75	2006	7	3	40	40	151	0	E		o							
60	T-74	2006	7	4	41	20	152	0	E		o							
61	T-73	2006	7	4	42	10	153	0	E		o							
62	T-72	2006	7	4	42	50	154	0	E		o							
63	T-71	2006	7	4	43	30	155	0	E		o	o	o	o				
64	T-70	2006	7	4	44	10	156	0	E		o							
65	T-69	2006	7	5	44	50	157	0	E		o							
66	T-68	2006	7	5	45	30	158	0	E		o							
67	T-67	2006	7	5	46	10	159	0	E		o							
68	T-66	2006	7	5	46	50	160	0	E		o	o	o	o				
69	T-65	2006	7	5	47	30	161	0	E		o							
70	T-64	2006	7	6	48	0	162	0	E		o							

Table 1. (continued)

NO	ST	Date	Latitude	Longitude	XBT	XCTD	CTD	Primary	NORPAC	ORI	Gillnet	Longline	Remarks					
71	T-63	2006	7	6	48	40	163	0	E		o							
72	T-62	2006	7	6	49	20	164	0	E		o							
73	T-61	2006	7	6	50	0	165	0	E		o	o	o					
74	T-60	2006	7	6	50	40	166	0	E		o							
75	T-59	2006	7	7	51	10	167	0	E		o							
76	T-58	2006	7	7	51	40	168	0	E		o							
77	T-57	2006	7	7	52	20	169	0	E		o							
78	T-56	2006	7	7	53	0	170	0	E		o	o	o					
79	T-55	2006	7	7	53	30	171	0	E		o							
80	T-54	2006	7	7	54	0	172	0	E		o							
81	T-53	2006	7	8	54	30	173	0	E		o							
82	T-52	2006	7	8	55	0	174	0	E		o							
83	T-51	2006	7	8	55	30	175	0	E		o	o	o					
84	T-50	2006	7	8	56	0	176	0	E		o							
85	ST-21	2006	7	9	58	30	180	0				o	o	o	o	o	o	
86	T-49	2006	7	10	58	0	180	0		o								
87	ST-20	2006	7	10	57	30	180	0				o	o	o	o	o	o	
88	T-48	2006	7	11	57	0	180	0		o								
89	ST-19	2006	7	11	56	30	180	0				o	o	o	o	o	o	
90	T-47	2006	7	12	56	0	180	0		o								
91	ST-18	2006	7	12	55	30	180	0				o	o	o	o	o	o	
92	ST-26	2006	7	13	56	30	179	0	E			o	o	o	o	o	o	

Table 2. Salmonids, other fishes, and squid catches at each station with sea surface temperature (SST, °C) during the summer research cruise of *Wakatake maru*, 2006. 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 fish 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	Steel-head	Var-den	Dolly total	Salmo- nid flying squid	Neon armed squid	Eight- armed squid	Hook- armed salmon shark	Spiny dog- fish	Lan- cet fish	Pacific saury	Pacific pom- fret	Atka- macke- rel	Square tail	Other fishes & squids	Sea- birds		
3	6/15/06	4100	18000	13.2	B	30	0	4	0	0	0	0	0	4	0	0	0	0	0	0	0	103	0	0	0	0		
					C	30	0	3	0	0	0	0	3	45	1	16	0	0	0	0	0	60	42	0	18	3	1	
					A	19	0	1	0	0	0	0	1	123	0	0	0	0	0	0	0	0	42	0	0	0	0	0
					Total		0	8	0	0	0	0	8	168	1	16	0	0	0	0	0	60	187	0	18	3	1	
					Rel.		0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	6/16/06	4200	18000	13.2	B	30	0	4	0	0	0	0	4	0	0	0	0	0	0	0	0	223	0	0	0	1		
					C	30	0	5	0	0	0	5	21	0	4	1	0	0	97	60	0	6	3	0				
					A	19	0	0	0	0	0	0	64	0	0	1	0	0	105	0	0	2	0					
					Total		0	9	0	0	0	9	85	0	4	2	0	0	97	388	0	6	5	1				
					Rel.		0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0				
5	6/17/06	4300	18000	12.0	B	30	0	40	3	34	0	0	77	0	0	0	0	0	0	0	112	0	0	0	0			
					C	30	0	19	0	14	0	33	6	3	11	0	0	0	122	0	0	0	0					
					A	19	0	1	0	25	0	27	12	0	0	4	1	0	113	0	0	0	0					
					Total		0	60	3	73	0	137	18	3	11	4	1	0	347	0	0	0	0					
					Rel.		0	32	2	28	0	92	0	0	0	0	0	0	0	0	0	0	0					
6	6/18/06	4400	18000	9.9	B	30	0	24	1	7	0	0	32	0	0	0	0	0	0	0	87	0	0	0	0			
					C	30	1	49	4	7	2	65	0	0	1	0	1	0	34	0	0	0	1					
					A	19	0	1	0	5	0	8	0	0	0	0	0	0	42	0	0	0	0					
					Total		1	74	5	19	2	105	0	0	1	0	1	0	163	0	0	0	1					
					Rel.		0	20	0	4	0	24	0	0	0	0	0	0	0	0	0	0	0					
7	6/19/06	4500	18000	8.7	B	30	0	10	1	2	0	2	15	0	0	1	0	0	0	0	0	0	0	0	0			
					C	30	0	14	1	19	0	34	0	4	0	0	2	0	3	0	0	0	1					
					A	19	0	1	1	15	1	20	0	0	0	0	4	0	1	0	0	0	0					
					Total		0	25	3	36	1	69	0	4	1	0	6	0	4	0	0	0	1					
					Rel.		0	9	0	1	0	12	0	0	0	0	0	0	0	0	0	0	0					
8	6/20/06	4600	18000	7.4	B	30	1	6	1	19	2	0	29	0	1	0	0	0	0	0	0	0	0	0	0			
					C	30	0	12	3	34	3	54	0	18	0	0	3	0	0	0	0	0	1					
					A	19	0	1	1	17	12	38	0	0	0	0	2	0	0	0	0	0	0					
					Total		1	19	5	70	17	121	0	19	0	0	5	0	0	0	0	0	1					
					Rel.		0	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0					

Table 2. (continued)

St	Date	Lat	Long	SST	Gear	No. unit	Sock-eye	Chum	Pink	Coho	Chi-nook	Steel-head	Var-den	Dolly total	Salmo-nid	Neon flying squid	Eight-armed squid	Hook-armed squid	Salmon shark	Spiny dog-fish	Lan-cet fish	Pacific saury	Pacific pommacke-fret	Atka rel	Square-tail	fishes & squids	Other Sea-birds					
9	6/21/06	4700	18000	7.3	B	30	0	16	0	51	1	0	0	68	0	0	0	0	0	0	1	0	0	0	0	0	0	0				
					C	30	5	9	4	30	2	6	0	56	0	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
					A	19	3	1	5	27	2	19	0	57	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
					Total		8	26	9	108	5	25	0	181	0	7	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
					Rel.		0	15	0	41	1	0	0	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	6/22/06	4730	18000	7.2	B	30	1	3	1	8	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
					C	30	1	12	1	20	0	3	0	37	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1		
					A	19	3	3	3	19	0	6	0	34	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	
					Total		5	18	5	47	0	9	0	84	0	1	0	1	3	0	0	0	0	0	0	0	0	0	0	0	2	
					Rel.		1	3	1	6	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
11	6/22/06	4830	18000	7.4	B	30	2	14	2	15	0	0	0	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
					Rel.		2	11	1	12	0	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
12	6/23/06	4930	18000	7.1	B	30	14	58	4	17	0	2	0	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
					Rel.		14	44	2	15	0	2	0	77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
13	6/24/06	5030	18000	7.2	B	30	14	22	0	0	0	0	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
					Rel.		12	18	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
14	6/25/06	5130	18000	4.7	B	30	4	24	2	1	0	0	0	31	0	0	0	0	0	0	0	0	0	0	7	0	0	0				
					Rel.		4	19	2	1	0	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
21	7/10/06	5830	18000	7.6	B	30	1	79	1	0	3	0	4	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
					C	30	35	117	11	0	2	1	12	178	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		
					A	19	16	101	6	0	6	0	9	138	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		
					Total		52	297	18	0	11	1	25	404	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2		
					Rel.		1	64	1	0	3	0	4	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
20	7/11/06	5730	18000	7.5	B	30	14	259	4	0	5	0	2	284	0	0	0	0	0	0	0	0	0	0	0	0	0					
					C	30	76	303	9	0	4	0	4	396	0	0	0	0	1	0	0	0	0	0	0	2	0	0	1			
					A	19	36	188	6	0	12	0	1	243	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1			
					Total		126	750	19	0	21	0	7	923	0	0	0	0	1	0	0	0	0	0	0	2	0	0	2			
					Rel.		11	132	2	0	2	0	2	149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
19	7/12/06	5630	18000	6.9	B	30	10	111	0	0	2	0	0	123	0	0	0	0	0	0	0	0	0	0	0	0	0					
					C	30	103	403	2	1	7	0	0	516	0	5	0	0	0	0	0	0	0	0	0	4	0	0	1			
					A	19	24	61	10	1	5	0	0	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2			
					Total		137	575	12	2	14	0	0	740	0	5	0	0	0	0	0	0	0	0	0	4	0	0	3			
					Rel.		7	71	0	0	2	0	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			

Table 2. (continued)

St	Date	Lat	Long	SST	Gear	No. unit	Sock-eye	Chum	Pink	Coho	Chi-nook	Steel-head	Dolly Var-den	Salmo-nid total	Neon flying squid	Eight-armed squid	Hook-armed squid	Salmon shark	Spiny dog-fish	Lan-cet fish	Pacific saury	Pacific pommacke-fret	Atka rel	Square-tail	Other fishes & squids	Sea-birds			
18	7/13/06	5530	18000	7.2	B	30	4	28	1	0	1	0	0	34	0	0	0	0	0	0	0	0	0	0	0	1			
					C	30	82	230	8	2	1	0	0	323	0	6	0	0	0	0	0	0	0	0	0	0	0	1	
					A	19	54	87	6	3	5	0	0	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
					Total		140	345	15	5	7	0	0	512	0	6	0	0	0	0	0	0	0	0	0	0	0	0	5
					Rel.		3	22	1	0	0	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	7/14/06	5630	17900E	7.0	B	30	15	79	2	0	0	0	0	96	0	0	0	0	0	0	0	0	0	0	0	0			
					C	30	73	117	2	2	9	0	0	203	0	2	0	0	0	0	0	0	0	0	0	0	0	0	
					A	19	27	44	3	2	9	0	0	85	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
					Total		115	240	7	4	18	0	0	384	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1
					Rel.		15	60	2	0	0	0	0	77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	B	510	80	781	23	154	14	4	6	1062	0	1	1	0	0	1	0	525	7	0	0	0	2						
	C	390	376	1293	45	129	30	14	16	1903	72	47	33	2	7	0	157	261	6	24	7	8							
	A	247	163	490	41	114	52	37	10	907	199	0	0	5	12	0	0	303	0	0	2	9							
	Total		619	2564	109	397	96	55	32	3872	271	48	34	7	19	1	157	1089	13	24	9	19							
	Rel.		71	528	15	125	10	4	6	789	0	0	0	0	0	0	0	0	0	0	0	0	0						

Table 3. Salmonids missing the adipose fin in the catch of the *Wakatake maru*, summer, 2006. Gear: A = commercial-mesh gillnet; C = research-mesh gillnet followed by mesh size (mm); and B = surface longline. – no data. * released with double disk tags MM4099, LL6999.

Date	Location		Gear	Species	Fork length (mm)	Body weight (g)	Sex	Gonad weight (g)	Age	Sample number
	Lat.	Long.								
6/17/06	43°00'N	180°00'	A115	steelhead	560	1780	M	2		17-17
6/18/06	44°00'N	180°00'	A115	steelhead	574	1780	F	3		23-8
6/18/06	44°00'N	180°00'	C157	steelhead	800	5500	M	3		26-1
6/18/06	45°00'N	180°00'	B	steelhead	522	-	-	-		-*
6/20/06	46°00'N	180°00'	C121	steelhead	690	3470	M	13		41-5
6/20/06	46°00'N	180°00'	A115	steelhead	592	1940	F	3		46-1
6/20/06	46°00'N	180°00'	A115	steelhead	547	1760	M	1		46-2
6/20/06	46°00'N	180°00'	A115	steelhead	689	2910	F	19		46-3
6/21/06	47°00'N	180°00'	C93	steelhead	642	2390	F	9		48-10
6/21/06	47°00'N	180°00'	C106	steelhead	569	1840	M	1		56-11
6/21/06	47°00'N	180°00'	C106	steelhead	560	1730	F	5		56-12
6/21/06	47°00'N	180°00'	C106	steelhead	683	2970	F	25		56-13
6/21/06	47°00'N	180°00'	C121	steelhead	694	2850	M	3		57-7
6/21/06	47°00'N	180°00'	A115	steelhead	562	1920	M	1		59-3
6/21/06	47°00'N	180°00'	A115	steelhead	642	2650	M	2		59-4
6/21/06	47°00'N	180°00'	A115	steelhead	636	2760	F	27		59-5
6/21/06	47°00'N	180°00'	A115	steelhead	535	1570	F	3		59-6
6/21/06	47°00'N	180°00'	A115	steelhead	690	3330	F	22		59-7
6/21/06	47°00'N	180°00'	A115	steelhead	723	3600	M	18		59-8
6/21/06	47°00'N	180°00'	A115	steelhead	685	3050	F	5		59-9
6/22/06	47°30'N	180°00'	C138	steelhead	668	2990	F	34		65-2
6/22/06	47°30'N	180°00'	A115	steelhead	702	3260	F	30		69-1
6/22/06	47°30'N	180°00'	A115	steelhead	660	2800	F	24		69-2
6/22/06	47°30'N	180°00'	A115	steelhead	656	2750	F	30		69-3

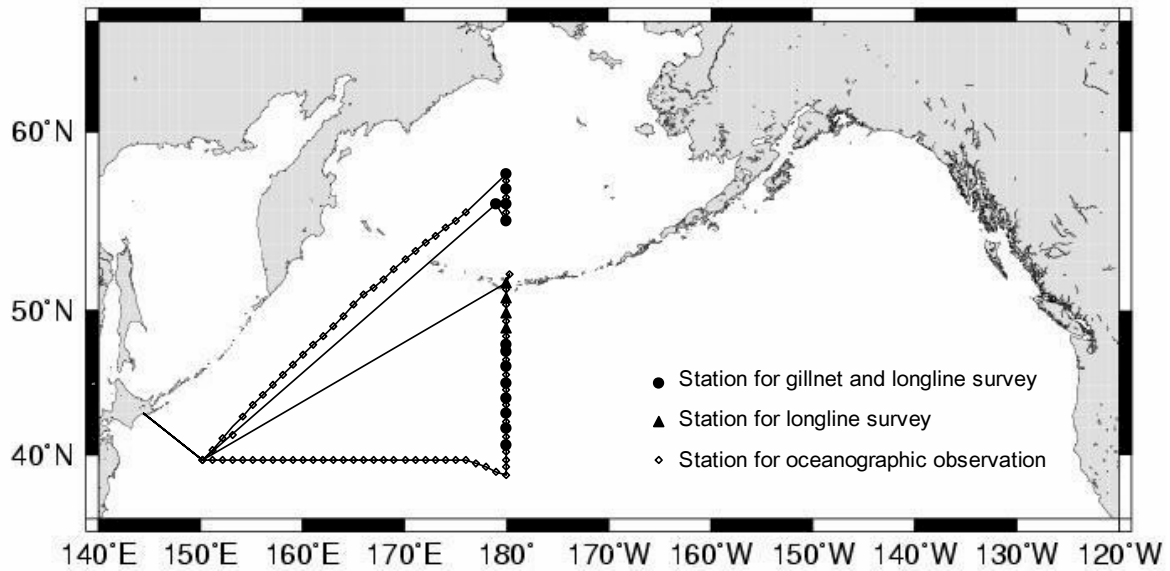


Fig. 1. Survey area of the R/V *Wakatake maru* salmon research cruise, summer 2006.

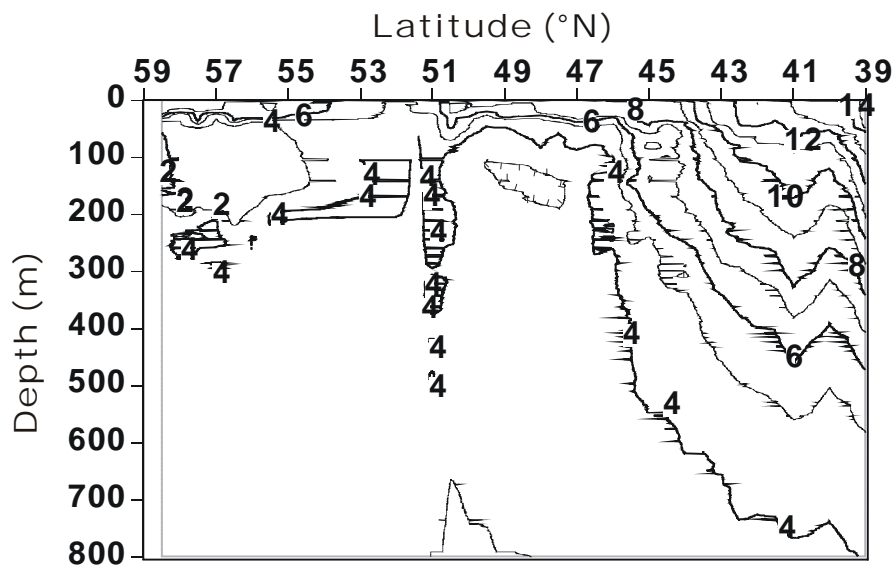


Fig. 2. Vertical section of water temperature (°C) along the 180° transect of the *Wakatake maru* cruise, 2006.

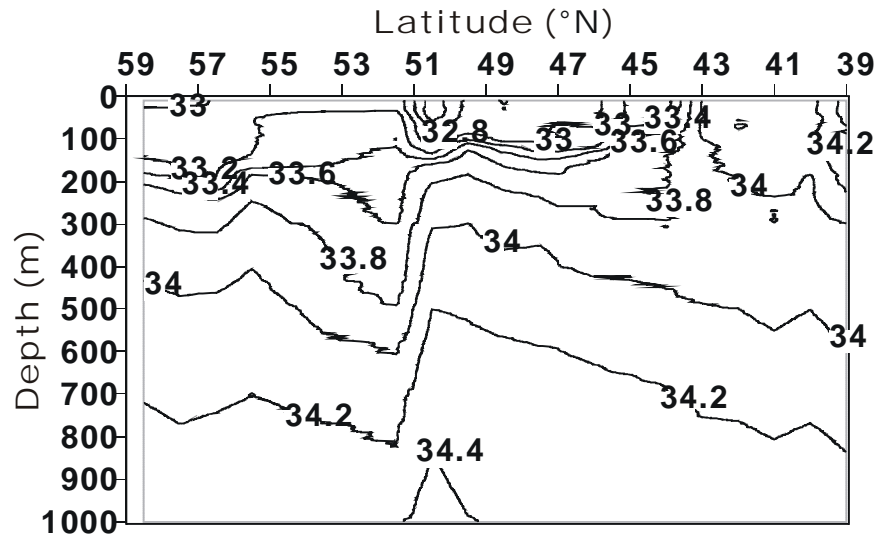


Fig. 3. Vertical section of salinity (psu) along the 180° transect of the *Wakatake maru* cruise, 2006.

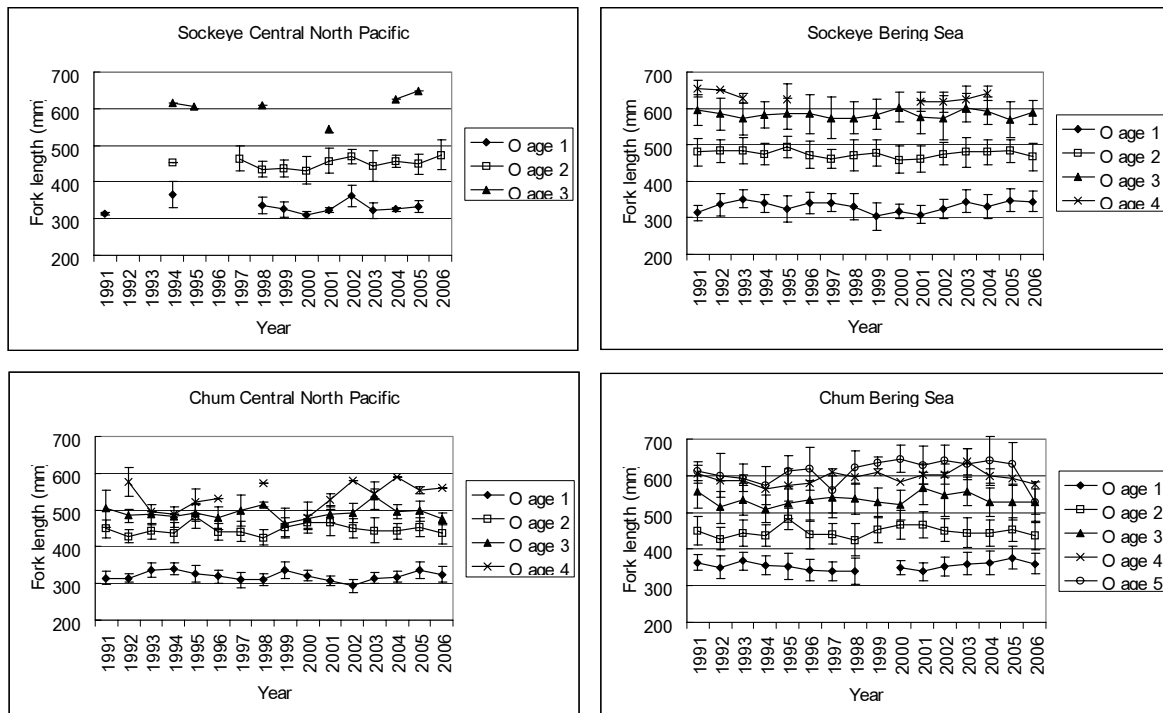


Fig. 4. Mean fork length (+/- one standard deviation) at ocean age by year for sockeye and chum salmon caught in the research-mesh gillnet (C-gear), 1991-2006. Fish were caught in the central North Pacific (CNP) and Bering Sea (BS).

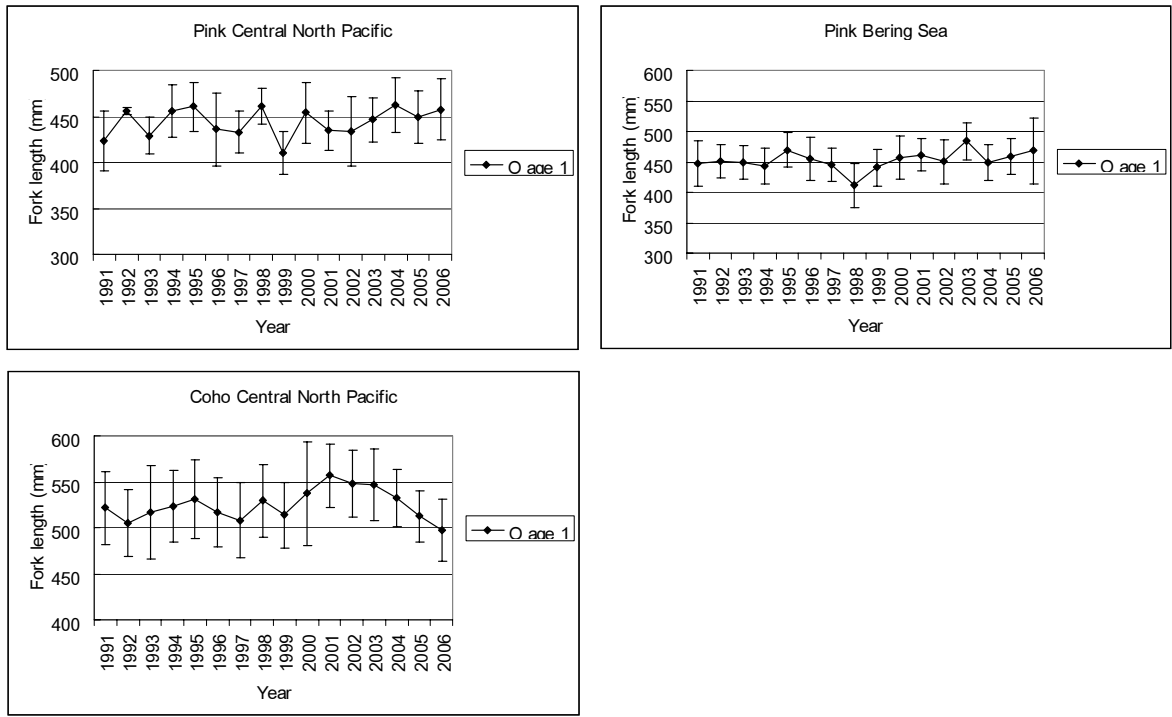


Fig. 5. Mean fork length (+/- one standard deviation) at ocean age by year for pink and coho salmon caught in the research-mesh gillnet (C-gear), 1991-2006. Fish were caught in the central North Pacific (CNP) and Bering Sea (BS).

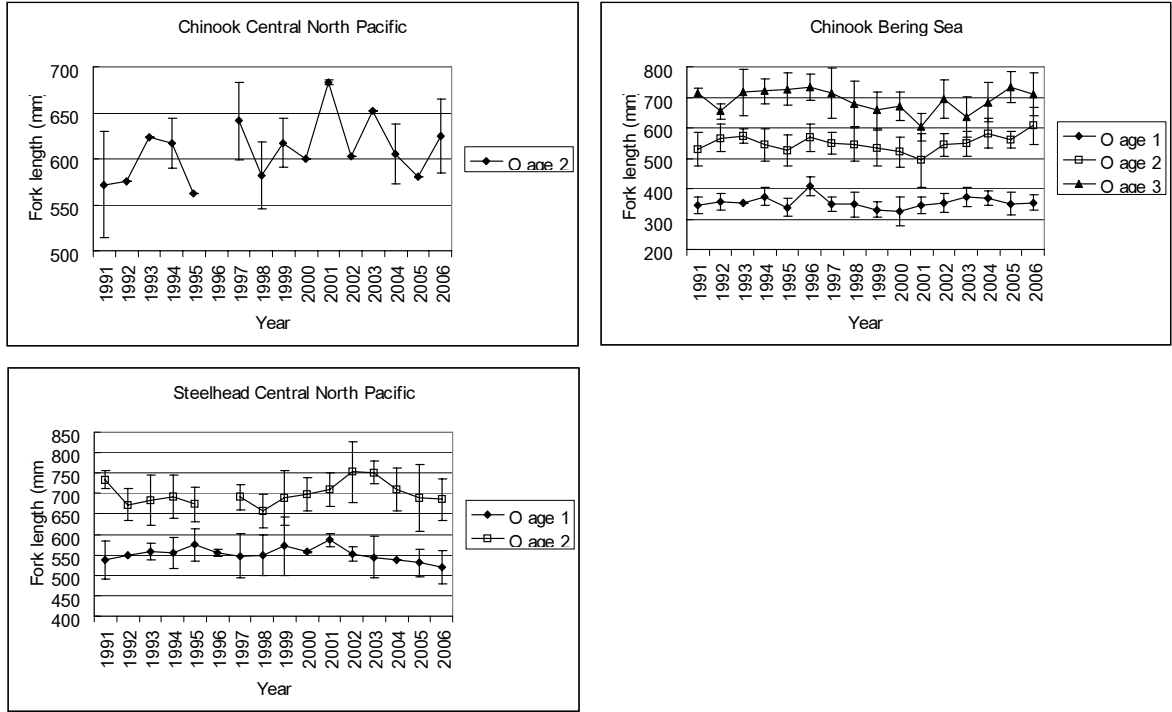


Fig. 6. Mean fork length (+/- one standard deviation) at ocean age by year for chinook salmon and steelhead caught in the research-mesh gillnet (C-gear), 1991-2006. Fish were caught in the central North Pacific (CNP) and Bering Sea (BS).