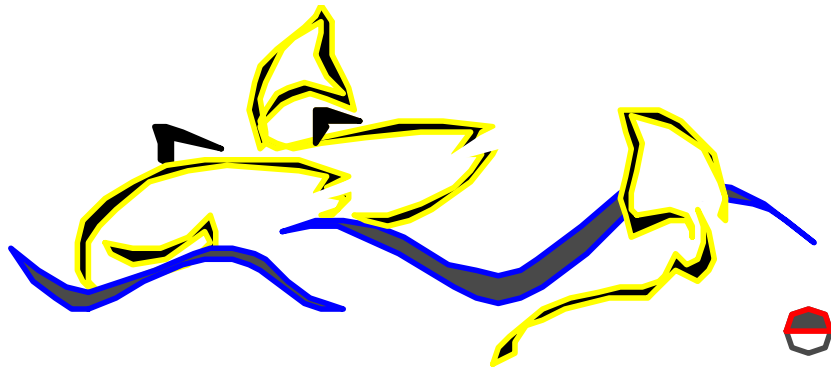


SAFS-UW-0402
April 2004

High Seas Salmon Research Program, 2003

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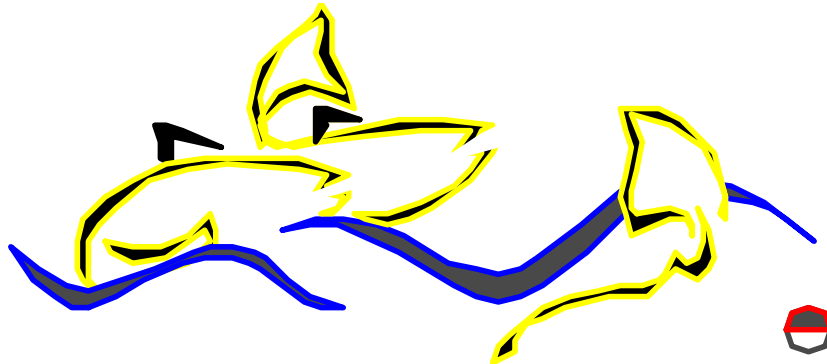
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Final Report for 2003:

NOAA Contract No. 50ABNF-1-00002,

JISAO, Task III,

YR DFA, Contract 2002-01,

NSF, Award No. OCE-0106139

NOAA Contract No. WASC-2-1520

Preface

The High Seas Salmon Research Program is a long-term (1953-present) research program at the Fisheries Research Institute (FRI), School of Aquatic and Fishery Sciences (SAFS), University of Washington. During our 50-year history, the faculty, staff, and students of the High Seas Salmon Research Program have carried out scientific investigations of the abundance, distribution, migration patterns, stock origins, life history, and ecology of Pacific salmon (*Oncorhynchus* spp.) in the North Pacific Ocean and Bering Sea. The results of our work have been used by the U.S. government and others to address issues of concern related to research, conservation, and management of salmon in the ocean. We are committed to continuing this long-term research, addressing current research problems, and identifying emerging issues of concern. The High Seas Salmon Research Program is dedicated to providing professional and public service at local, regional, state, national, and international levels. We promote and benefit from collaboration with other people, and our work could not be done without the provision of data, samples, ship time, and many other things by agencies in the USA, Canada, Japan, and Russia. The High Seas Salmon Research Program is funded entirely by external grants and contracts, and we gratefully acknowledge this support.

In 2003 the grant and contract work of the High Seas Salmon Research Program included six projects: (1) “North Pacific Anadromous Fish Commission (NPAFC) Research Coordination,” (2) “Migration Studies of Salmon in the Bering Sea,” (3) “Food Habits of Bering Sea Salmon,” (4) “Stock Origins of Chinook Salmon in the Eastern Bering Sea,” (5) “Global Ocean Ecosystems Dynamics (GLOBEC) 2000: Feeding, Growth, Condition, and Energetics of Juvenile Pink Salmon in the Northern Gulf of Alaska,” and (6) “Age and Growth of Juvenile Chinook Salmon in Coastal Marine Waters of Southeast Alaska.” This final report for 2003 includes reports on specific tasks as described in the Statement of Work for “NPAFC Research Coordination” (National Oceanic and Atmospheric Administration (NOAA) Contract No. 50ABNF-1-0002), as well as related tasks funded by the other grants and contracts.

This report may be cited as follows:

Myers, K.W., R.V. Walker, N.D. Davis, and J.L. Armstrong. High Seas Salmon Research Program, 2003. SAFS-UW-0402, School of Aquatic and Fishery Sciences, University of Washington, Seattle. 93 p.

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Introduction

In 2003 the grant and contract work of the High Seas Salmon Research Program, Fisheries Research Institute (FRI), School of Aquatic and Fishery Sciences (SAFS), University of Washington, included six projects: (1) “North Pacific Anadromous Fish Commission (NPAFC) Research Coordination,” (2) “Migration Studies of Salmon in the Bering Sea,” (3) “Food Habits of Bering Sea Salmon,” (4) “Stock Origins of Chinook Salmon in the Eastern Bering Sea,” (5) “Global Ocean Ecosystems Dynamics (GLOBEC) 2000: Feeding, Growth, Condition, and Energetics of Juvenile Pink Salmon in the Northern Gulf of Alaska,” and (6) “Age and Growth of Juvenile Chinook Salmon in Coastal Marine Waters of Southeast Alaska.” This final report for 2003 includes reports on specific tasks as described in the Statement of Work for “NPAFC Research Coordination” (National Oceanic and Atmospheric Administration (NOAA) Contract No. 50ABNF-1-0002), as well as related tasks funded by the other grants and contracts.

1. NPAFC Research Coordination

Since 1955, the U.S. Government has contracted the FRI/SAFS to conduct research on issues related to Pacific salmon and steelhead trout in the North Pacific Ocean. This work has included participation of SAFS scientists in the deliberations of the International North Pacific Fisheries Commission (INPFC, 1955-1992) and the North Pacific Anadromous Fish Commission (NPAFC, 1993-present). The results of our research have been used by the U.S. Government to establish a strong scientific basis for conservation and management of U.S. salmon stocks in international waters. This project is a continuation of research coordination efforts and international cooperative high seas salmon research in support of U.S. commitments to the NPAFC. The “NPAFC Research Coordination” project operates under the National Oceanic and Atmospheric Administration (NOAA) Authorization Act of 1992 (PL 102-567, Title VIII: North Pacific Anadromous Stocks Convention). Our funding agency, the Auke Bay Laboratory (ABL), Alaska Fisheries Science Center (AFSC), National Marine Fisheries Service (NMFS), NOAA, Juneau, Alaska, is charged with the mission of stewardship for this program. Our work is closely coordinated with our colleagues at ABL’s Ocean Carrying Capacity Research Program (<http://www.afsc.noaa.gov/abl/occ/research1.htm>).

In 1993 the Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean established the NPAFC. The Convention prohibits salmon fishing in international waters of the North Pacific Ocean and Bering Sea, and emphasizes the importance of scientific research for the conservation of anadromous salmon stocks. The development of the NPAFC science plan was coordinated with the North Pacific Marine Sciences Organization (PICES). The overarching goal of this plan is to investigate the effects of change in the productivity of the North Pacific Ocean on Pacific salmon, including: (1) current trends in ocean productivity and effects on carrying capacity, and (2) changes in biological characteristics of salmon (growth, size and age at maturity, oceanic distribution, survival, and abundance).

In 2000 the NPAFC adopted a new five-year science plan (2001-2005) that emphasizes cooperative science activities in three areas: (1) Bering Sea salmon research, (2) juvenile salmon research in eastern and western North Pacific waters, and (3) winter salmon research. An important aspect of research in all three areas is to investigate the stock-specific abundance, distribution, growth, and other biological characteristics of Asian and North American salmon with respect to ocean productivity and salmon carrying capacity in the North Pacific Ocean and Bering Sea. Our NPAFC Research Coordination project in 2003 included contract work in two major areas: (1) international cooperative high seas salmon research and (2) participation in NPAFC workshops, symposia, and meetings.

1.1 International Cooperative High Seas Salmon Research

Participation in cooperative cruises on foreign salmon research vessels has proven to be a cost-efficient and effective method for U.S. scientists to obtain up-to-date samples and data on the distribution, abundance, growth, and stock origins of salmon in offshore waters. Our international cooperative salmon research began in 1983 with participation of FRI scientists in high seas salmon tagging cruises aboard U.S.S.R. research vessels in the North Pacific Ocean and Bering Sea. In 2003 our contract work included cooperative NPAFC high seas salmon tagging research, high seas salmon research vessel cruises, and salmon scale sample and data exchanges.

1.1.1 Cooperative NPAFC high seas salmon tagging

1.1.1.1 High Seas disk and data storage tags

For most natural populations of Pacific Rim salmon and steelhead, the historical high seas tagging database (1954-present) is the only direct information available on ocean ranges, seasonal migration patterns, overlaps in distribution, and individual migration and growth rates. Information from high seas tagging is often used to validate the results of other high seas salmon stock identification methods. Since the beginning of the high seas tagging program in 1954, the U.S. government has contracted FRI/SAFS to do this work. In recent years, the high seas tag database has continued to provide direct, stock-specific information on offshore distribution and migration patterns. R. Walker serves as the U.S. representative/co-operator with the NPAFC high seas salmon tagging program.

Since 1956, FRI/SAFS has provided the North American processing center for recovery of high seas salmon tags. This activity requires advertising for tag returns, returning tags and recovery information to appropriate agencies, returning information on tag recoveries and a reward to fishermen and processors who return high seas tags, and reporting new tag recoveries in documents for NPAFC (Walker et al. 2002, 2003). We also update and maintain the historical high seas salmon tag release and recovery databases, and fulfill NPAFC-related requests to the U.S. government for these data. In 2002, we fulfilled a request from Russia (O. Gritsenko, VNIRO) for the high seas tag databases for use in an atlas of marine distribution of major regional stocks of Asian and North American salmon (Klovatch et al. 2002). This book (published in Russian), which

was distributed to scientists and libraries in North America in 2003, acknowledges NOAA Contr. 50-ABNF-1-0002 for support of high seas salmon tag database work.

In spring 2003, we advertised for return of high seas salmon tags by mailing approximately 1,400 informational packets to addresses in Alaska, British Columbia, Washington, Oregon and California. These packets were sent to federal, state, and tribal fisheries research and management agencies, fishermen's organizations, salmon buyers and processors, and post offices. The informational packet included a letter explaining the tagging program and the importance of returning tags, a poster advertising for tag returns (Fig. 1), and a business-reply envelope that included a form for recording recovery information (tag number, date, location, fishing gear) and salmon biological data (species, sex, body weight, how to collect scales). Since 1991, we have offered a custom-embroidered cap as a reward for people who return high seas tags. The reward caps are embroidered with colorful, stylized salmon and lettering emphasizing the cooperative aspects of the high seas tagging program.

The behavior and habitat of salmon on the high seas are poorly known. The ocean temperatures and depths where salmon swim and the routes of their migrations can only be inferred from fishing, oceanographic sampling, tagging studies, and stock identification. Since 1998 NMFS and SAFS scientists have collaborated in the deployment of data storage tags (DSTs) that measure water temperature or water temperature and depth for international cooperative high seas programs. These new tagging technologies have enabled us to get precise detailed data from individual fish as they migrate, and data from a few recoveries have already yielded a wealth of information.

U.S. high-seas disk tags are 20 mm diameter plastic red-and-white Petersen disk tags. Five models of two types of DSTs were used in 2003. One type is a small circuit board potted in a clear urethane, manufactured by Lotek Marine Technologies. Models LTD_1100-300 and LTD_1100-500 are 27 x 16 x 8 mm and weigh 5 g. These tags record temperature and depth data. iButton-type tags are ThermoChron iButton data storage devices (DS-1921H-F5 and DS-1921Z-F5) manufactured by Dallas Semiconductor, Inc., and repackaged in urethane for fish tagging by AlphaMach, Inc.; all models record temperature data only. Model iB4 tags are oval, 24 x 16 x 8 mm and weigh 3.8 g in air. Model iBLite tags are hexagonal, 26 x 17 x 7 mm and weigh 3 g. Model iBKrill tags are hexagonal, 25 x 13 x 8 mm and weigh 3.2 g. DSTs were attached to fish just anterior to the dorsal fin using two 76 or 64 mm nickel pins, with labeled U.S. and Japanese disk tags placed on the pins on the other side of the fish.

In June and July 2003, scientists aboard the *Wakatake maru* tagged viable salmon and steelhead trout caught by longline (Fig. 2; Fukuwaka et al. 2003a,b, Walker et al. 2003). In the central North Pacific Ocean 145 fish were disk tagged and released, and 689 disk-tagged fish were released in the central Bering Sea. The total (n=834) included release of 26 sockeye, 166 chum, 579 pink, 30 coho, and 29 chinook salmon, and 4 steelhead. Among these releases, 140 salmonids were also tagged with DSTs. In the central North Pacific Ocean, 4 sockeye and 1 chinook salmon were released with an LTD tag. In the

Bering Sea, 14 maturing sockeye and 10 maturing chum salmon were tagged with an LTD tag. In addition, 3 sockeye, 30 chum, 60 pink, and 18 chinook salmon were released carrying an iB4 (temperature-recording) archival tag.

In August 2003, scientists aboard the *Kaiyo maru* in the Gulf of Alaska released thirty-six salmon (20 chum, 11 sockeye, 2 pink, 2 chinook, and 1 coho salmon) tagged with Petersen disks (9) or with disks and DSTs (27) (Walker et al. 2003). Most (33) were caught by hook-and-line, but three chum salmon, in good condition, from trawl catches were also tagged. The highest number of salmon tagged (10) was at Patton Seamount (54°38'N, 150°24'W), despite poor weather conditions there.

Six DSTs, from three chum salmon tagged during 2002 operations in the Bering Sea, were recovered in September 2002 in Hokkaido (Walker et al. 2003). They had each been tagged with two types of DSTs for comparisons of the data from the different tags. The overall pattern of temperatures from the two types of tags generally conformed (Figs. 3-5). However, individual temperatures from temperature-only tags tended to be about 1°C higher than temperatures from the tags that recorded temperature and depth data.

Three new recoveries of high-seas tagged salmon in North America were reported by fishermen in 2003. All were from sockeye salmon tagged in the Bering Sea in 2003, and all were recovered in the Bristol Bay-north Alaska Peninsula area. One fish carrying a DST recording temperature and depth data was caught in Nelson Lagoon, Alaska Peninsula (Fig. 6). Another DST, recording temperature data, was returned from a fish caught in Naknek, Bristol Bay (Fig. 7). A third sockeye, carrying disk tags only, was caught just north of False Pass at the eastern end of the Alaska Peninsula.

1.1.1.2 High Seas coded-wire tags

In 1980 a U.S. scientist aboard a Japanese research vessel noted several steelhead with missing adipose fins (ad-clipped) in the catch. Coded-wire tags (CWTs) were recovered from the snouts of these fish, and NMFS/ABL became responsible for analyzing snout samples from ad-clipped salmon and steelhead recovered during high seas research and commercial fishing operations. Information on high seas recoveries of CWT salmonids has been reported annually to the INPFC (1981-1992) and to the NPAFC (1993-present). The Regional Mark Processing Center, Pacific States Marine Fisheries Commission, incorporates the high seas CWT recovery data into their coastwide, on-line CWT recovery data set (Regional Mark Information System (RMIS), <http://www.rmis.org/>). We collaborate with NMFS scientists in this program by assisting in the recovery of CWT salmon and steelhead during NPAFC cooperative high seas salmon research vessel cruises, maintaining, updating, and correcting the historical high seas CWT database, reporting recoveries to NPAFC, and fulfilling requests from other agencies for high seas salmonid CWT data.

During Japanese high seas salmon research vessel operations in 2003, snouts were collected from three ad-clipped steelhead in the central North Pacific and three ad-clipped chinook salmon in the Gulf of Alaska (Table 1). Snouts were packed with salt, and sent

to the NMFS/ABL for potential recovery of coded-wire tags. In addition, Russian scientists in 2003 reported the recovery of approximately 20 ad-clipped steelhead, caught in summer 2002-2003 research cruises in the far western Pacific Ocean near the Kurile Islands. Snouts from these fish have not yet been examined to determine if they contain coded-wire tags.

In 2003 data for 124 new recoveries of CWT salmonids were reported to the NPAFC (Myers et al. 2003). Reported recoveries are from U.S. groundfish (trawl) fisheries in the eastern Bering Sea and Gulf of Alaska portions of the U.S. Exclusive Economic Zone (103 recoveries) and from U.S. and Japanese salmon research vessel operations in the Bering Sea, Gulf of Alaska, and central North Pacific Ocean (21 recoveries). Starting in 2003, recoveries of CWT salmon caught by the Pacific hake (*Merluccius productus*) fishery along the U.S. West Coast were no longer processed by ABL or reported to NPAFC.

Recoveries of CWT fish that provided new information on ocean distribution and migration patterns of regional stocks of salmon and steelhead were summarized by Myers et al. (2003a). These included three U.S. research vessel recoveries of juvenile (age-.0) CWT chinook salmon released from a hatchery in the Canadian Yukon Territory (Whitehorse Hatchery) and caught in the northeastern Bering Sea (Norton Sound) during their first fall (October) at sea, which are northern extensions of the known ocean range of Yukon River chinook salmon (Fig. 8). Two new groundfish vessel recoveries of immature (age-.1) chinook salmon in the southeastern Bering Sea in February are the first recoveries that show the overwintering location of Yukon river salmon during their first winter at sea. Two groundfish vessels recoveries of older (ages 0.2 and 0.3) CWT hatchery chinook salmon near the Pribilof Islands in the eastern Bering Sea are northwestern extensions of the known ocean ranges of Columbia River Basin (Washington) and Oregon chinook salmon (Figs. 9 and 10). Three U.S. research vessel recoveries of juvenile CWT coho salmon (two Cook Inlet wild fish and one Oregon (Columbia River Basin) hatchery fish) demonstrate overlap in the distributions of hatchery and wild juvenile salmon from Alaska and U.S. West Coast production regions in the Shelikof Strait in early August (Figs. 11 and 12). Three U.S. research vessel recoveries of southeast Alaska coho salmon show that the distributions of northward migrating hatchery and wild juvenile fish and southward migrating hatchery adult fish overlap in the coastal waters off Yakutat Alaska in mid July (Fig. 13). One Japanese research vessel recovery of a steelhead trout at 56°N, 145°W is a significant northern extension of the known range of North Washington Coast steelhead trout in the Gulf of Alaska (Fig. 14).

1.1.2 Participation in NPAFC salmon research vessel cruises

In 2003, SAFS scientists participated in cooperative salmon research cruises with the Hokkaido National Fisheries Research Institute (HNFRI, *Wakatake maru*) and the Fisheries Agency of Japan (FAJ, *Kaiyo maru*). The *Wakatake maru* conducted a gillnet and longline survey at 180° in the central North Pacific in June and in the Bering Sea in July (Fukuwaka et al. 2003a; Fig. 2). The *Kaiyo maru* conducted trawling operations in

the Gulf of Alaska in August at transects along 145°W, 150°W, 155°W and 160°W. This work includes analysis of data and preparation of cruise and data reports, as summarized below.

1.1.2.1 Wakatake maru cruise

One SAFS scientist (N. Davis) participated in the *Wakatake maru* cruise, which surveyed salmonids in the central North Pacific and Bering Sea from June 7 to July 22, 2003 (Fig. 2; Fukuwaka et al. 2003a). The objective of this cruise was to monitor salmon stock condition. Research cruise activities included collection of data on oceanography, primary production, zooplankton, salmonids, and other organisms.

The results of oceanographic sampling show that the average sea surface temperatures in the central North Pacific were 0.4°C cooler in 2003 than in 2002. However, in the Bering Sea, sea surface temperatures in 2003 were 0.5°C warmer than in 2002. The total catch by longline and gillnet sampling in 2003 was 12,725 salmonids, including 1,108 fish in the central North Pacific Ocean (stations 3-14) and 11,617 salmon in the central Bering Sea (stations 15-31). In the North Pacific, pink salmon was the most abundant species (48.6% of the salmonid catch) followed by chum (25.0%), coho (20.2%), and sockeye salmon (4.2%), steelhead trout (1.4%), and chinook salmon (0.6%). In the Bering Sea, pink salmon was the most abundant species (76.4% of the salmonid catch), followed by chum (17.9%), sockeye (4.3%), chinook (1.3%), and coho salmon (0.1%). A total of 846 salmon stomach samples was examined onboard the research vessel, and 140 chum salmon brain, pituitary, gonad, and blood samples were obtained for endocrine studies.

Abundance of sockeye in the central North Pacific Ocean in 2003 was greater than it had been since 1999, and it was the first time in four years that catch per unit of effort (CPUE; number of fish caught per 1500 m of research-mesh gillnet) was substantially above the 13-year mean (2003: 4.3, 13-year average: 1.8; Fig. 15; Table 2). Abundance of sockeye salmon in the central North Pacific has been higher in 1998–2003 than in the earlier period (1991-1997; Fig. 15). Sockeye salmon fork length and body weight at age were smaller in 2003 than in 2002 (Table 3), and most of the sockeye salmon caught in this area were immature age-1.1 (43%) and age-2.1 (47%; Fig. 16; Table 4). In the Bering Sea sockeye salmon abundance has been declining since 2001, when the highest abundance of sockeye was observed in the Bering Sea during the 13-year record (2003: 22.4, 2001: 60.8; 13-year average 39.6; Fig. 17). Mean body size of ocean age-.1, -.2, and -.3 sockeye salmon was larger in 2003 than in 2002 (Table 3). Immature age-1.1 (23%) and age-2.1 (31%) were the most common sockeye salmon age-maturity groups caught in the Bering Sea (Fig. 18; Table 5).

After two years (2001 and 2002) of relatively high abundance of chum salmon in the central North Pacific, abundance decreased to just above the 13-year average in 2003 (2003: 19.0; 13-year average 17.4; Fig. 15; Table 2). In 2003, mean fork length and body weight of age 0.1, 0.2, and 0.3 chum salmon were larger than in 2002 (Table 6). Immature age 0.1 (42%) and 0.2 (42%) were the most common ages of chum salmon

caught in the central North Pacific Ocean (Fig. 16; Table 7). Chum salmon were less abundant in the Bering Sea in odd-numbered years when pink salmon abundance was high (Fig. 17; Table 2), and chum salmon abundance was at a minimum level every four years (1991, 1995, 1999 and 2003; Fig. 17). In 2003, age 0.1, 0.3 and 0.4 chum salmon were larger, and age 0.2 chum salmon were smaller than fish caught in 2002 (Table 6). Most chum salmon caught in 2003 were immature ocean age-.1 (22%) and -.2 (30%) fish, and maturing age-.3 (24%) fish (Fig. 18; Table 7).

In the central North Pacific, pink salmon abundance in 2003 was at the highest level observed since 1991 (Fig. 15; Table 2). The abundance of pink salmon in this area in odd-numbered years has been increasing since 1993. All pink salmon in the catches were maturing age 0.1 (Table 8), and in 2003 pink salmon body size was larger than in 2002. In the Bering Sea, pink salmon have a high abundance in odd-numbered years (Table 2). Pink salmon catches in the Bering Sea in even-numbered years have followed a decreasing trend since 1994.

In 2003, the abundance of coho salmon in the central North Pacific was higher than in 2002, however, coho abundance remained below the 13-year average (2003: 8.9; 13-year average 10.9; Fig. 15, Table 2). All the coho salmon caught by the *Wakatake maru* are maturing age-.1 fish (Table 9). Mean fork length and body weight of coho caught in the central North Pacific was approximately the same as those of coho salmon caught there in 2002.

Chinook salmon were not abundant in the central North Pacific Ocean in 2003 (Fig. 15; Table 2). Only one chinook salmon was caught by research gillnet in the central North Pacific, a relatively large, immature age-.2 chinook salmon (Tables 10 and 11). In the Bering Sea, although chinook salmon were relatively more abundant than in the central North Pacific (Table 2), the abundance of fish there in 2003 was lower than in 2002, and remained below the 13-year average (2003: 4.6; 13-year average: 6.9; Fig. 17). Chinook salmon were mostly immature age 1.2 (62%) fish, and the size at age was approximately the same in 2003 as it was in 2002 (Tables 10 and 12).

In 2003, the abundance of steelhead trout was slightly lower than in 2002 and abundance has remained below the 13-year average since 2000 (2003:1.0; 13-year average 1.7; Fig. 15; Table 2). Three fish were immature ages 1.1, 3.1, and 4.1, and three fish were maturing 1.2 (n=1) and 3.2 (n=2) age fish (Table 14).

A total of 840 stomach samples was examined onboard the *Wakatake maru* in 2003. This total included 234 samples collected from the central North Pacific (41°-50°N; Table 15), 14 samples collected in the vicinity of the Aleutian Islands (51°30'N; Table 16), and 592 samples collected from the central Bering Sea (52°-58°; Table 17).

In the central North Pacific Ocean, squid (sub-adult *Berryteuthis anonychus*) was the most common prey organism found in the stomach contents of sockeye, pink, coho, and chinook salmon and steelhead (Table 15). Chum salmon consumed mostly gelatinous zooplankton (coelenterates, ctenophores, and salps) and chaetognaths. Among all the

salmonids examined, sockeye salmon consumed the most diverse prey including high proportions of hyperiid amphipods, pteropods, and chaetognaths, in addition to squid. In 2003, mean SCI (prey weight standardized to salmon body weight, $SCI = PW * 100 / \text{body weight}$) was higher in samples examined from sockeye and pink salmon than in 2002. The mean SCI of pink salmon was the highest level observed during the 13-year data series, indicating that the feeding conditions for pink and sockeye salmon may have been favorable in this area. The mean SCI of coho salmon was approximately equal in 2002 and 2003, while in 2003 it was lower for chum and chinook salmon, and steelhead.

Each year, relatively few stomach samples are collected from the Aleutian Islands area because only one station in the *Wakatake maru* survey is located there (Amchitka Pass, Fig. 2; Table 16). In 2003, chum salmon consumed a high proportion of gelatinous zooplankton and appendicularia and the mean SCI was lower than in 2002. Pink salmon consumed mostly fish, squid, and pteropods in this area, and the mean SCI was higher than samples collected in 2001 (most recent year for which there are data).

Diet composition of salmon was more diverse in the central Bering Sea than in the central North Pacific and Aleutian Islands (Table 17). In 2003, euphausiids, squid, and fish were important components of the diets of sockeye, pink, coho, and chinook salmon in this area. Euphausiids were also common in the stomach contents of chum salmon, however, chum salmon also consumed pteropods and gelatinous zooplankton. The mean SCI of chum and pink salmon was higher in 2003 than in 2002, and the mean SCI of sockeye and coho salmon was lower.

Prey organisms observed in stomach contents collected in 2003 from both the central North Pacific and Bering Sea included ctenophores (*Beroë*), polychaetes (*Rhynchonerella*, *Tomopterus*), euphausiids (*Thysanoessa longipes*), copepods (*Candacia columbiae*, *Neocalanus cristatus*, *Eucalanus bungii*), hyperiid amphipods (*Themisto pacifica*, *Primno abyssalis*), gammarid amphipods (Lysianassidae), ostracods (*Conchoecia*), shrimp (*Hymendora frontalis*), pteropods (*Limacina helicina*, *Clione limacine*), unknown juvenile squid (5-44 mm ML), and fish (poachers 21 mm SL, *Hemilepidotus* 17-30 mm SL, sand lance *Ammodytes hexapterus* 32-35 mm SL, Atka mackerel *Pleurogrammus monopterygius* 28-78 mm SL). Prey organisms observed only in samples collected from the central North Pacific included euphausiids (*Euphausia pacifica*), squid (*B. anonychus* 42-120 mm ML), pteropods (*Clio pyramidata*), and heteropods (*Carinaria*). Prey organisms observed only in stomach samples collected from the Bering Sea included brachyuran crab zoea; squid, including *Gonatopsis borealis* (45-134 mm ML) and *Gonatus kamtschaticus* (200 mm ML); and fish, including *Bathymaster* 38-55 mm SL, *Atheresthes* 23-30 mm SL, halibut *Hippoglossus stenolepis* 20-23 mm SL, and northern lampfish *Stenobranchius leucopsarus* 60-124 mm SL.

In related analyses, the historical *Wakatake maru* salmon food habits database (1991-2000; collected under previous NOAA contracts: 50ABNF1-27, 50ABNF4-1, 50ABNF7-3, and 50ABNF0-8) was used by N. Davis in her Ph.D. dissertation to characterize the food habits and feeding ecology of salmon and steelhead in the central North Pacific Ocean and Bering Sea in summer (Appendix 1; Davis 2003); an evaluation of the

potential for trophic interactions among salmon in offshore habitats where Yukon River salmon are known to migrate (see section 3 of this report; Davis et al. 2003); and ongoing bioenergetic modeling and related studies of salmon in the Bering Sea (see section 2 of this report).

1.1.2.2 *Kaiyo maru* cruise

From 1993 to 2002 SAFS scientists participated in cooperative Japan-US salmon gillnet surveys conducted aboard the T/S *Oshoro maru* in the central North Pacific Ocean and Gulf of Alaska (GOA), primarily along a 145°W-longitude transect in the central GOA in early July. In 2003, the R/V *Kaiyo maru* instead of the T/S *Oshoro maru* was used for sampling on the 145°W-longitude transect. Two SAFS scientists (K. Myers and R. Walker) participated in the R/V *Kaiyo maru* cruise from 28 July to 21 August 2003 (Fig. 2). The salmon survey was conducted in an area (165°-145°W, 50°-58°N), time period (August), and using gear (trawl) for which there is little comparable historical data. The trawl was towed for one hour during daylight hours, while gillnets used by the *Oshoro maru* were soaked overnight. Day/night differences may be a significant source of differences in catches and salmon stomach contents between *Kaiyo maru* and *Oshoro maru* sampling. The primary objective of the 2003 *Kaiyo maru* survey was to collect oceanographic and biological data in the central North Pacific Ocean and GOA, particularly to study distribution of immature (Japanese) chum salmon that may have been ‘displaced’ from the Bering Sea due to high abundance of eastern Kamchatka pink salmon in an odd-numbered year. Four north-south transects were fished (160°W, 155°W, 150°W, and 145°W). These transects cut across oceanographic regions (such as the northern boundary of the Subarctic Current, the Ridge Domain/Alaska Gyre, and the Alaska Current) that generally trend diagonally WSW to ENE in this area. Sea surface temperatures were warm (11.4°-15°C; average 12.8°C; Table 18), as would be expected in late summer. Surface temperatures were generally higher at northern and eastern stations.

The total catch at 25 trawl stations was 2,082 salmon, mostly chum salmon (n=1,577, Table 18). Almost no salmon were caught at southeastern stations; for example only six (chum) salmon were caught along 145°W south of 56°N. Along this line in early July in previous years, 1,000-2,000 salmon were usually caught by gillnet by the *Oshoro maru*. (In early July the *Oshoro maru* also caught fewer salmon at southern than at northern 145°W stations, but catches at southern stations still numbered in the 100s.) SSTs were not significantly warmer at stations of low catch (<5) than at those of higher catches (22-256). Pink salmon (n=179), maturing fish likely returning to Kodiak and south central Alaska, were caught at northern stations closer to shore. Sockeye salmon (n=288), primarily immatures, were caught mainly at southwestern stations. Chum salmon, mostly immatures, were caught throughout the survey area. Very few chinook (n=26) or coho salmon (n=11) or steelhead trout (n=2) were caught. Pink and coho salmon were maturing, but chum and sockeye salmon were mostly immature, reflecting that most maturing fish had already returned to inshore waters by August.

Preliminary analyses of salmon stomach contents data show that crab larvae were much more abundant in August than in *Oshoro maru* samples from early July on the 145°W transect, but *Kaiyo maru* stations were closer to the shelf, further west, and later in the season. Large squid were not as dominant in stomach contents from southern (Subarctic Current) stations as in *Oshoro maru* samples from early July along 145°W, and more squid prey were smaller juveniles and larvae. Chum diets were quite varied, with pteropods, crab larvae, amphipods, squid, fish, polychaetes, and gelatinous zooplankton as major prey items. Chum stomach contents were more likely to be unidentifiable at eastern stations, perhaps indicating more quickly-digested gelatinous prey, but fullness was not lower at these stations. Sockeye diets differed more by latitude than longitude. At northern stations pteropods dominated; in mid-latitude samples pteropods, crab, and fish were the main prey, with some squid as well; and at southern stations amphipods and squid were predominant. Pink salmon diets were more uniform, but samples were all from northern stations. Crab larvae were the dominant prey, with significant numbers of pteropods and fish larvae at a few stations.

1.1.3 Historical scale collections

As part of our NOAA contract work we also update and maintain a historical collection of salmon scales and associated biological data, and coordinate fulfilling requests to the U.S. government for NPAFC-related salmon scale sample and data exchanges. The collection includes salmon scales, acetate impression of scales, associated biological data, and scale measurement data (1956 through present), including samples from U.S., Canadian, and Japanese INPFC-related high seas research cruises and observer programs (1955-1992), cooperative U.S.-U.S.S.R. high seas salmon research (1983-1991, cooperative NPAFC-related research (1992-present), and various NMFS high seas observer programs (1976-present). Our high seas scale collections from historical FRI/SAFS tagging studies comprise over 240,000 scales from 1956-1991. We are also the repository of scales collected during high seas salmon research by the former Bureau of Commercial Fisheries (BCF, now NMFS) from 1955-1973, and from various NMFS observer programs (Japanese mothership and squid driftnet fisheries, and some salmon bycatch samples from Bering Sea and Gulf of Alaska groundfish fisheries). We also have an extensive collection of acetate impressions of scales and biological data from Canadian high seas salmon research in the Gulf of Alaska (1962-1969), and from *Oshoro maru* (1980-2002) and *Wakatake maru* (1991-2002) cruises in the central North Pacific, Bering Sea, and Gulf of Alaska, as well as a unique historical collection of acetate impressions and scales from major stocks of Russian salmon. There is also an electronic archive of scale measurement data from over 100,000 fish from six salmonid species. These historical scale collections and electronic data bases are useful for retrospective analyses of age, growth, and stock composition of salmon in the North Pacific Ocean and Bering Sea. In 2003, these collections and databases were updated with new acquisitions from NPAFC cooperative research cruises, as well other related projects (see sections 2, 4, 5, and 6 of this report). We also coordinated U.S.-Russia exchanges of chum salmon scales and associated biological data from the 2002 R/V TINRO survey in the Russian EEZ for ABL scientists.

1.2 Participation in NPAFC Workshops, Symposia, and Meetings

A large part of “NPAFC Research Coordination” contract work involves preparation of necessary documents, reports, and publications for NPAFC meetings and participation in these meetings. The NPAFC Research Planning and Coordinating Meeting (RPCM), May 29, 2003, was hosted by the High Seas Salmon Research Program at SAFS in Seattle. SAFS scientists (K. Myers, R. Walker, N. Davis, and J. Armstrong) participated in the meeting. K. Myers was the rapporteur for preparation of the summary report of the RPCM meeting (NPAFC 2003a). In 2003, K. Myers was rapporteur for preparation of a summary report of all research by NPAFC member nations for the 11th Annual Meeting of the Committee on Scientific Research and Statistics (CSRS). At the 11th Annual Meeting of the NPAFC (October 26-31, 2003), K. Myers and R. Walker participated in the deliberations of the Committee on Scientific Research and Statistics (CSRS). The CSRS annual report was prepared with the help of K. Myers and the editorial committee, which included R. Walker (NPAFC 2003b). SAFS scientists also provided summaries of international salmon research activities for the NPAFC newsletter (Myers 2003a,b). K. Myers has served since 1998 as the U.S. member of the Science Sub-Committee of CSRS, and is a U.S./CSRS Point of Contact for the NPAFC Secretariat. The NPAFC Workshop, “Application of Stock Identification in Defining Marine Distribution and Migration of Salmon” November 1-2, 2003 was attended by K. Myers and R. Walker, and K. Myers made an oral presentation, “A History of U.S. High Seas Salmon and Steelhead Stock Identification Research,” (Myers et al. 2003c). K. Myers was a co-author with NMFS scientists on a review paper, “Research conducted by the United States on the Early Ocean Life History of Pacific Salmon,” for NPAFC Bulletin No. 3 (Brodeur et al. 2003).

K. Myers also serves as a U.S. member of NPAFC’s Bering Aleutian Salmon International Survey (BASIS) working group. The BASIS working group meeting (May 30, 2003) was hosted by the High Seas Salmon Research Program at SAFS in Seattle. K. Myers assisted the BASIS working group in drafting the report of the meeting (NPAFC 2003c). K. Myers was appointed as a U.S. contact for the Annual BASIS Report and Implementation Plan Drafting Committee and the Proposal Drafting Committee for the BASIS Working Group, and prepared the annual report of the results of BASIS research in 2002 (NPAFC 2003d) (see section 2 of this report for additional BASIS-related research and activities).

2. Migration Studies of Salmon in the Bering Sea

This collaborative project with scientists at the Alaska Fisheries Science Center, NMFS, is an extension of work in support of U.S. research commitments to the NPAFC, which operates under the NOAA Authorization Act of 1992 (PL 102-567, Title VIII: North Pacific Anadromous Stocks Convention). The work by SAFS scientists involves research and research coordination activities related to the NPAFC’s BASIS research. The goal of BASIS research is to investigate how Pacific salmon and their marine ecosystems respond to climate change.

In 2002 NPAFC/BASIS scientists cooperated for the first time in the design and execution of a complex ecosystem survey of salmon across the entire Bering Sea. Data on biology and ecology of foraging salmon and other fish species were obtained. Oceanographic and other environmental data were collected simultaneously with fishing operations. Six research vessels sampled all major geographic regions, marine habitats (coastal, shelf, basin), and life history stages of salmon during summer and fall (July-November) 2002. A variety of fishing gear (trawl, gillnet, and longline) and plankton sampling gear were used. Calibration experiments were conducted to evaluate differences in some vessel/gear combinations. Samples and data for salmon age, growth, food habits, lipid content, bioenergetics, stock identification, and parasite research were collected. A shipboard technique to rapidly identify genetic stocks of salmon on the high seas was tested by Japanese scientists. Some fish were tagged and released with archival and data-storage tags that measure water temperature, swimming depth, and swimming speed.

Work by SAFS scientists in 2002-2003 included: (1) participation in BASIS and related cooperative salmon research cruises, (2) data acquisition for bioenergetic modeling and other studies of salmon in the western Bering Sea, (3) coordination and implementation of NPAFC salmon tagging, partially funded by the North Pacific Research Board (NPRB), (4) review of historical data on salmon distribution, migration, and interceptions in the Bering Sea, and (5) participation in NPAFC/BASIS meetings.

2.1 Participation in BASIS high seas salmon research cruises

A SAFS scientist, N. Davis, participated in a U.S. BASIS cruise in 2002 (Murphy et al. 2003). Due to the length of the Russian BASIS research cruise (6 months), it was not feasible to place a U.S. scientist aboard the R/V *TINRO* in 2003. A U.S. BASIS research cruise in international waters was not funded in 2003.

2.2 Bioenergetic modeling and related studies of salmon in the western Bering Sea

Changes in oceanographic conditions may adversely affect growth of salmon, leading to smaller sizes, lower survival rates, and reduced fecundity. N. Davis is coordinating our work on bioenergetic modeling and related studies of salmon in the western Bering Sea. Activities in 2003 included acquisition and organization of diet, plankton, and oceanographic data for growth potential analyses from Japanese and Russian high seas BASIS cruises. We also assisted NMFS in the coordination of sample and data collection for growth, stock identification, and other BASIS-related analyses. In May 2003, SAFS hosted two visiting Russian scientists, Drs. Olga Temnykh and Vladimir Sviridov, Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), Vladivostok, Russia. At this meeting, we reviewed methods of tagging salmon and measuring and aging salmon scales for age, growth, and stock identification studies. We also facilitated exchanges of sampling instructions and materials for collecting sockeye and chinook salmon genetic samples of interest to U.S. scientists during the 2003 R/V *TINRO* cruise. We assisted NMFS in gathering information on scientific equipment and supplies needed by TINRO-Center and other Russian agencies for BASIS research. In 2003, we also

obtained sockeye salmon scale samples from Russia for potential use in future stock identification studies of salmon in the western Bering Sea. These samples include 2002 baseline samples from the Ozernaya, Kamchatka, Bolshaya, Palana, and Khailulya rivers in Kamchatka, and mixed-stock fishery samples from the Bering Sea and the Petropavlovsk-Kommander subzone of the North Pacific (1995-97) and 2000 samples from the Karaginskaya subzone of the Bering Sea (operations of the vessel *Kumano maru-36*) and the northwestern Pacific and western Bering Sea (operations of the vessel SRTM-K *Altair*).

2.3 Coordination of NPAFC Salmon Tagging

The goal of “NPAFC Salmon Tagging” (NPRB, Project #: R0204, J. Helle, PI, <http://www.nprb.org/>) is to gain a better understanding of the distribution patterns, habitat utilization, and movements of Asian and North American salmon migrating in the Bering Sea and adjacent waters. The research is coordinated by the NPAFC/BASIS Working Group. R. Walker is the U.S. point of contact for NPAFC salmon tagging. The NPRB funding is used by NPAFC primarily to purchase tags that are deployed on salmon caught during BASIS research vessel cruises in the Bering Sea and adjacent waters. Several types of tags, ranging from simple numbered plastic discs to complex electronic tags that record sea temperature and depth have been deployed during BASIS research cruises. Oceanographic data from these tags can be used to infer migration routes of salmon and possible exposure to adverse ocean conditions.

In 2003 there were 10 reported recoveries in Asia and North America from salmon tagged and released with electronic data storage (DST) tags (Tables 19 and 20). Five salmon tagged with iButton tags, which record sea temperature, were recovered (4% recovery rate, to date), one in Alaska and four in or off of eastern Kamchatka. Five salmon with tags that record sea temperature and depth were recovered (14% recovery rate, to date), one in Alaska, one in Sakhalin, one off southern Kamchatka, and two in Hokkaido. These recoveries provide important new time-series data that show the temperature-depth habitats of maturing Russian, Japanese, and western Alaska salmon from release in common feeding grounds in the central Bering Sea in July to recovery in coastal fisheries, natal streams, or hatcheries, including:

- The first DSTs from Asian pink salmon (Figs. 19 and 20);
- The second and third DSTs from Bristol Bay/North Peninsula sockeye salmon (Figs. 6 and 7);
- The first DST from a Russian hatchery salmon;
- The second DST from a Russian sockeye salmon; and
- A DST from a Japanese chum (Fig. 21) and the first DST from a Russian chum salmon (Fig. 22), which will allow BASIS scientists to compare and infer possible differences in migration routes of Japanese and Russian fish.

Additional information on NPAFC Salmon Tagging and NPAFC’s tag recovery and reward program can be found on the NPAFC web page (<http://www.npafc.org/>, see “Fish Tag Recovery Program”).

2.4 Review of historical data on salmon distribution, migration, and interceptions in the Bering Sea

In 2003, R. Walker and N. Davis compiled historical oceanographic information, catch statistics, tagging data, food habits, and stock identification studies for a comprehensive review of distribution, migration, and interceptions of salmon in the Bering Sea. This will include new maps of stock distribution using historical tagging data and mapping of salmon catches in the Bering Sea. Several reports and publications authored or co-authored by SAFS scientists in 2002-2003 are pertinent to this comprehensive review (Ishida et al. 2002; Brodeur et al. 2003; Davis 2003 (see Appendix 1); Davis et al. 2003; Myers et al. 2003b; Ruggerone et al. 2003).

2.5 Participation in NPAFC/BASIS meetings

R. Walker was appointed as a U.S. Point of Contact for salmon tagging for the BASIS Working Group, and summarized progress on “NPAFC Salmon Tagging” research at the BASIS meeting (Walker 2003). N. Davis was appointed as a U.S. Point of Contact for salmon food habits and bioenergetics modeling for the BASIS Working Group, and reviewed salmon food habits methods used by Russia and other countries for BASIS research (Davis and Myers 2003).

3. Bering Sea Salmon Food Habits

In 2003, the Yukon River Drainage Fisheries Association (YR DFA) funded SAFS scientists to analyze Bering Sea salmon food habits data from samples collected during BASIS trawl surveys in fall 2002. The goal of this project was to evaluate the potential for inter- and intra-specific interactions among salmon in offshore habitats where Yukon River salmon are known to migrate (Davis et al. 2003). Analysis of fall samples is important, as few studies have reported on the ocean food habits of salmon in this region during seasons other than summer. The specific objectives of this study were to: (1) analyze overlap in salmon food habits by species and habitat in fall 2002, (2) compare results of summer and fall 2002 data with an existing time series of summer Bering Sea salmon food habits (1991-2001), and (3) discuss inter- and intra-specific overlap in salmon food habits in the Bering Sea and speculate on the potential effect of competition on marine growth and survival of Yukon River salmon.

Samples of salmon stomach contents were collected during the September 2002 cruise of the Japanese research vessel *Kaiyo maru* (n=349), which conducted a salmon survey in the Bering Sea basin (>200-m depth contour) and the central Aleutian Islands (Fig. 23; Davis et al. 2003). Stomach contents data were collected during the September-October 2002 salmon survey of the U.S. vessel *Northwest Explorer* (n=467), which conducted operations in the Bering Sea basin, western and central Aleutian Islands, and eastern Bering Sea shelf (<200-m depth contour). Other data sources included samples collected during the central Bering Sea survey of the *Wakatake maru* (June-July 1991-2002), which were included for seasonal (summer-fall 2002) and long-term comparison (odd-numbered years, 1991-2001, and even-numbered years, 1992-2000) of salmon food

habits in the Bering Sea. The *Wakatake maru* data were separated into odd- and even-numbered years because biennial fluctuations in pink salmon abundance potentially provide alternating periods of increased (odd-numbered year) and decreased (even-numbered year) pressure from inter- and intra-specific competition for food. Data were stratified into three habitats in the Bering Sea, including basin, Aleutian Islands, and eastern shelf that are representative of the known distribution of Yukon River salmon in this region. Diet overlap was estimated for fall samples using a modified Schoener's index (PSI, percent similarity index), where 0% indicates no diet overlap and 100% indicates complete overlap in diet of two predators. In addition, prey composition was compared graphically by species and habitat for summer and fall 2002 data, and by species, salmon ocean age, and time period for basin data only.

In the Bering Sea basin, diet overlap between sockeye and chum salmon was moderate (PSI=49%), and sockeye and chum salmon consumed the same species and sizes of prey within prey categories having the greatest overlap (Table 21; euphausiids 17%, fish 17%, amphipods 12%). High consumption of gelatinous zooplankton was unique to chum salmon, and may decrease food competition with sockeye salmon. Diet overlap of sockeye and chinook salmon was low (21%), with overlap mainly in fish prey (17%). Diet overlap between chum and chinook salmon was somewhat higher (28%) because chum salmon consumed more fish prey than did sockeye salmon. Diet overlap between sockeye and chum salmon in the Aleutian Islands was very high (80%), because both salmon consumed large volumes of identical species of euphausiids (44%) and amphipods (27%). Diet overlap between chum and chinook salmon on the shelf was moderate (30%), and fish prey contributed most to the overlap (23%).

There were seasonal and spatial shifts in prey composition within and among salmon species collected in the three habitats (Fig. 24). In summer, sockeye salmon in the basin consumed primarily amphipods, followed by euphausiids, squid, and fish. In fall, sockeye salmon collected from all three habitats consumed a higher proportion of euphausiids than in summer. Fish were more common in sockeye salmon diets in the basin than in other habitats, and pteropods were more common in their diets on the shelf. Chum consumed a more varied diet than sockeye salmon in summer and fall. In summer, chum salmon in the basin consumed mainly euphausiids and pteropods, and lesser volumes of amphipods, squid, fish, and gelatinous zooplankton, while in the Aleutian Islands, they consumed large volumes of gelatinous zooplankton. In fall fish and pteropods were a large component of chum salmon diets on the shelf, while their diets in the Aleutian Islands included a large proportion of euphausiids and amphipods. Gelatinous zooplankton were a significant component of the prey of chum salmon in both basin and shelf habitats in fall. Fish consumed by chum salmon in the basin were composed of different species than those consumed on the shelf. Chinook salmon were more specialized consumers. In summer, chinook salmon stomachs collected in the basin contained high volumes of euphausiids, squid, and fish, while in fall they contained relatively low volumes of euphausiids.

Further stratification of data by salmon ocean age showed a seasonal reduction in the diversity of diets of sockeye, chum, and chinook salmon in the basin in fall (Fig. 25).

Squid was reduced or eliminated from diets of sockeye and chum salmon, and chinook salmon consumption of euphausiids was dramatically reduced in fall. Conversely, fish increased in the diets of sockeye and chum salmon, and squid consumption by chinook salmon increased in fall. Reduction in the diversity of prey groups in fall could be caused by changes in prey availability due to shifts in prey distribution, abundance, or progression of prey life-history stages resulting from seasonal environmental changes. Trends in prey composition by ocean age of salmon also changed between summer and fall. For example, in summer the proportion of euphausiids increased with ocean age of sockeye and chum salmon, however, there was a decrease of euphausiids in older salmon in fall. Age-.1 sockeye and chum salmon in summer consumed a larger proportion of amphipods than older fish, while in fall the amount of amphipods was not related to ocean age. In summer, gelatinous zooplankton increased in the diets of older (age-.3 and -.4) chum salmon, however, in fall less gelatinous zooplankton was consumed by older fish. In summer, fish predominated in the diets of young (age-.1) chinook salmon, while in fall fish consumption was not related to chinook salmon ocean age.

Previous studies have suggested that there are inter- and intra-specific competitive interactions for food among immature and maturing sockeye and chum salmon in the Bering Sea. Although chum salmon have a diverse diet, competition for food within and among stocks may occur when chum salmon are locally abundant. Published analyses indicated that intra-specific competition can cause a reduction in the body size of Japanese chum salmon during their third year of life. Although shifts in the proportions of several prey groups may reduce diet overlap among salmon, these shifts are not without cost. Previous studies have shown dramatic increases in the weight of low energy-density prey in salmon stomach contents in odd-numbered years, when pink salmon were abundant in the central Bering Sea. In addition, bioenergetic models have shown that over relatively short time periods small decreases in daily ration caused by competition, or other causes, could significantly decrease growth.

While previous studies have focused on the inter- and intra-specific interactions among pink, sockeye, or chum salmon, there is no information about these types of interactions for chinook salmon in the Bering Sea. Our estimates of diet overlap suggest there is a relatively low level of inter-specific food competition between immature chinook and immature sockeye or chum salmon. Compared to other salmon species, the low abundance of immature chinook salmon may serve to reduce intra-specific competition at sea. Consumption of nektonic organisms (fish and squid) may be efficient because they are relatively large and have a higher caloric density than zooplankton, such as pteropods and amphipods. However, there is an energetic investment required of chinook salmon to capture actively swimming prey. If nekton abundance is reduced and chinook foraging effort becomes less efficient, then a smaller proportion of ingested energy would be available for chinook salmon growth. If salmon prey availability is reduced by predation from abundant stocks of pink and chum salmon, or in combination with adverse climatic and oceanographic changes in the Bering Sea, then increased inter- and intra-specific competition could decrease growth of Yukon River salmon. Furthermore, reduced growth could negatively affect Yukon River salmon survival.

Future studies should focus on determining the season(s), location(s), and salmon life history stage(s) when inter- and intra-specific competition for food is likely to have the greatest impact on growth. This research should include food habits data from all species, age groups (including juvenile (age-0), immature, and maturing salmon), and seasons. Studies that integrate salmon food habits, prey availability, and bioenergetics are needed, and would substantially increase our understanding of the relationship between inter- and intra-specific competition for food and the ocean growth and survival of salmon.

4. Stock Origins of Chinook Salmon in the Eastern Bering Sea, 1997-1999

In 2002 and 2003, the Yukon River Drainage Fisheries Association (YR DFA) funded SAFS scientists to conduct research on stock origins of chinook salmon in incidental catches by groundfish fisheries in the eastern Bering Sea. The effect on western Alaska chinook salmon of incidental catches by commercial groundfish fisheries has been a major concern since 1977, when the NMFS began to monitor and estimate salmon bycatch by groundfish vessels operating in the U.S. EEZ. Most of the chinook salmon bycatch in Bering Sea and Aleutian Island (BSAI, Fig. 26) groundfish fisheries is taken by the walleye pollock (*Theragra chalcogramma*) trawl fisheries.

In a similar study conducted in the 1980s SAFS scientists used scale pattern analysis to estimate the age, regional stock composition, and interceptions of western Alaska chinook salmon in incidental catches by foreign and joint-venture groundfish fisheries operating in the BSAI area of the U.S. EEZ in 1979–1982. This was a period (1977–1986) of high abundance of western Alaska chinook salmon, and an estimated 60% of the total chinook salmon bycatch in the Bering Sea groundfish fisheries was western Alaska stocks. During the late 1990s returns of chinook salmon to western Alaska rivers declined to record lows. Because of this decline in abundance, the results of the earlier study may overestimate the contribution of western Alaska chinook salmon to the groundfish bycatch in recent years.

In 2003, we completed work to estimate the age and stock composition of chinook salmon in 1997–1999 BSAI groundfish fishery bycatch samples collected by the North Pacific Groundfish Observer Program, NMFS. Scale measurement data (Fig. 27; 14 variables) from mature chinook salmon returning to major production regions in Asia and North America were used to establish five brood-year specific baselines (BY 1991–1995; Table 22). Maximum likelihood estimates (MLE) of the proportions of regional (Russia, Western Alaska, Central Alaska, and Southeast Alaska/British Columbia) and western Alaska subregional (Yukon, Kuskokwim, and Bristol Bay) stock groups in the fishery (mixture) bycatch samples were calculated. Accuracies of the brood-year models were evaluated by computer simulations and by test mixture samples of baseline scales that were not included in the 4-group regional models (Tables 23 and 24).

During the period of our study, the largest bycatch samples were taken during winter (January and February) and late summer–fall (September and October) in the BSAI area east of 170°W. The 1997–1999 bycatch samples were dominated by age 1.2 fish in

summer and ages 1.3 and 1.4 fish in winter (Table 25). In contrast, the previous SAFS study found that younger (age 1.2) fish dominated winter bycatch samples in 1979–1982. This difference may be related to an eastward shift in the fishery area from offshore areas (west of 170°W) in 1979–1982 to inshore areas (east of 170°W) in 1997–1999. In winter, immature age-2 chinook salmon may be distributed farther offshore than older age groups of immature and maturing fish

As in the previous SAFS study of 1979–1982 samples from the BSAI, our results indicate that western Alaska was the dominant regional stock of chinook salmon in bycatch samples from the groundfish fisheries in the eastern Bering Sea. The estimated regional stock composition of chinook salmon in the five brood-year strata averaged 56% Western Alaska, 31% Central Alaska, 8% Southeast Alaska–British Columbia, and 5% Russia (Table 26a). In winter age-1.4 western Alaska chinook salmon were largely from the Yukon and Kuskokwim sub-regions, and percentages of Bristol Bay fish were highest in samples of age-1.3 fish (Table 27b). In fall age-1.2 western Alaska chinook salmon were predominantly from the Kuskokwim and Bristol Bay subregions, and there was a large component of Cook Inlet chinook salmon stocks (Table 27b).

The results of both SAFS studies indicate that: (1) the proportions of the three western Alaskan subregional stocks (Yukon, Kuskokwim, and Bristol Bay) in the BSAI area vary considerably with such factors as brood year, time, and area; (2) Yukon River chinook salmon are often the dominant stock in the BSAI in winter, particularly among age 1.2 fish in the western BSAI (west of 170°W) and age 1.4 fish in the eastern BSAI (east of 170°W); (3) Bristol Bay and Cook Inlet are the dominant stocks of age 1.2 chinook salmon in the eastern BSAI in fall; and (4) age 1.1 chinook salmon in the eastern BSAI in fall are largely Gulf of Alaska stocks (Cook Inlet, southeast Alaska-British Columbia).

The spatial and temporal distributions of Yukon, Cook Inlet, southeast Alaska, and British Columbia chinook salmon in the eastern Bering Sea are corroborated by recoveries of CWT fish (Figs. 8, 28, 29, and 30). The results of previous scale pattern analyses of samples from the Japanese mothership salmon driftnet fishery in the Bering Sea and historical high seas tagging studies indicate that in summer immature western Alaska chinook salmon are distributed farther to the west in the Bering Sea than other North American stocks (Fig. 31), which may explain their relatively low percentages in fall 1997-1999 bycatch samples from the eastern BSAI.

In ongoing analyses, we are calculating estimates of interception (numbers of fish) of Yukon, Kuskokwim and Bristol Bay chinook salmon by the BSAI groundfish fishery and evaluating the effects of the salmon bycatch in 1997–1999 on western Alaska chinook salmon runs. A poster of our research results, entitled “Stock Origins of Chinook Salmon in Incidental Catches by Groundfish Fisheries in the Eastern Bering Sea, 1997-1999” was presented at the NPAFC Workshop, “Application of Stock Identification in Defining Marine Distribution and Migration of Salmon,” in November 1-2, 2003 (Myers et al. 2003b)

5. GLOBEC 2000: Feeding, Growth, Condition, and Energetics of Juvenile Pink Salmon in the Northern Gulf of Alaska

The High Seas Salmon Research Program staff are collaborating with SAFS faculty (D. Beauchamp, PI) and graduate students (J. Moss, A. Cross), as well as scientists at the University of Alaska Fairbanks (UAF), School of Fisheries and Ocean Sciences (L. Haldorson, PI) in a 5-year study to understand the conditions that favor rapid growth and survival of juvenile pink salmon in the coastal Gulf of Alaska (CGOA). This research is part of the U.S. GLOBEC/CGOA component of the Northeast Pacific Program (<http://globec.oce.orst.edu/groups/nep/projects/>). This work is also coordinated with scientists at ABL/AFSC, NMFS, who are conducting GLOBEC research on factors affecting the distribution of juvenile salmon in the Gulf of Alaska (<http://globec.oce.orst.edu/groups/nep/projects/>). The results will contribute directly to the GLOBEC program goal, which is to understand how production of upper trophic level species is linked to variation in oceanographic conditions in the CGOA.

The major objectives of our GLOBEC research are:

- (1) Describe spatial and temporal variation in juvenile pink salmon diets and surface zooplankton abundance from Prince William Sound and the adjacent continental shelf from July-October;
- (2) Measure prey selectivity by pink salmon as a function of size, time, and location;
- (3) Measure growth and condition of pink salmon and relate them to prey availability and water temperature;
- (4) Estimate daily ration of pink salmon with field experiments and bioenergetic models;
- (5) Evaluate spatial and temporal variation in the growth potential of pink salmon in the marine environment over the continental shelf using foraging and bioenergetic models; and
- (6) Determine the relationship between pink salmon prey use and prey use by other planktivorous fishes over the continental shelf.

In 2003 process-oriented fieldwork, conducted in two field phases (July-October, 2001 and 2003) of the CGOA program, was completed. SAFS scientists and graduate students participated in UAF cruises, and performed laboratory analyses of diet (stomach content analysis) and growth (scale pattern analysis) of juvenile pink salmon collected from the 2001 and 2003 field seasons. Additional samples and data collected by UAF in 1999 and 2000 were also analyzed.

SAFS and UAF scientists jointly analyzed salmon body size and stomach contents data collected from juvenile (ocean age-0) pink salmon distributed along the Seward Line (GOA) and in Prince William Sound (PWS), Alaska, in 1999-2001 (Fig. 32; Armstrong et al., *in review*). Major interannual (August 1999, 2000, and 2001), seasonal (July to October, 2001) and diel (August 2000, and July, August, and September, 2001) trends in salmon food habits were summarized. Diets of juvenile pink salmon were more diverse in 2001 compared to either 1999 or 2000. Pteropods (*Limacina helicina*)

composed the majority of prey consumed in 1999 and 2000; whereas high proportions of copepods, pteropods, euphausiids, amphipods, crabs, gastropods, and fish were consumed in 2001. Juvenile pink salmon consumed increasingly larger prey from July to October 2001 in the GOA. The diets of GOA juvenile pink salmon was different and more diverse than diets of fish caught in PWS. The main prey in PWS during July-October was hyperiid amphipods, whereas the primary prey in the GOA were larvaceans and euphausiids in July, and primarily copepods plus pteropods (*L. helicina*), amphipods, euphausiids, crabs and shrimp in August. In September and October, diets in both PWS and GOA included high proportions of larger prey items including fish, euphausiids, and large pteropods (*Clio pyramidata*). Diel comparisons of stomach contents showed pink salmon fed during daylight hours with stomach fullness increasing from dawn to a maximum fullness 8-12 hours after sunrise, and declining thereafter.

Further work will integrate food habits with fish condition and growth data, zooplankton abundance, and water temperature to develop foraging and bioenergetics models. These models will enable assessment of habitat quality and growth conditions for juvenile pink salmon, and, therefore, how tertiary production is affected by changes in ocean conditions.

6. Age and Growth of Juvenile Chinook Salmon in the Coastal Marine Waters of Southeast Alaska

In 2003, the High Seas Salmon Research Program collaborated with a Northwest Fisheries Science Center (NWFSC), NMFS, scientist on analyses of scales from research vessel samples of juvenile chinook salmon in the coastal marine waters of Southeast Alaska in 1998-2000. The purpose of the study was to estimate the freshwater age, size at freshwater annulus formation and salt water entry, and growth rates during fresh- and salt-water residence for each fish. The methods, age and scale measurement data, and estimates are reported in Myers (2003d).

The estimated age composition of juvenile chinook salmon in the total sample of fish with usable scales was 97.3% age 1.0 (n=177 fish) and 2.7% age 2.0 (n = 5 fish). Scale measurement data were collected along a single measurement axis, the longest axis in the anterior (sculptured) field of the scale, and included the diameter of the focus, the width of each circulus increment, and the width of the last increment at the edge of the scale. As each scale was measured, the circuli were assigned to life history zones (freshwater, plus growth, ocean growth). The Fraser and Lee back-calculation method was used to estimate the fork length of each fish at annulus formation. The fork length (mm) of each age 1.0 fish at annulus formation was estimated by the equation (1): $L_a = ((L - 43.7895)/R) * R_a + 43.7895$, where L_a = fork length at annulus formation, L = fork length at capture, R = scale radius at capture, R_a = scale radius at annulus formation, and 43.7895 is the intercept from the regression of R on L (Fig. 33). The length-weight relationship was used to calculate L for a few fish with missing values (Fig. 34). The estimated fork length at scale formation (44 mm) seemed reasonable for this species, e.g., a detailed histological study of age 0.0 chinook salmon reared at the University of Washington found that scales first begin to form near the lateral line when fish are between 40 and 50

mm standard length. Given that the growth rates of age 0.0 (ocean type) chinook salmon are faster than age 1.0 (stream type) chinook salmon, stream type chinook salmon may be somewhat smaller at the time of scale formation than ocean type Washington chinook salmon. To our knowledge, however, there are no published data comparing size at scale formation for chinook salmon of different freshwater ages, stocks, or geographic origins.

A reasonable assumption for all of the fish in this study was that the size at annulus formation is the size at saltwater entry. Stream-type chinook salmon smolts typically move rapidly through river estuaries to the ocean in spring, exhibiting little or no additional feeding or growth in freshwater habitats. The scales of many fish in this sample, however, exhibited a zone of intermediate (plus) growth immediately following the freshwater annulus. Most or all of this intermediate growth may have occurred in nearshore (littoral) saltwater habitats, which were not sampled in the present study. For each fish, back-calculated fork lengths at the end of the intermediate (plus) growth zone, as well as the fork lengths when the last and second to last saltwater circuli formed on the scale, were estimated. The last two variables can be used as indicators of recent fork lengths prior to capture.

The growth rates of individual fish during the fresh-water residence period are best characterized by the number of freshwater circuli and the average spacing (width) of freshwater circuli, which are assumed to be positively correlated with growth rate. The use of scale circulus counts and widths as a proxy for fish growth in Pacific salmon is a well-accepted technique. The distribution of freshwater circuli counts for age 1.0 chinook salmon in the samples was very broad, and modes in the distribution likely represent different stocks of chinook salmon (Fig. 35). The results of tagging experiments have shown that age 1.0 chinook salmon stocks from southeastern Alaska, British Columbia, Washington, and Oregon occur in the study area.

Saltwater growth rates in fork length (L) for each fish during early (plus or littoral growth), later (ocean or neritic growth), entire (annual growth rate), and recent saltwater growth phases were calculated as: $(L - L_a) / \Delta d$, where L is the fork length at capture, L_a is the estimated fork length at annulus formation, Δd is the estimated number of days between saltwater entry and capture. Because the dates of saltwater entry for individual fish were unknown, they were estimated from the average rates of circulus formation of fish caught during the June-October period (Table 28). For fish caught in summer (June-August), each circulus represented an average of 7 days of growth. A rough estimate of 1 circulus per 7.5 days was used for fish caught in September-October because estimated circulus formation rate slowed from 0.14/day in summer to 0.12/day in fall. The number of days of growth in each saltwater life-history zone was calculated by multiplying these rates times the circulus counts in these zones. Recent saltwater growth rates in body weight were calculated from weight estimates. The final analyses and results will be reported as part of a Ph.D. dissertation by a SAFS student (L. Weitkamp, NWFSC, NMFS).

7. Acknowledgements

The NPAFC Secretariat in Vancouver, B.C., Canada, J. Helle and the scientists of the Ocean Carrying Capacity Project (NMFS/AFSC/ABL), L. Low (NMFS/AFSC), and many other colleagues in Canada, Japan, Russian, and the United States are acknowledged for their assistance with NPAFC research coordination. Special acknowledgments are given to Captain Doi and the officers, crew, and students aboard the *Kaiyo maru*, and Captain Y. Murata and the officers, crew, and students aboard the *Wakatake maru* who cooperated in high-seas salmon research in 2002-2003. We are grateful to the individuals and agencies who returned salmon tags and recovery information. The North Pacific Groundfish Observer Program, AFSC, provided snout samples from salmonids lacking the adipose fin and recovery data collected by observers from the U.S. groundfish fishery. J. Berger (AFSC) provided data on catch locations, when observer data accompanying the samples were incomplete or erroneous. E. Farley and A. Celewycz, ABL, coordinated analysis of CWT snout samples and CWT recovery data management. E. Reiter (ABL) dissected salmon snouts, read tags, and coded data. The Fisheries Agency of Japan and Hokkaido University provided salmonid head samples and accompanying biological and catch data from Japanese salmon research vessels. We thank E. Martinson (ABL) for collecting stomach samples during the 2002 *Kaiyo maru* cruise. We appreciate the efforts of J. Murphy (ABL), T. Azumaya, O. Yamamura, and M. Fukuwaka (Hokkaido National Fisheries Research Institute, Kushiro) in providing *Kaiyo maru*, *Northwest Explorer*, or *Wakatake maru* cruise data and samples. S. Urawa (National Salmon Resources Center, Sapporo), O. Ivanov (Pacific Scientific Fisheries Research Centre, TINRO Centre, Vladivostok), M. Rohr, S. Elmajatii (University of Alaska, Fairbanks), and W. Barber (Anchorage) are thanked for their assistance collecting fish samples. Salmon scales and associated biological data from the BSAI groundfish fishery bycatch in 1997-1999 were provided by the North Pacific Groundfish Observer Program, AFSC. Agency personnel in Alaska, British Columbia, and Russia, loaned or provided duplicate copies of scale samples and biological data for scale pattern baselines. At the Alaska Department of Fish and Game (ADFG), these include L. Brannian, T. Lingnau, D. Molyneaux, R. Price, and L. Dubois of AYK region; B. Bue, L. Fair, F. West, M. Willette, and S. Moffitt of Central region; and K. Pahlke, M. Olson, and I. Frank of Southeast region. In British Columbia we were helped by B. Riddell, S. MacLellan, and K. Cooke, Department of Fisheries and Oceans. In Russia, we were helped by A. Bugaev, Kamchatka Research Institute of Fisheries and Oceanography. W. Patton, who now works for the Northwest Indian Fisheries Commission, helped us measure chinook salmon scales for the BSAI groundfish fishery bycatch project. Special acknowledgements are given to J. Boldt, who now works for the AFSC, for her help with laboratory and data analyses of juvenile pink salmon diets for GLOBEC research. We thank the crews of the R/V *Pandalus* and Mikhail Blikshteyn for help in GLOBEC sample collection. L. Weitkamp, Northwest Fisheries Science Center, NWFSC, NMFS, provided scales and associated biological data for juvenile chinook salmon.

The “NPAFC Research Coordination” project is funded by ABL (NOAA Contract No. 50ABNF-1-0002). “Migration studies of salmon in the Bering Sea” is a

collaborative project with AFSC, administered as part of the Joint Institute for the Study of the Atmosphere and Ocean (JISAO, Task III). “Bering Sea Salmon Food Habits” and “Stock Origins of Chinook Salmon in the Eastern Bering Sea, 1997-1999” were funded by the Yukon River Drainage Fisheries Association, Anchorage, Alaska (YRDFFA, Contract 2002-01, through a grant from NOAA). “GLOBEC 2000: Feeding, Growth, Condition, and Energetics of Juvenile Pink Salmon in the Northern Gulf of Alaska” research is funded by a grant from NOAA and the National Science Foundation (Award No. OCE-0106139). “Age and Growth of Juvenile Chinook Salmon in the Coastal Marine Waters of Southeast Alaska” was funded by Contract No. WASC-2-1520, NWFSC, NMFS, NOAA, Seattle. The views expressed in this report do not necessarily reflect the views of any of these funding agencies or their sub-agencies.

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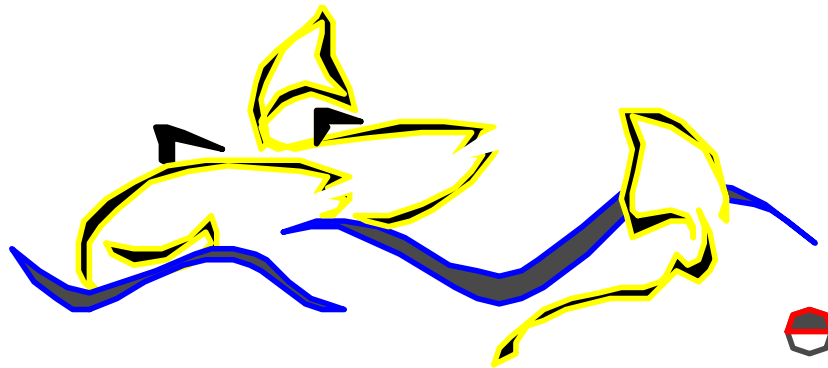
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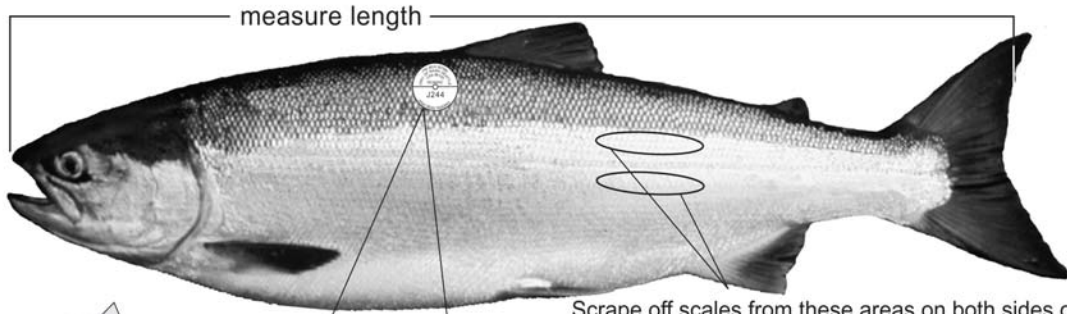
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RETURN HIGH SEAS SALMON AND STEELHEAD TAGS



RETURN high-seas salmon tag

- ENTER drawing
- GET embroidered cap

North Pacific Anadromous Fish Commission Tag Drawing 2004

- \$5,000 1st
- \$3,000 2nd
- \$1,500 3rd
- \$ 500 4th

Examples of high seas tags

Tag color is red and white

Some fish carry an electronic tag

SPECIAL \$500 REWARD FOR GEOLOCATING TAG

\$500 REWARD
HI SEAS SALMON, BOX 355020
U. WASH. SEATTLE, WA 98195
TEL. 206-543-1101

Scrape off scales from these areas on both sides of the fish and place the scales into a folded piece of paper

- Collect tag, if tag cannot be collected then get tag number and description
- Collect scales and carefully measure fish length as shown
- Record location, date, species, gear, sex, and weight
- Send your name, address, and phone number for cash drawing

Send to: **High Seas Salmon Research Program
School of Aquatic & Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195-5020**

Info call: 206-543-1101
e-mail: kwmyers@u.washington.edu

Websites: <http://www.fish.washington.edu/research/highseas/> <http://www.npafc.org/>

INTERNATIONAL HIGH SEAS SALMON TAGGING

Fig. 1. Poster advertising for return of high seas disk and data storage tags, 2003-2004.

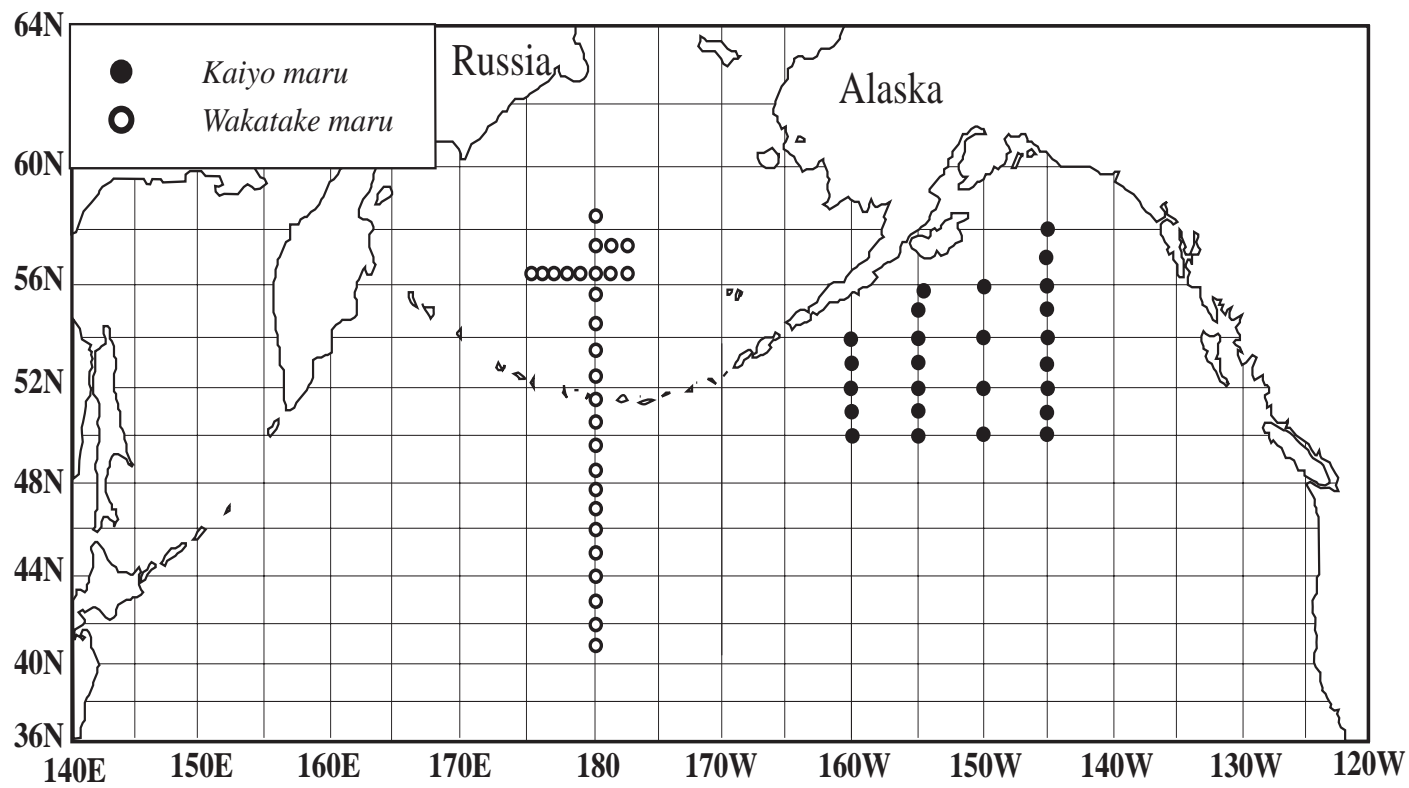


Fig. 2. Sampling areas of international cooperative high seas salmon research cruises in 2003.

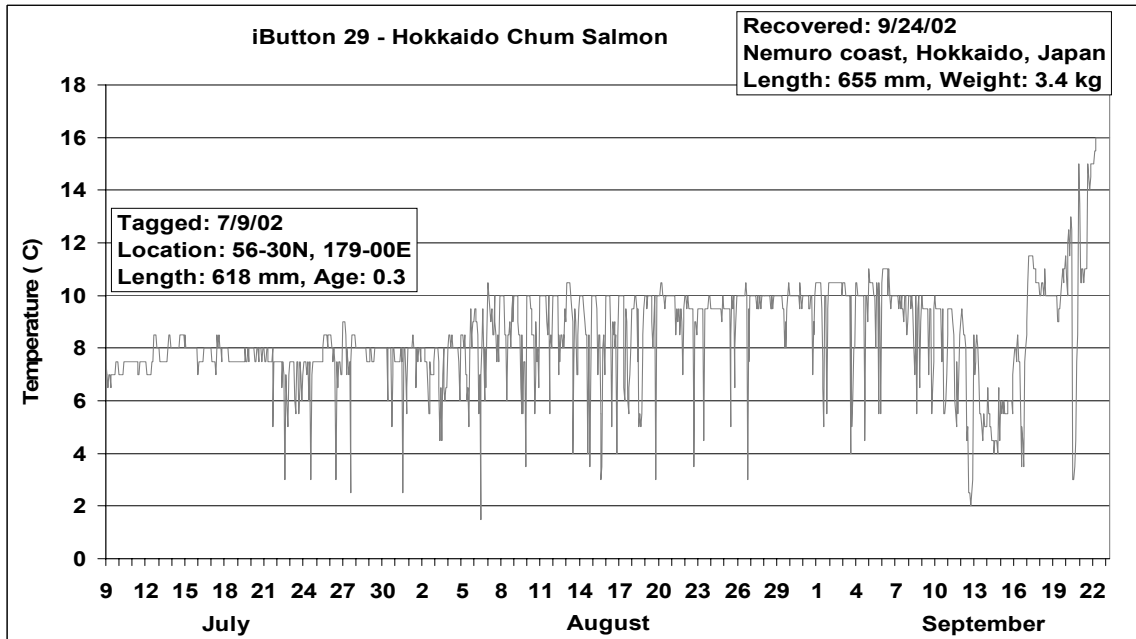
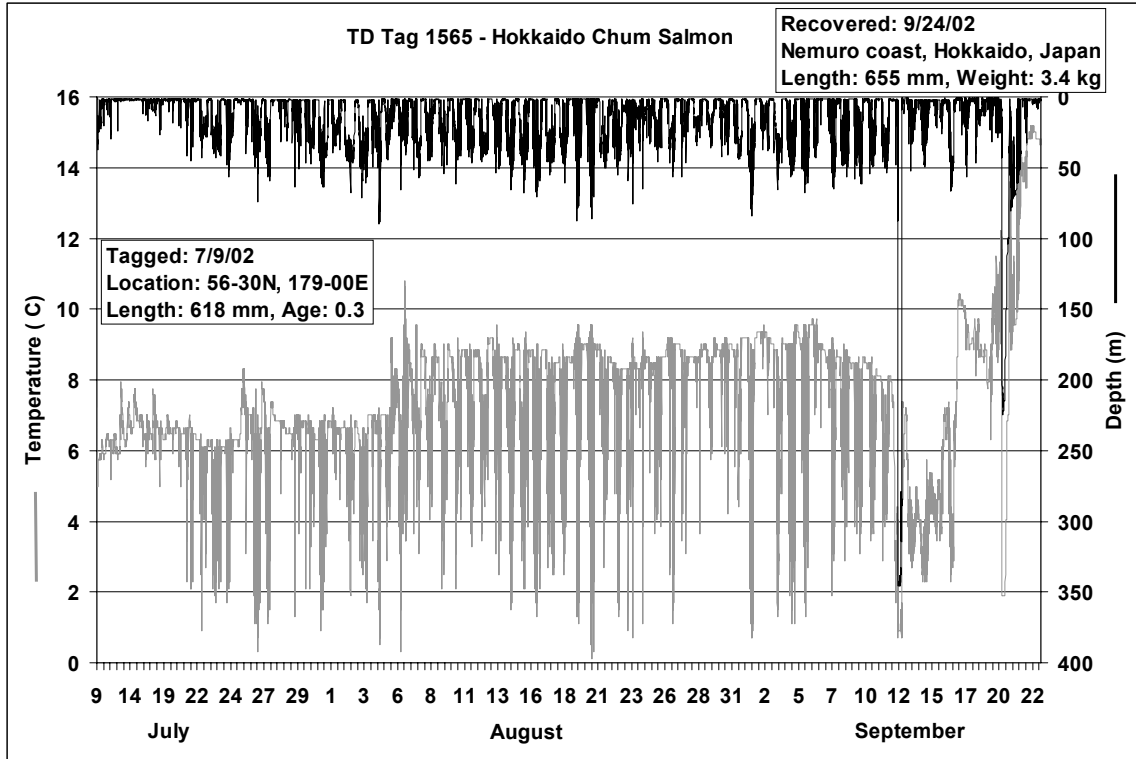


Fig. 3. Temperature and depth data recorded on two data storage tags placed on a 618-mm chum salmon in the Bering Sea on 9 July 2002 and recovered on the Nemuro coast, Hokkaido, Japan, on 24 September 2002.

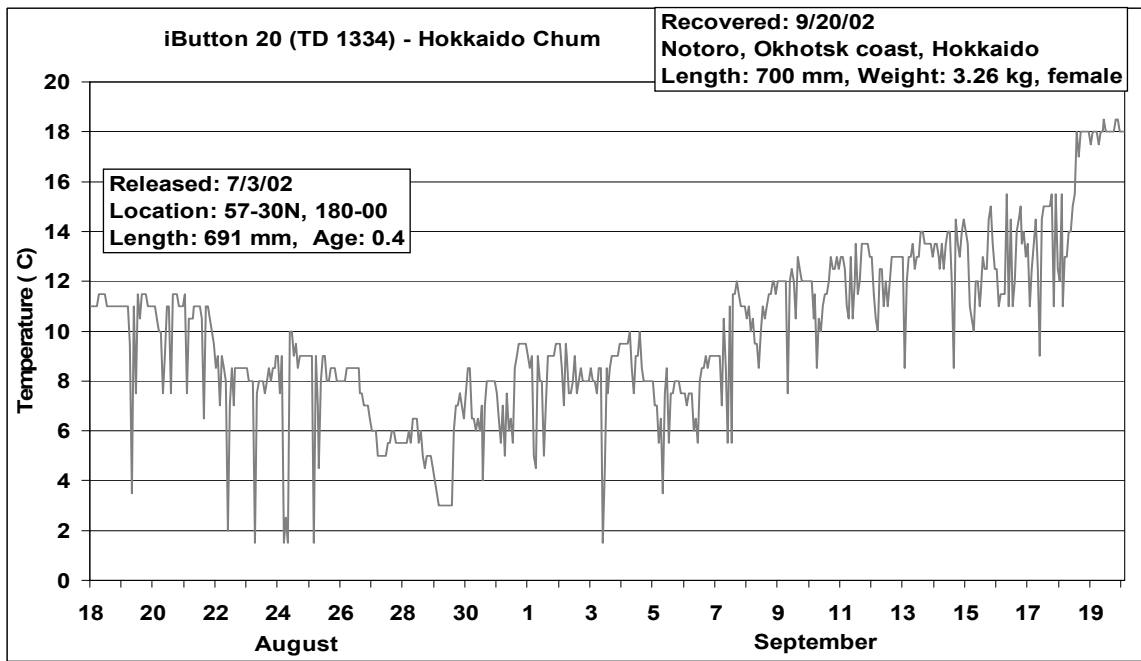
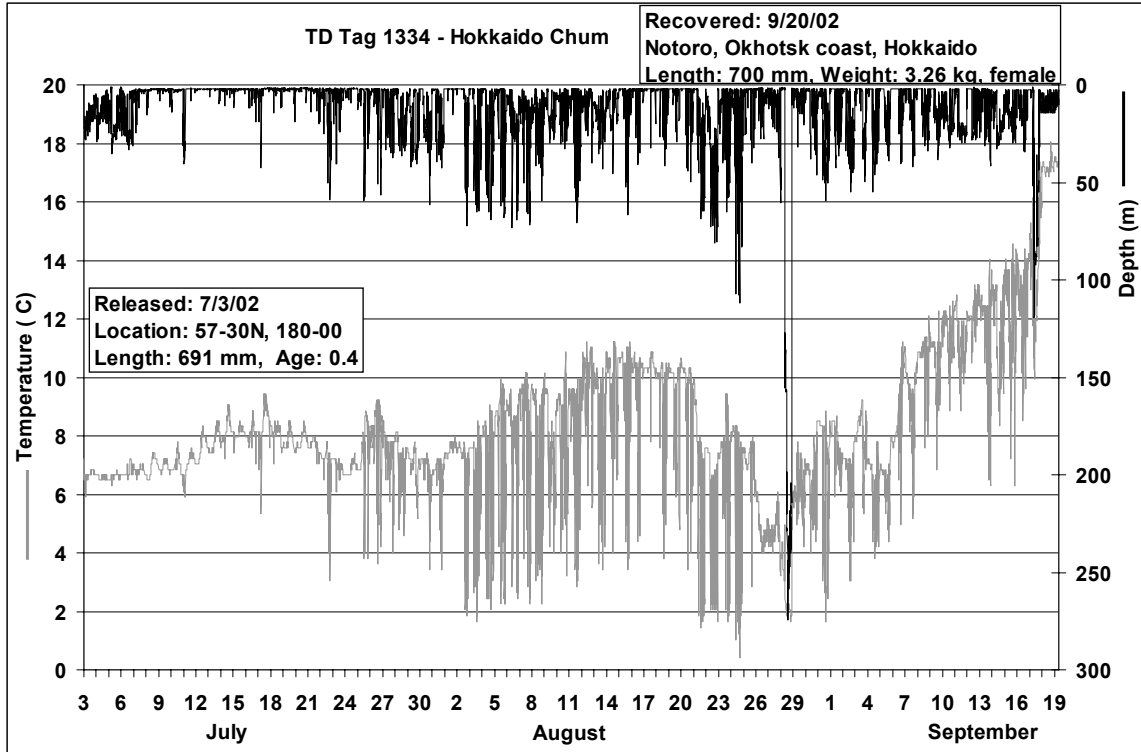


Fig. 4. Temperature and depth data recorded on two data storage tags placed on a 691-mm chum salmon in the Bering Sea on 3 July 2002 and recovered at Noto, Okhotsk Sea coast, Hokkaido, on 20 September 2002. Note different time scales for the two charts.

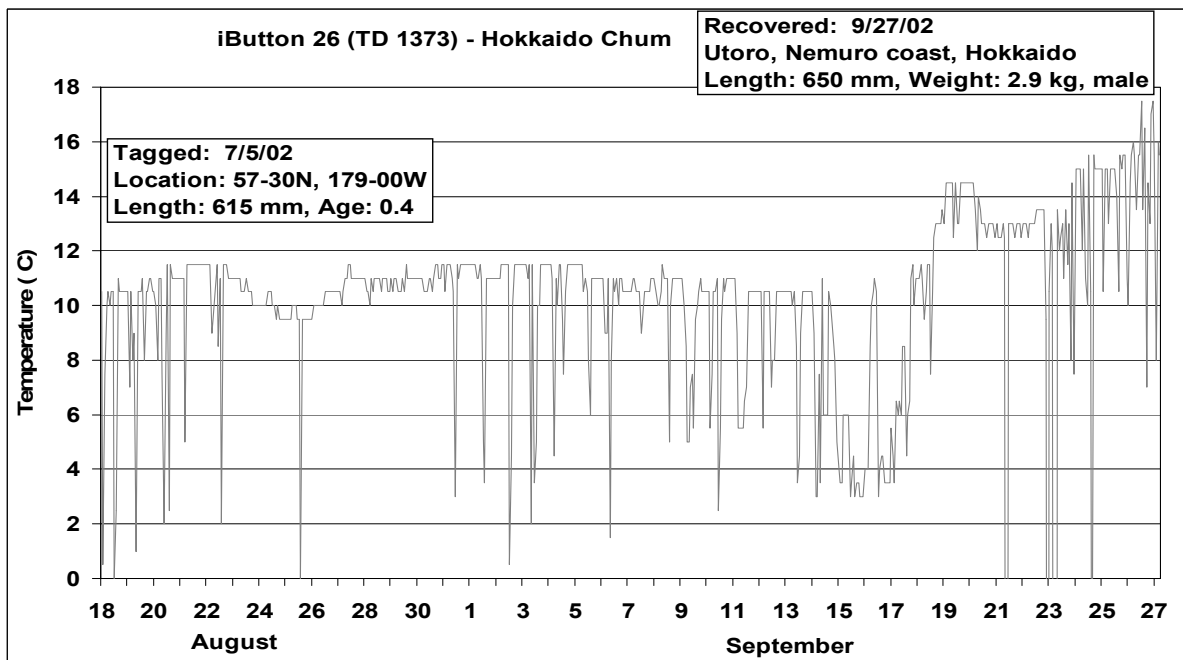
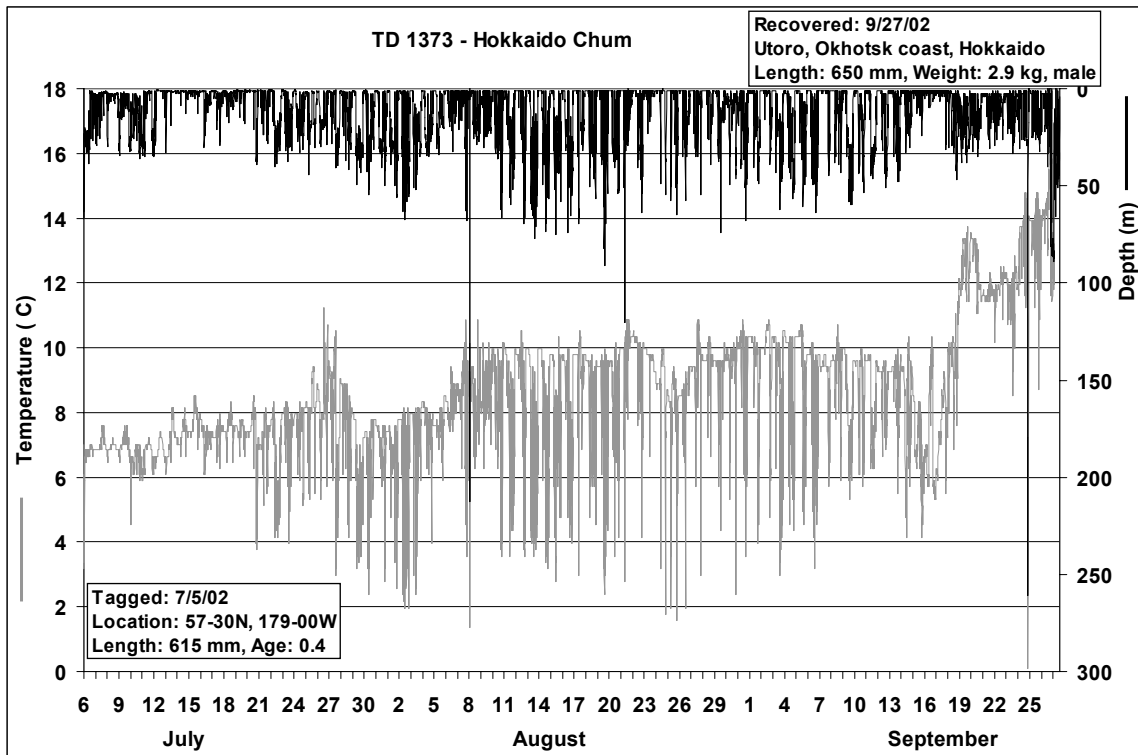


Fig. 5. Temperature and depth data recorded on two data storage tags placed on a 615-mm chum salmon in the Bering Sea on 5 July 2002 and recovered at Utoro, Okhotsk Sea coast, Hokkaido, on 27 September 2002. Note different time scales for the two charts.

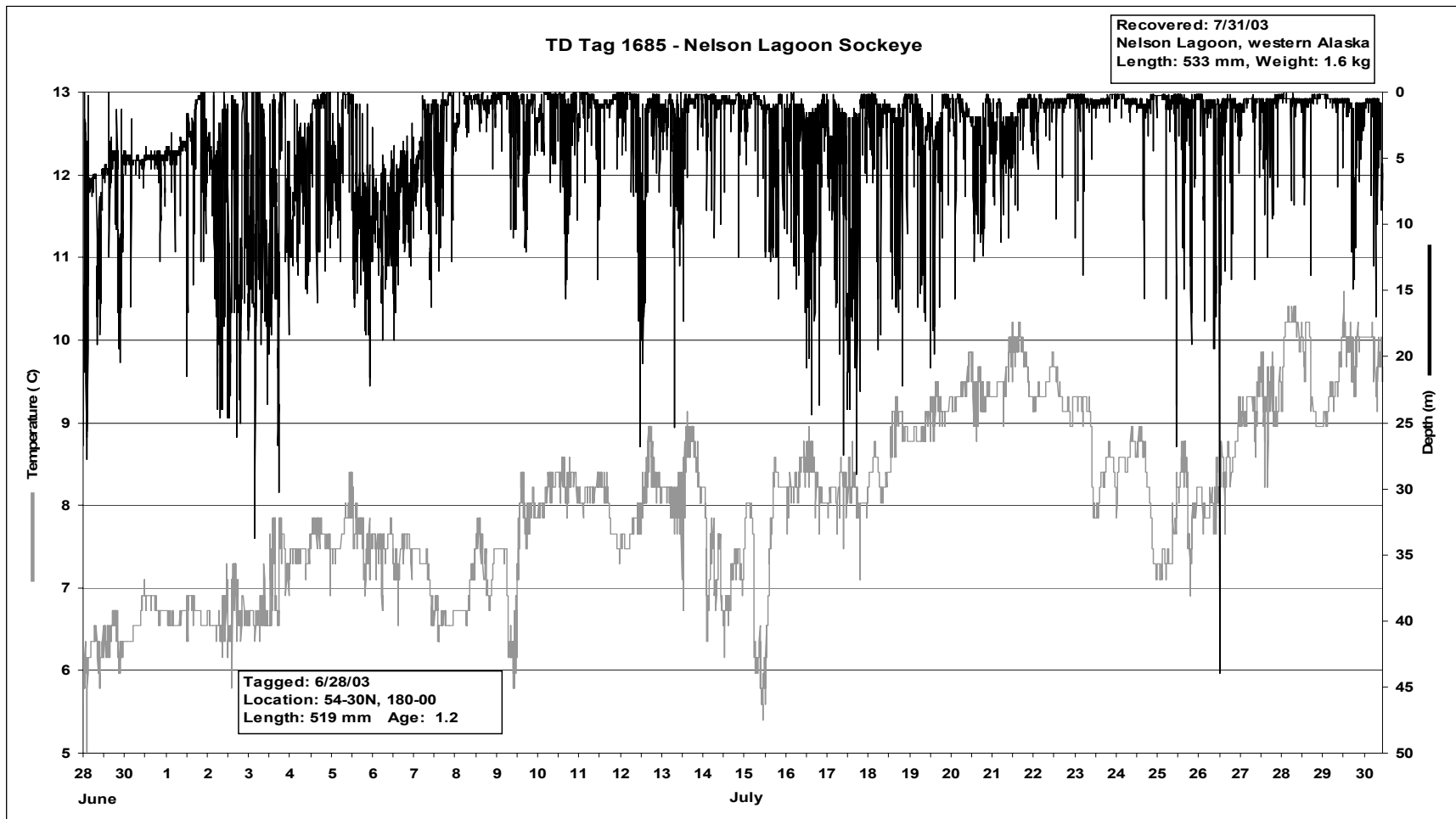
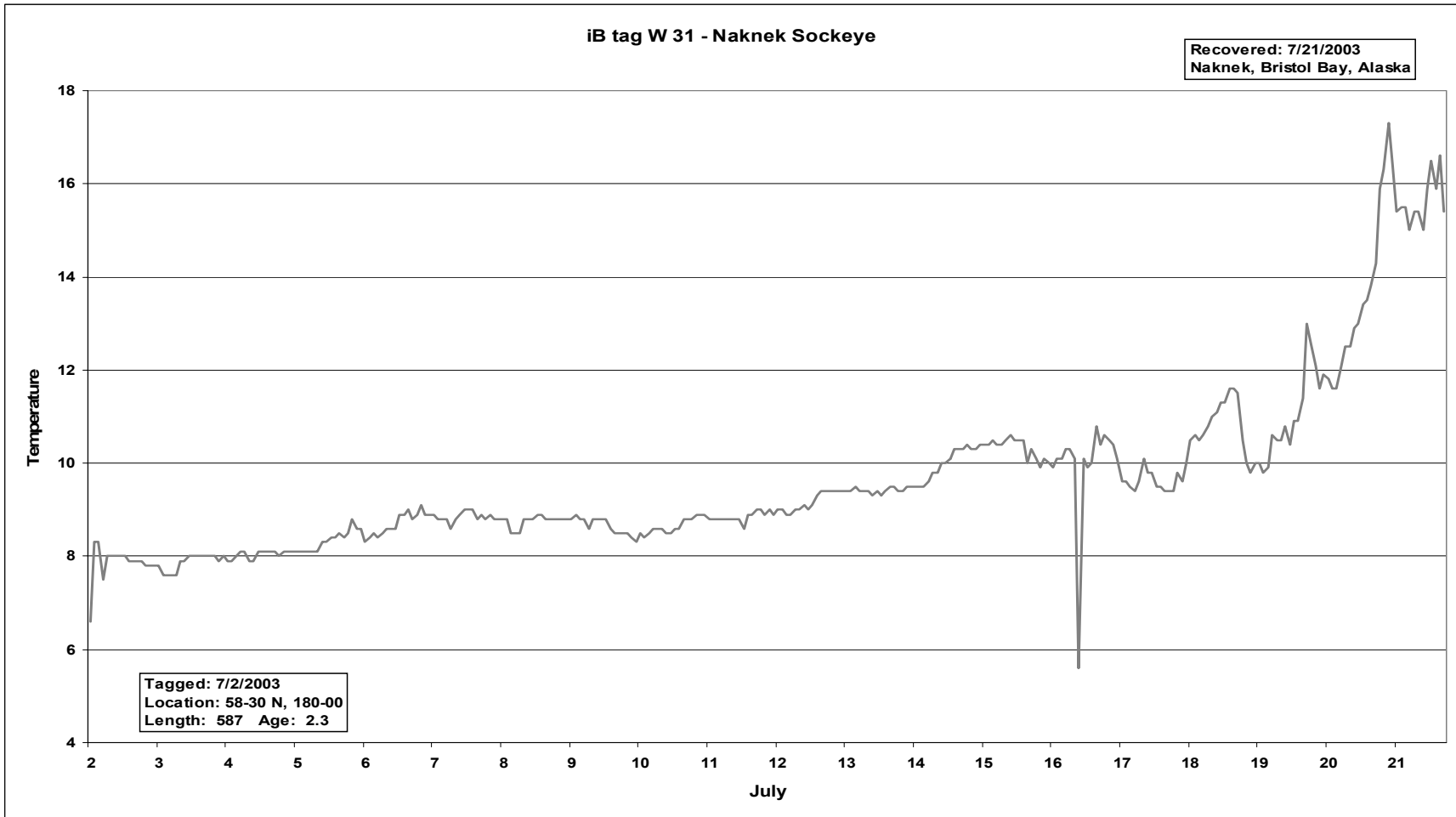


Fig. 6. Temperature and depth data recorded on a data storage tag placed on a 519-mm sockeye salmon in the Bering Sea on 28 June 2003 and recovered in Nelson Lagoon, Alaska Peninsula, Alaska, on 31 July 2003.



11

Fig. 7. Sea temperature (°C) data from a data storage tag placed on a 587-mm sockeye salmon in the Bering Sea on 2 July 2003 and recovered in Naknek, Bristol Bay, Alaska, on 21 July 2003.

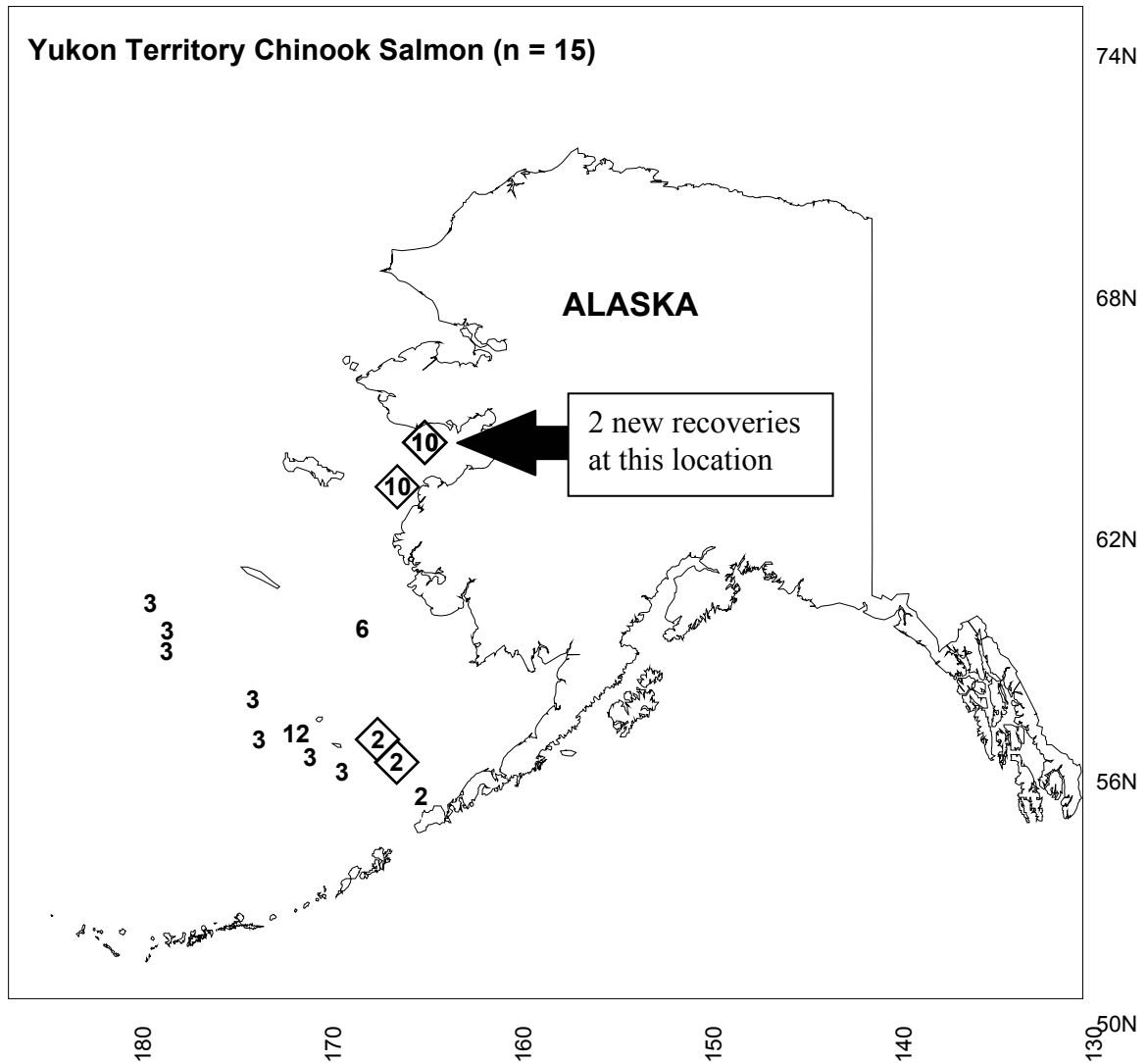


Fig. 8. Recovery locations of coded-wire tagged (CWT) Yukon River (Yukon Territory) hatchery chinook salmon caught by U.S. research and groundfish (trawl) fishery vessels in the eastern Bering Sea, 1992-2003. The numbers at each location indicate the month of recovery. Five new recoveries reported by Myers et al. (2003a) are indicated by open diamonds. Three new recoveries of coded-wire tagged juvenile (ocean age-0) fish during a U.S. NMFS survey in October 2002 at 64°06'N, 164°31'W (2 recoveries) and at 63°00'N, 165°58'W are northern extensions of the known ocean range of Yukon River chinook salmon. The previous northern record was an immature (age 1.3) chinook salmon tagged and released during high seas research vessel operations at 59°03'N, 178°59'E in July 1972 and recovered two years later in the Yukon River, Alaska. Two new recoveries in February show the overwintering location of Yukon River salmon during their first winter at sea.

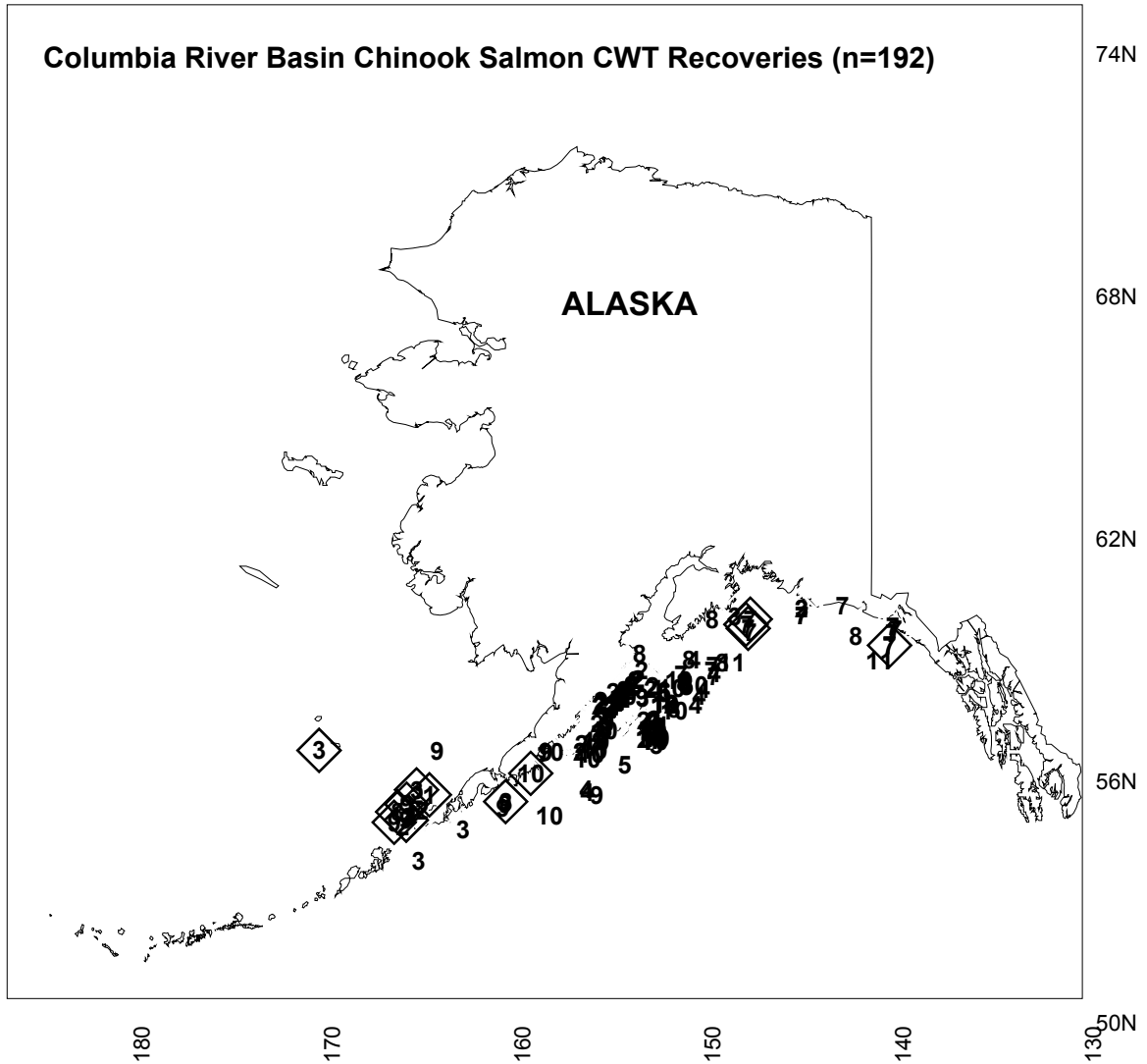


Fig. 9. Recovery locations of coded-wire tagged (CWT) Columbia River Basin chinook salmon caught by U.S. research vessels and by U.S. and joint-venture groundfish (trawl) fishery vessels in the eastern Bering Sea and Gulf of Alaska, 1982-2003. The numbers at each location indicate the month of recovery. Thirteen new recoveries reported by Myers et al. (2003a) are indicated by open diamonds. One recovery of an age 0.3 coded-wire tagged hatchery (Ringold Springs, Washington) salmon at 56°27'N, 170°01'W is a northwestern extension of the known ocean range of Columbia River Basin and Washington chinook salmon in the eastern Bering Sea.

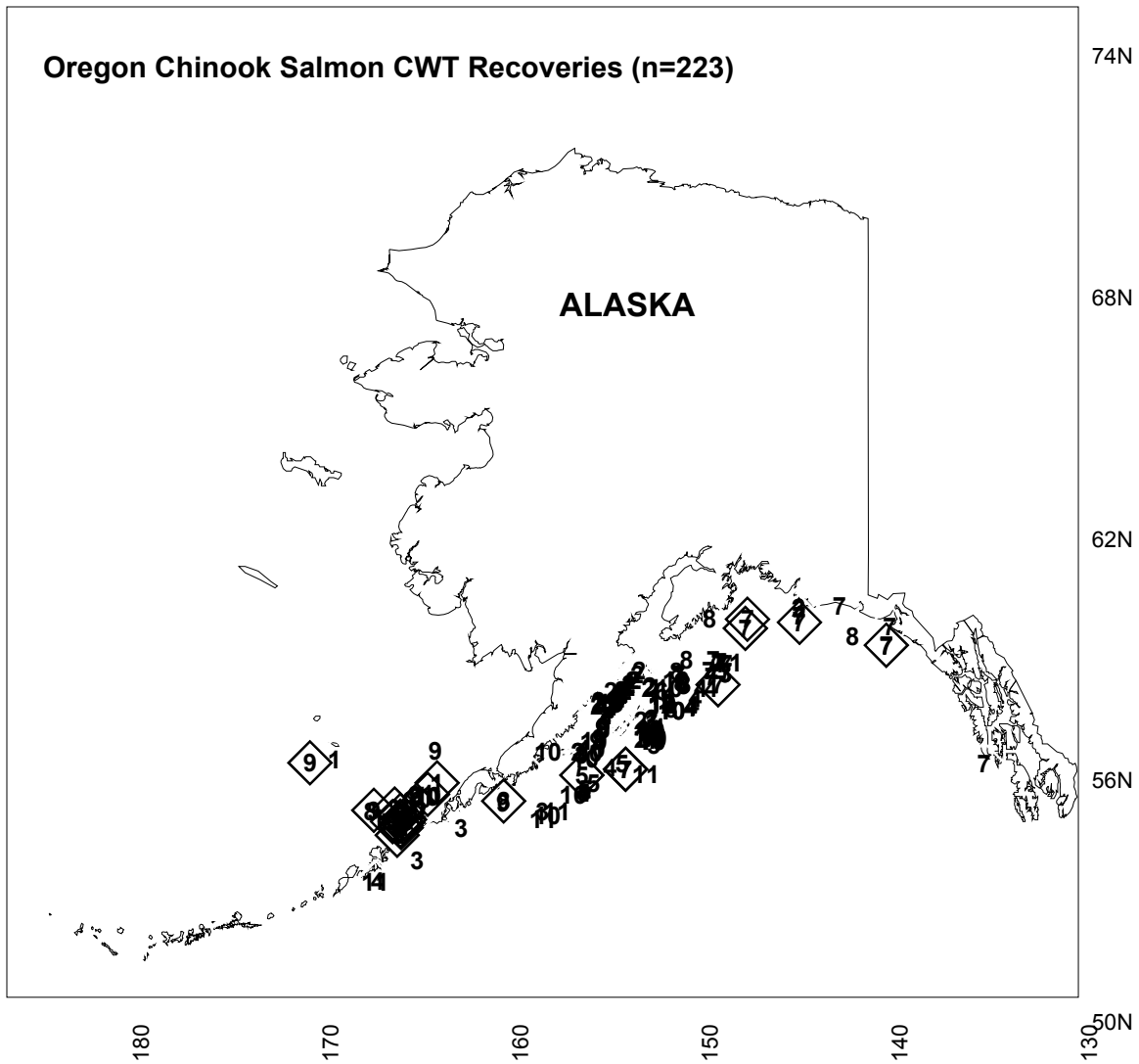


Fig. 10. Recovery locations of coded-wire tagged (CWT) Oregon chinook salmon, including recoveries in the Columbia River Basin, caught by U.S. research vessels and by U.S. and joint-venture groundfish (trawl) fishery vessels in the eastern Bering Sea and Gulf of Alaska, 1982-2003. The numbers at each location indicate the month of recovery. Twenty-one new recoveries (including recoveries of Columbia River Basin fish) reported by Myers et al. (2003a) are indicated by open diamonds. One recovery of an age 0.2 hatchery salmon at 56°08'N, 170°26'W in September 2002 is a northwestern extension of the known ocean range of Oregon chinook salmon in the eastern Bering Sea.

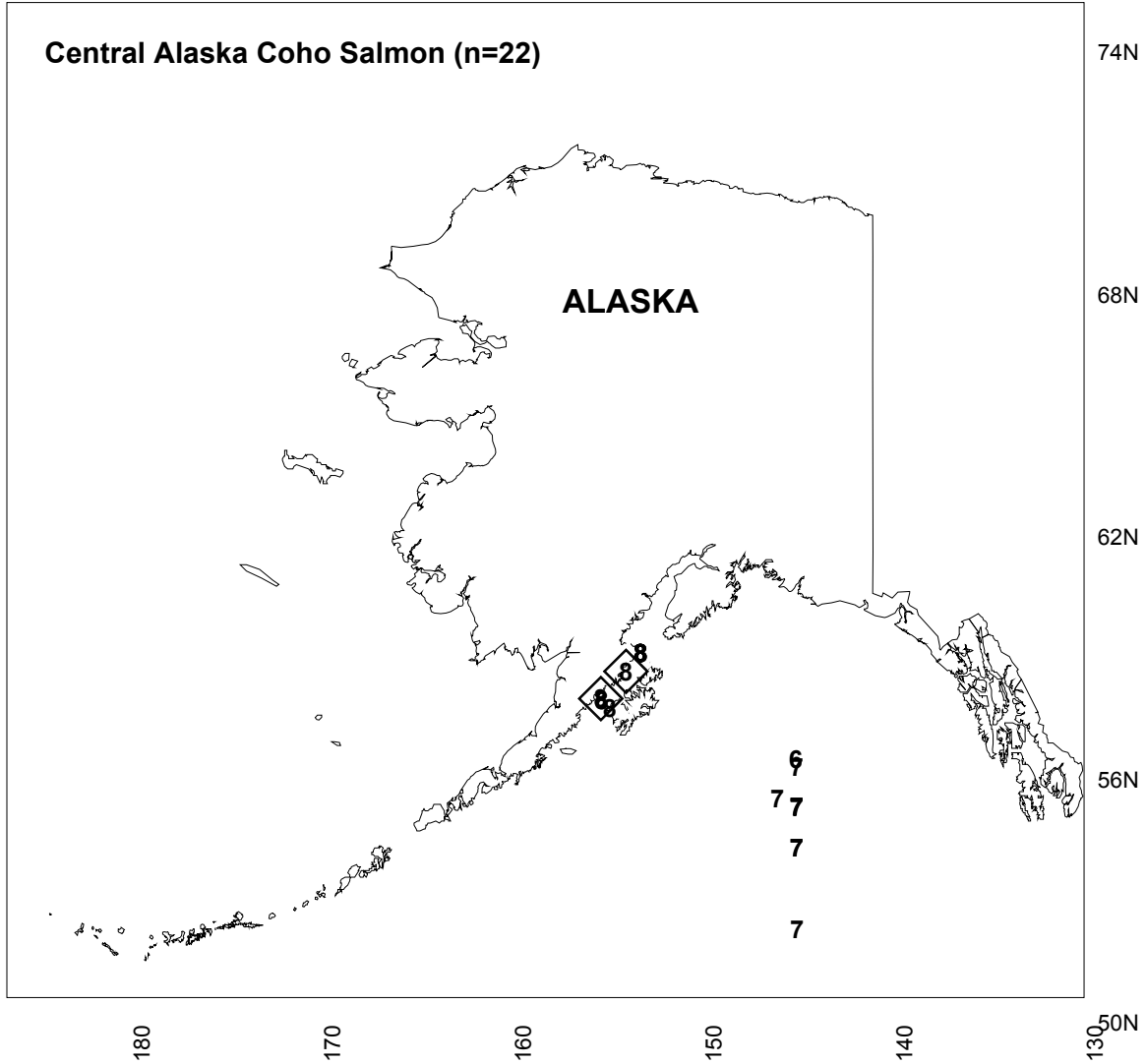


Fig. 11. Recovery locations of coded-wire tagged (CWT) central Alaska (Cook Inlet) coho salmon caught by U.S. and Japanese research vessels in the Gulf of Alaska (north of 50°N), 1993-2002. The numbers at each location indicate the month of recovery. All offshore recoveries in June and July are maturing fish and all inshore recoveries in August are juvenile (age-0) fish in their first summer at sea. Two new inshore recoveries of juvenile coho salmon reported by Myers et al. (2003a) are indicated by open diamonds.

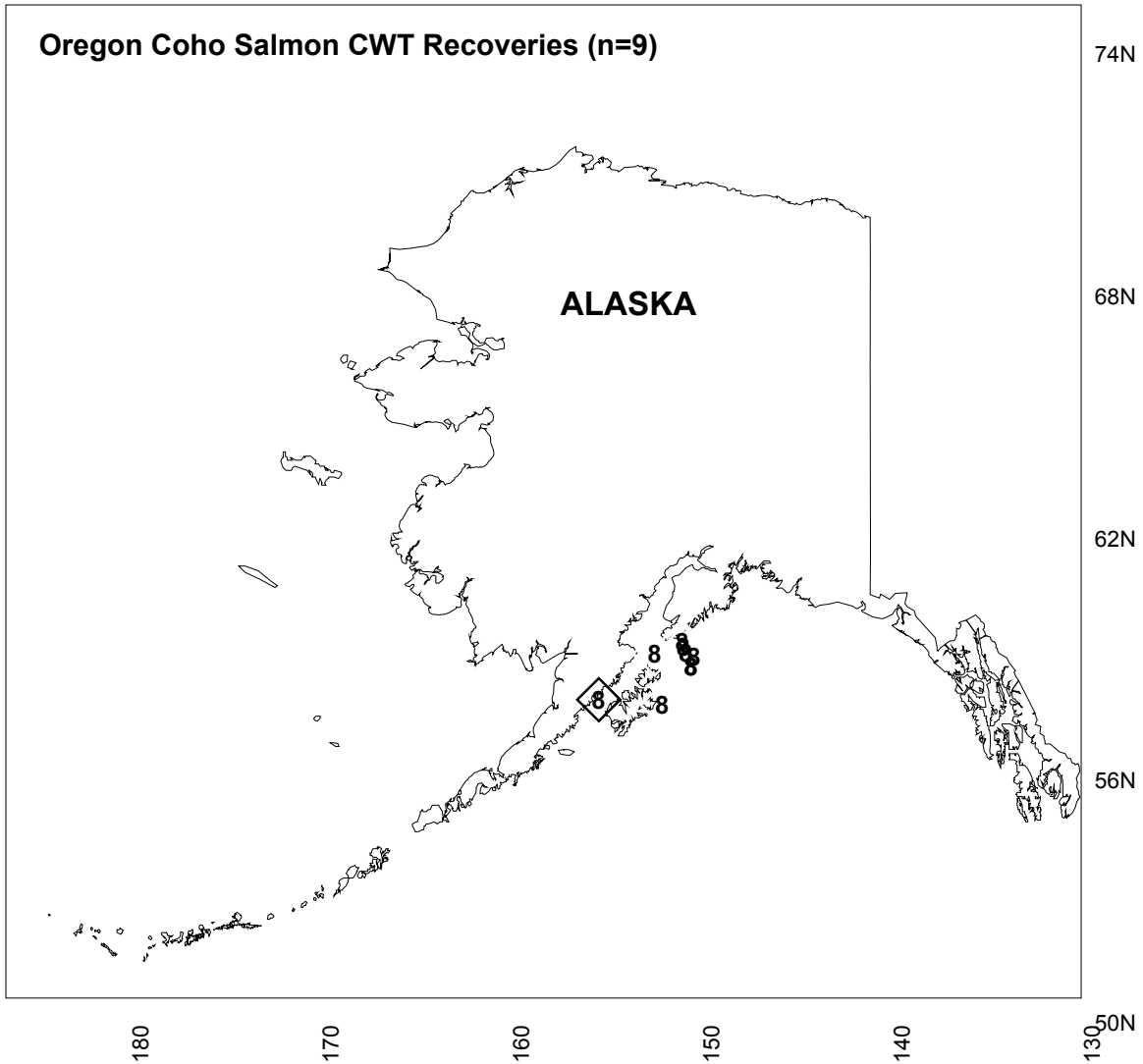


Fig. 12. Recovery locations of coded-wire tagged (CWT) Oregon coho salmon caught by U.S. research vessels in the Gulf of Alaska (north of 50°N), 1996-2002. The numbers at each location indicate the month of recovery. All recoveries are juvenile (age-0) fish in their first summer at sea. The location of one new recovery in August reported by Myers et al. (2003a) is indicated by an open diamond.

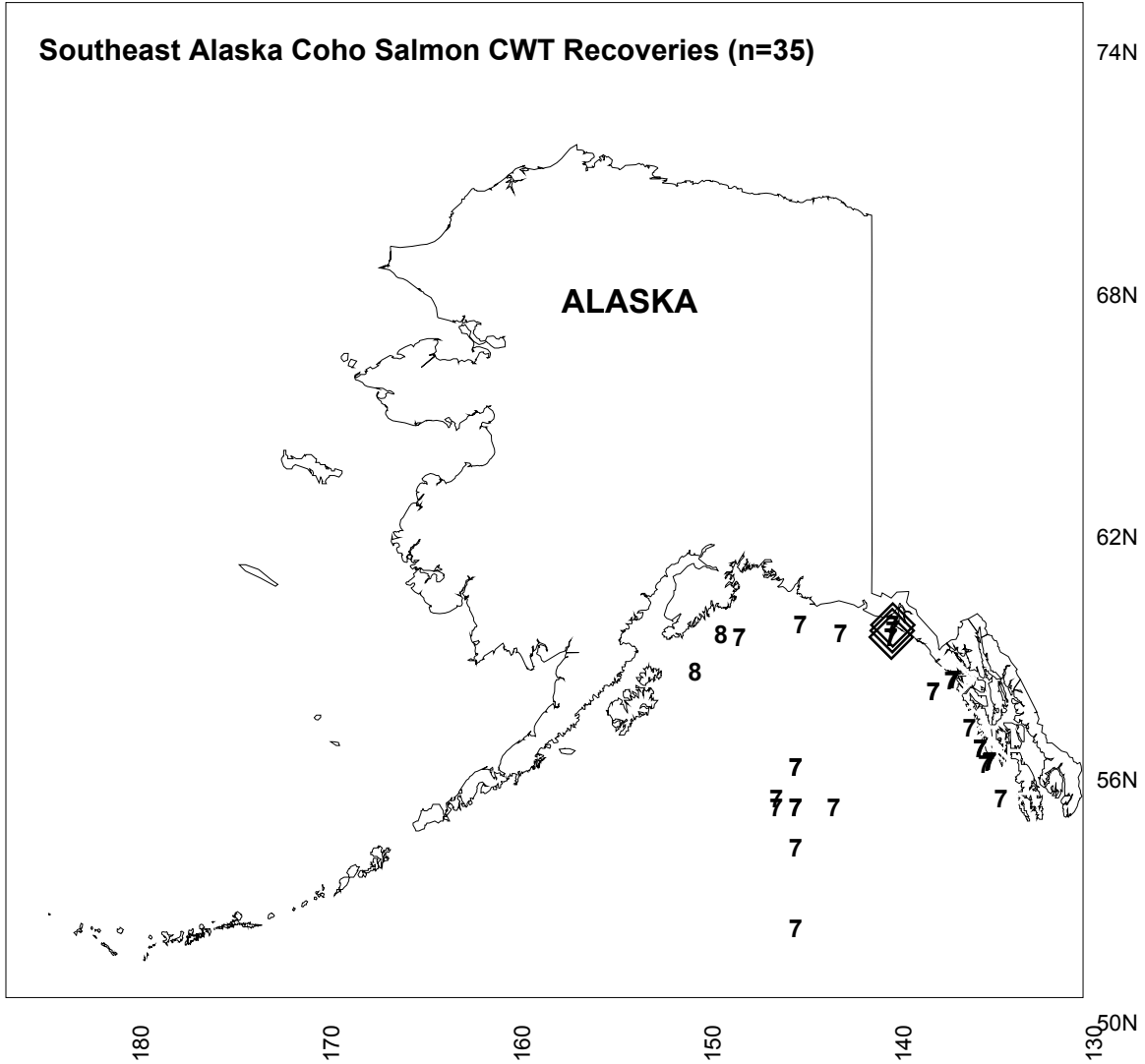


Fig. 13. Recovery locations of coded-wire tagged (CWT) southeast Alaska coho salmon caught by U.S. and Japanese research vessels in the Gulf of Alaska (north of 50°N), 1982-2002. The numbers at each location indicate the month of recovery. All offshore recoveries in July are maturing fish and inshore recoveries are a mixture of juvenile and maturing fish. The locations of three new recoveries in July (2 juvenile and 1 maturing fish) reported by Myers et al. (2003a) are indicated by open diamonds.

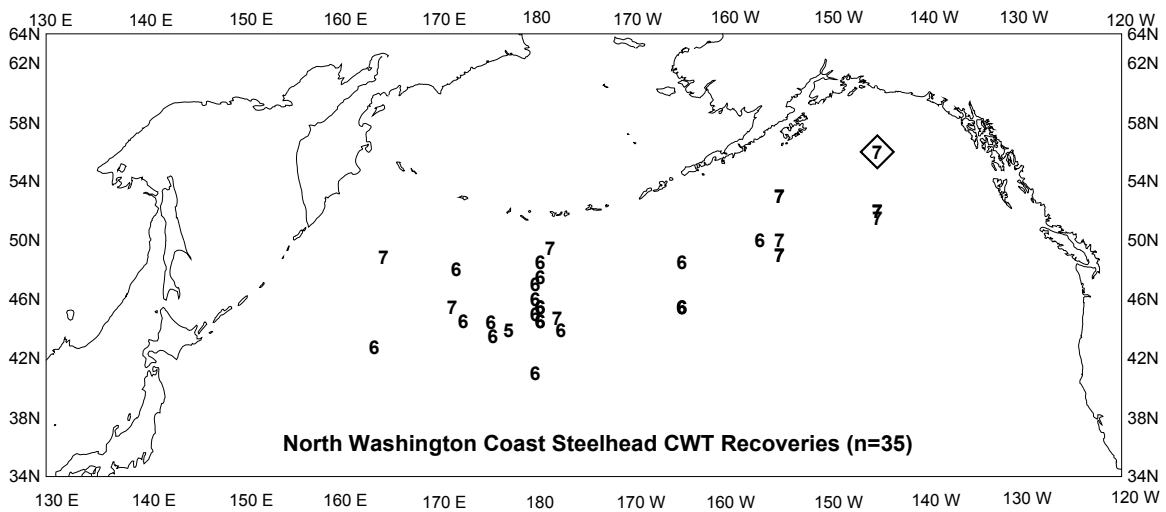


Fig. 14. Recovery locations of coded-wire tagged (CWT) North Washington Coast steelhead caught by Japanese research and driftnet fishery vessels in the North Pacific Ocean, 1982-2002. The numbers at each location indicate the month of recovery. The location of one new research vessel recovery in July 2002 reported by Myers et al. (2003a) is indicated by an open diamond. This recovery at 56°N, 145°W is a northern extension of the known high seas range of North Washington Coast steelhead.

Central North Pacific

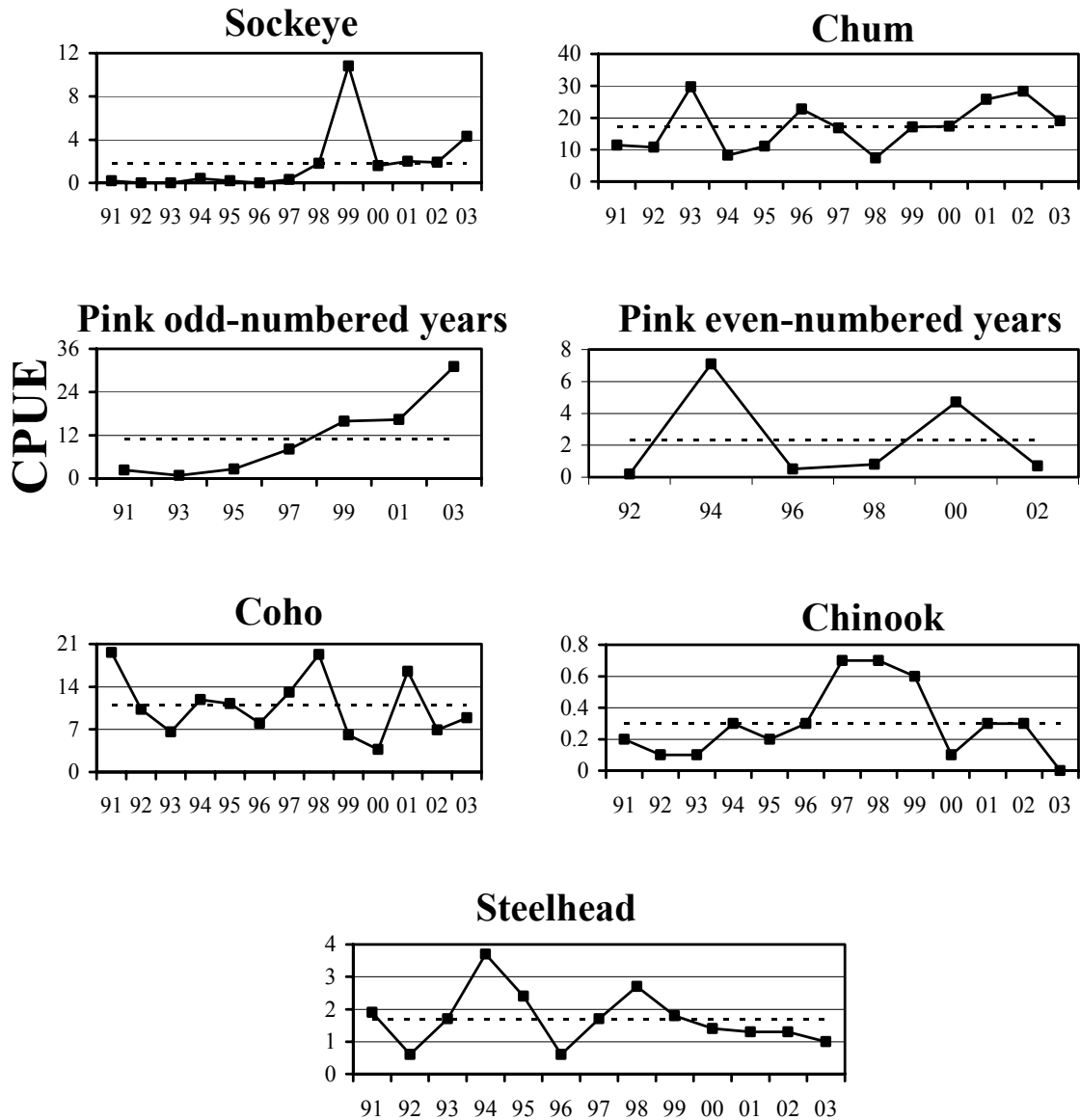


Fig. 15. Annual catch (number of salmonids) per unit of effort (CPUE; 30-tans, 1500 m) by research-mesh gillnet (C-gear) from fishing operations of the *Wakatake maru* in the central North Pacific Ocean 1991-2003. Solid line=annual CPUE, dashed line=mean CPUE 1991-2003.

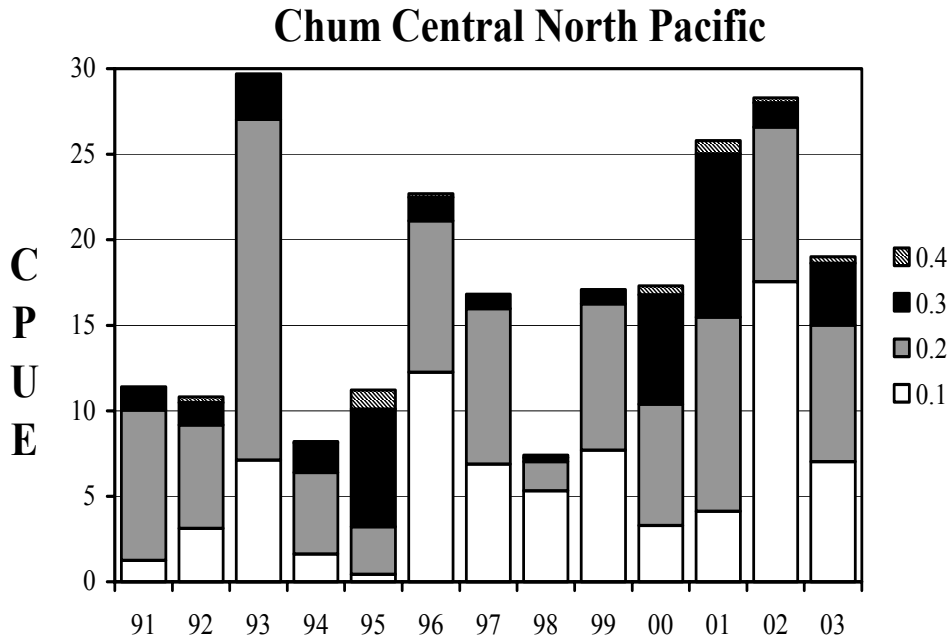
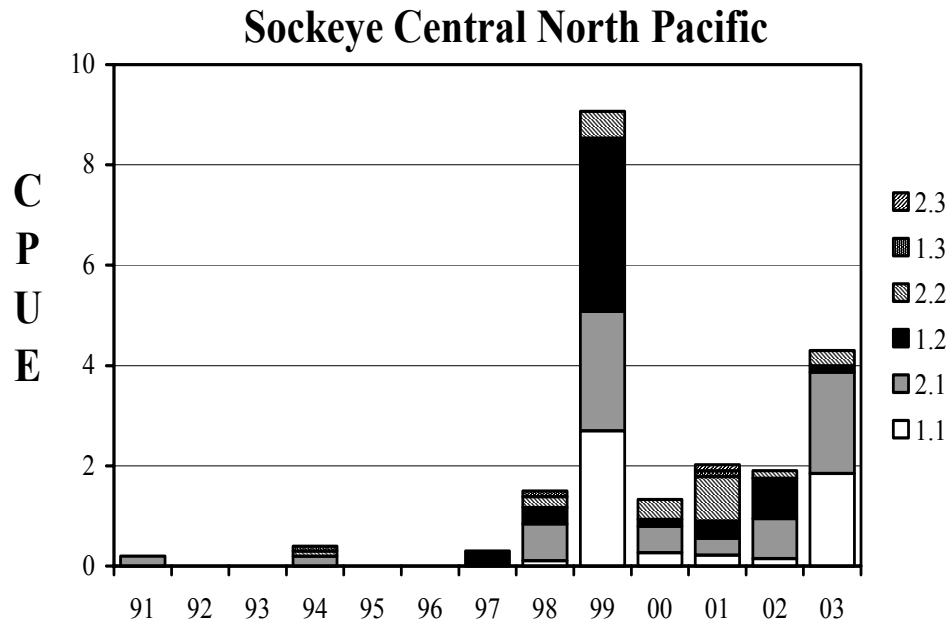
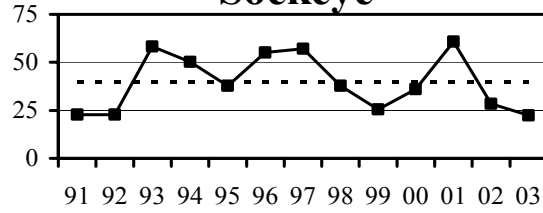


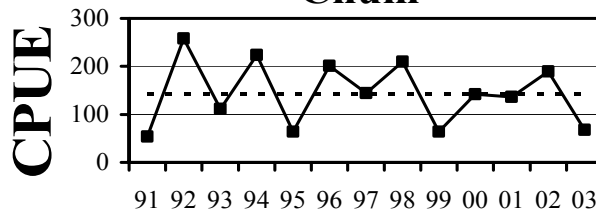
Fig. 16. Estimates of CPUE represented by each age group of sockeye and chum salmon in the central North Pacific Ocean, 1991-2003. CPUE=number of fish per unit (30-tans) of effort by C-gear (research-mesh gillnet). Values estimated by multiplying CPUE by % age composition and dividing by 100.

Central Bering Sea

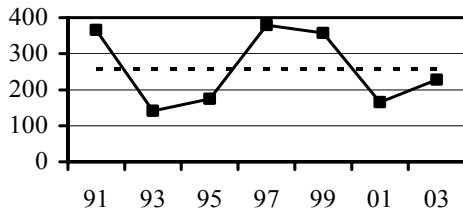
Sockeye



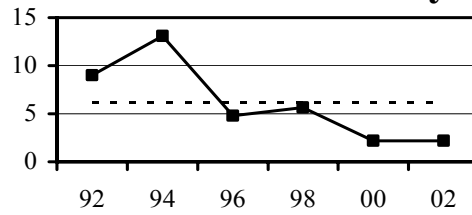
Chum



Pink odd-numbered years



Pink even-numbered years



Chinook

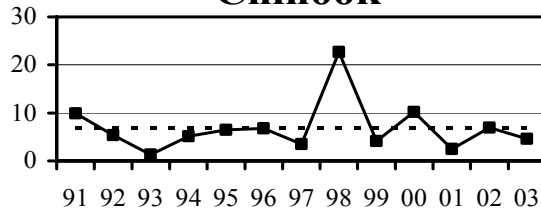


Fig. 17. Annual catch (number of salmonids) per unit of effort (CPUE; 30-tans, 1500 m) by research-mesh gillnet (C-gear) from fishing operations of the *Wakatake maru* in the central Bering Sea 1991-2003. Solid line=annual CPUE, dashed line= mean CPUE 1991-2003.

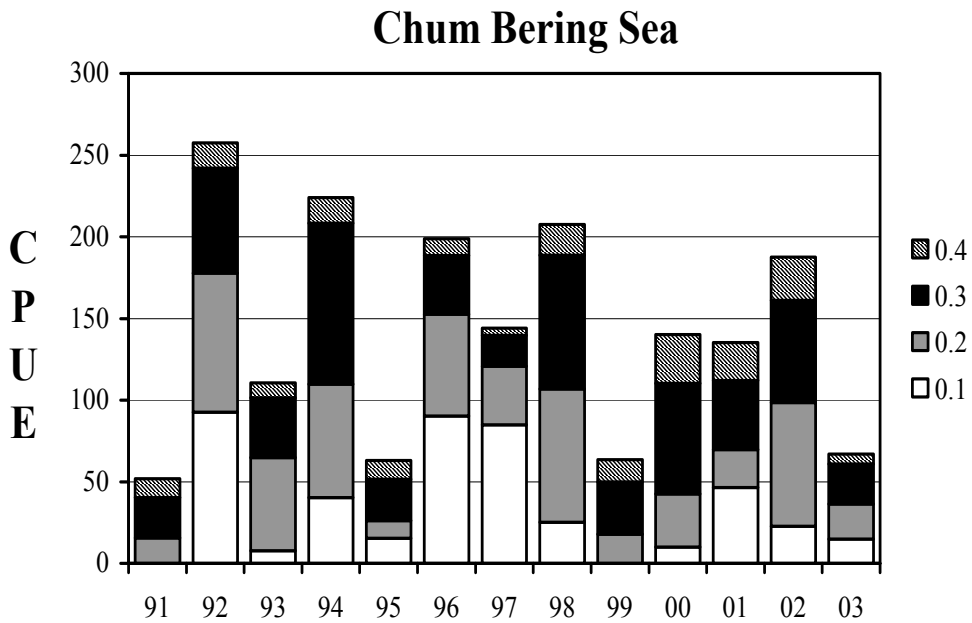
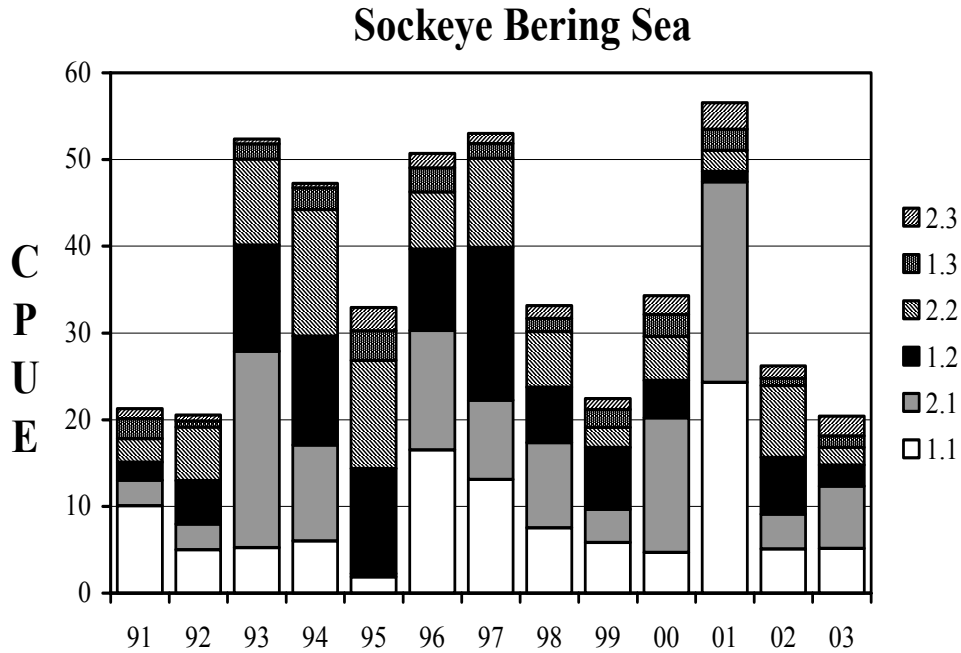


Fig. 18. Estimates of CPUE represented by each age group of sockeye and chum salmon in the central Bering Sea, 1991-2003. CPUE=number of fish per unit (30-tans) of effort by C-gear (research mesh) gillnet. Values estimated by multiplying CPUE by % age composition and dividing by 100.

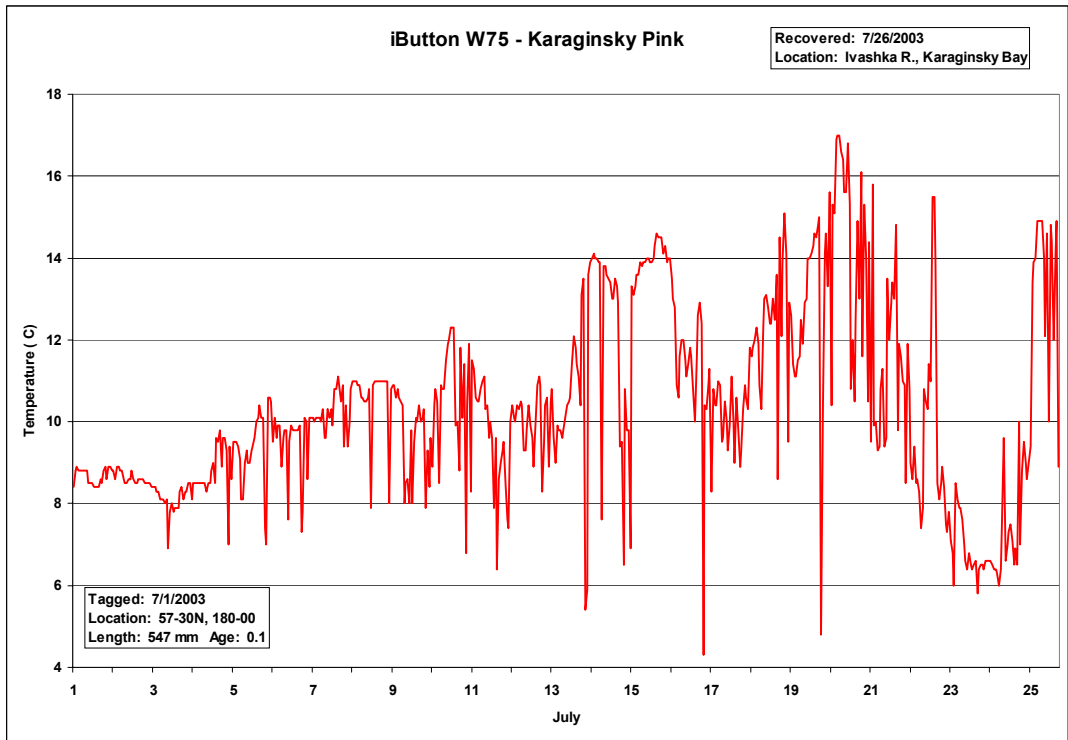


Fig. 19. Sea temperature (°C) data from iButton tag W-75. Pink salmon released in the Bering Sea (57°30N, 180°-longitude) on 7/1/03 and recovered in northeastern Kamchatka, Russia (Karaginsky Bay) 7/26/03.

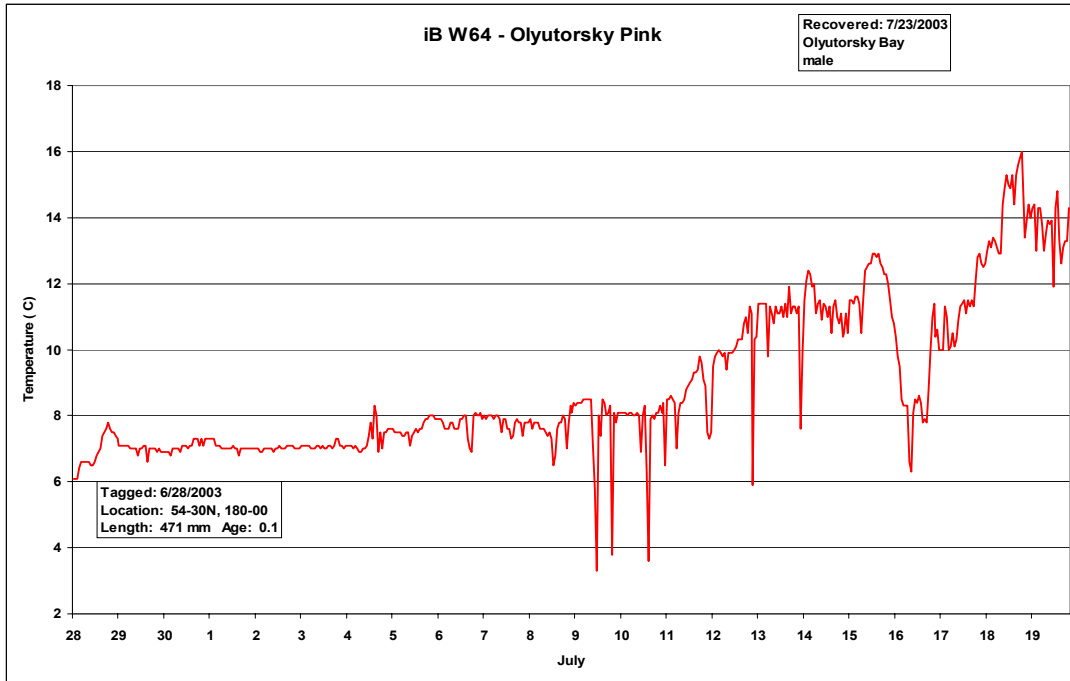


Fig. 20. Sea temperature (°C) data from iButton tag W-64. Pink salmon released in the Bering Sea (54°30N, 180°-longitude) on 6/28/03 and recovered in NE Kamchatka, Russia (Olyutorsky Bay) on 7/23/03.

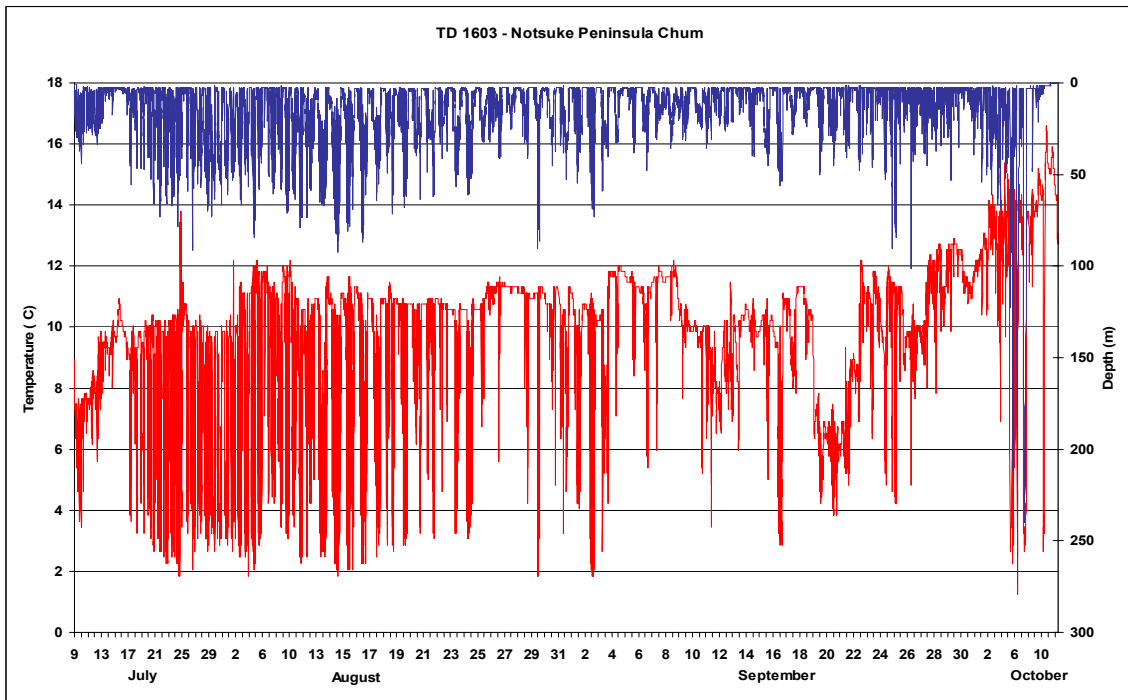


Fig. 21. Sea temperature ($^{\circ}\text{C}$ on left axis, bottom line) and depth (m on right axis, top line) data from TD 1603. Chum salmon released in the Bering Sea ($56^{\circ}30\text{N}$, $177^{\circ}00\text{E}$) on 7/9/03 and recovered in on the Nemuro Coast, Hokkaido, Japan on 10/11/03.

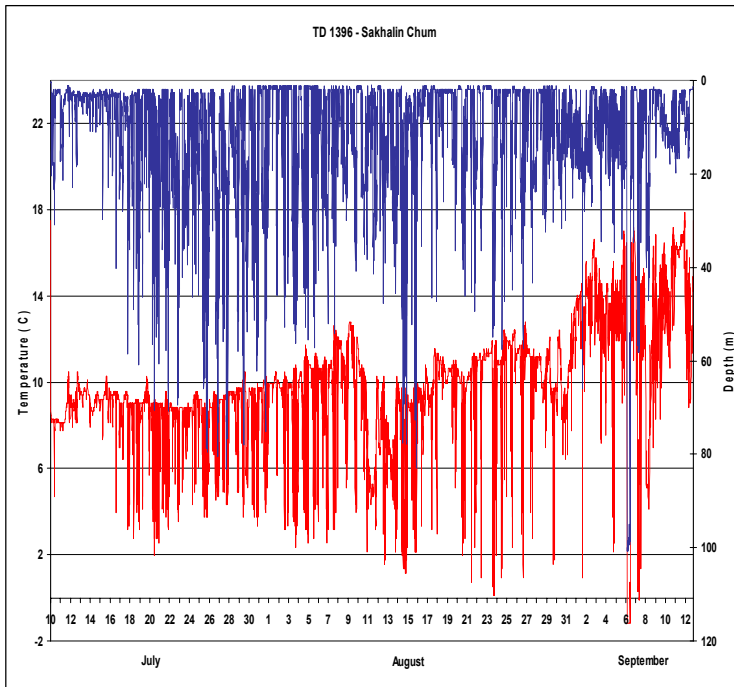


Fig. 22. Sea temperature ($^{\circ}\text{C}$ on left axis, bottom line) and depth (m on right axis, top line) from TD 1396. Chum salmon released in the Bering Sea ($57^{\circ}30\text{N}$, $177^{\circ}00\text{E}$) on 7/10/03 and recovered at the Kalininsky Hatchery, Sakhalin Island, Russia on 9/12/03.

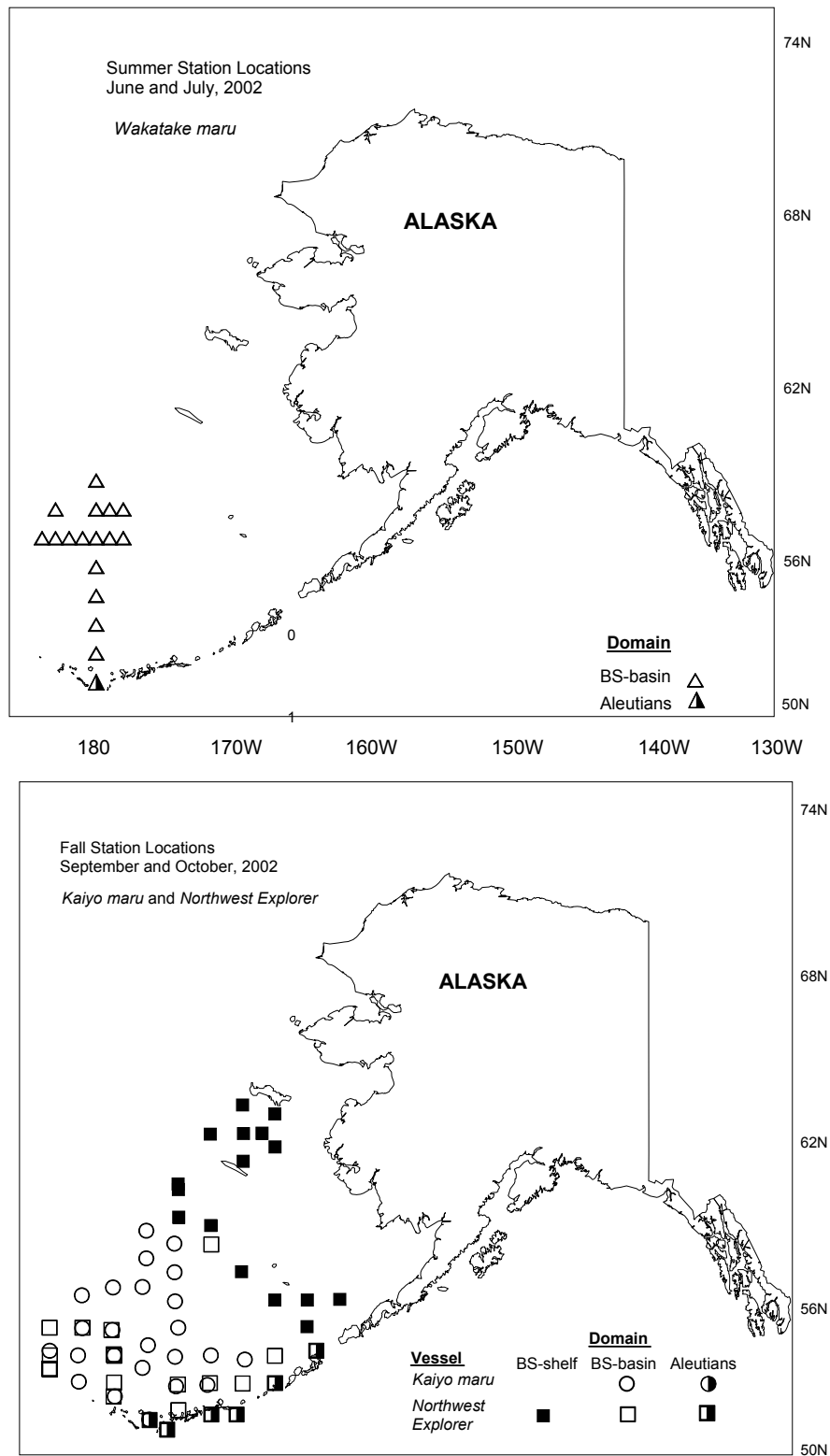


Fig. 23. Station locations in summer (upper panel) and fall (lower panel) 2002 where samples were collected for food habits analysis. Shapes depict station locations for each research vessel. Triangles = *Wakatake maru*, circles = *Kaiyo maru*, and squares = *Northwest Explorer*. Geographical habitats are indicated by fill pattern; basin = no fill, shelf = solid fill, and Aleutian Islands = partial fill.

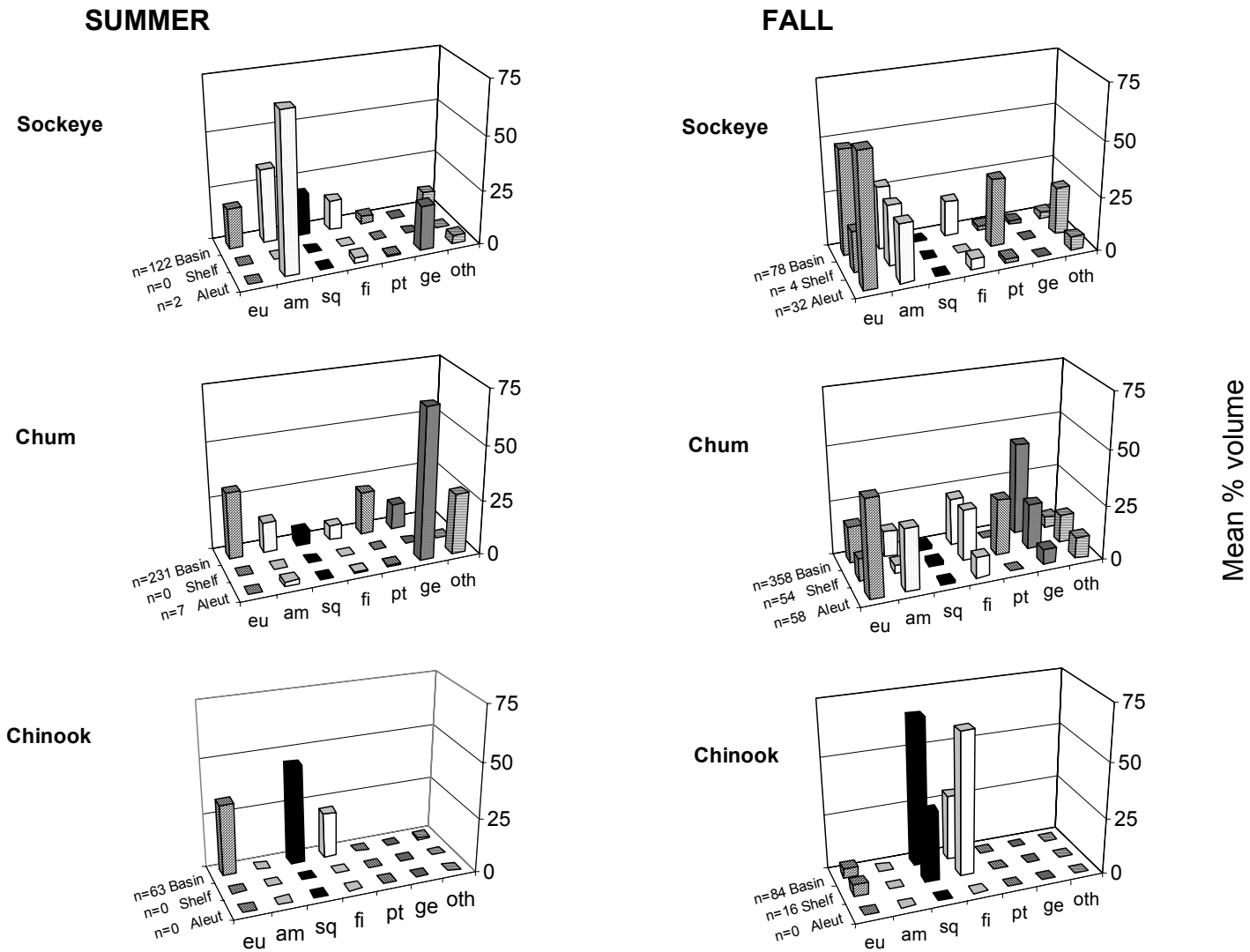


Fig. 24. Diet composition (mean percent volume) of sockeye, chum, and chinook salmon collected in the basin, shelf, and Aleutian Islands during summer and fall 2002. Prey categories include; eu = euphausiids, am = amphipods, sq = squid, fi = fish, pt = pteropods, ge = gelatinous zooplankton (medusae and ctenophores), and oth = other. Sample size (n) shown for each habitat.

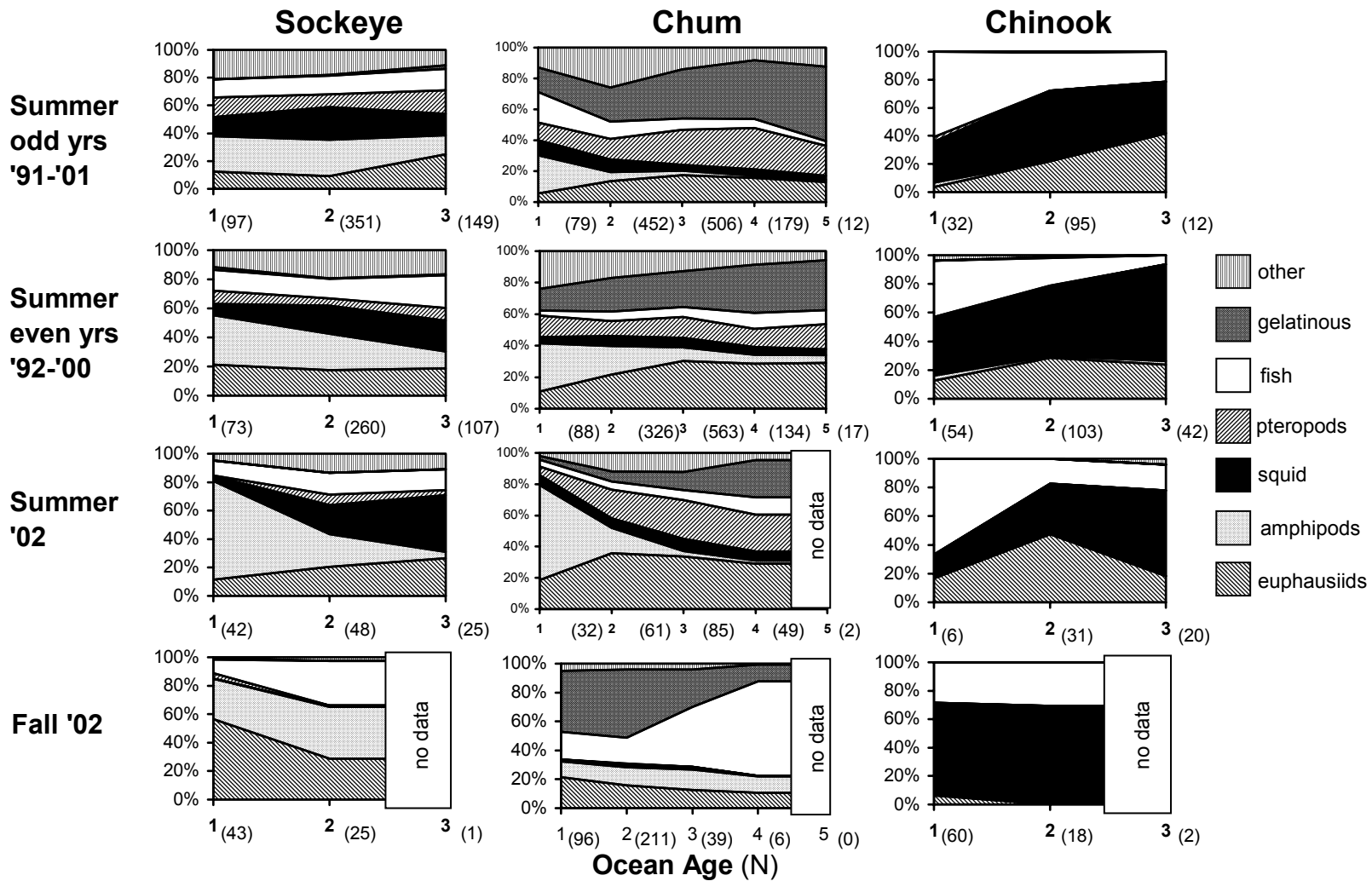


Fig. 25. Diet composition (mean percent volume) of sockeye, chum, and chinook salmon collected in the Bering Sea basin stratified by season and ocean age of fish. Sample sources include data for summer in odd-numbered years (1991-2001), summer in even-numbered years (1992-2000), summer 2002, and fall 2002. Ocean age followed by number of salmon stomachs in each age group containing prey is shown on the x-axis. Age groups labeled with “no data” indicate sample sizes too small to characterize stomach contents ($n \leq 5$).

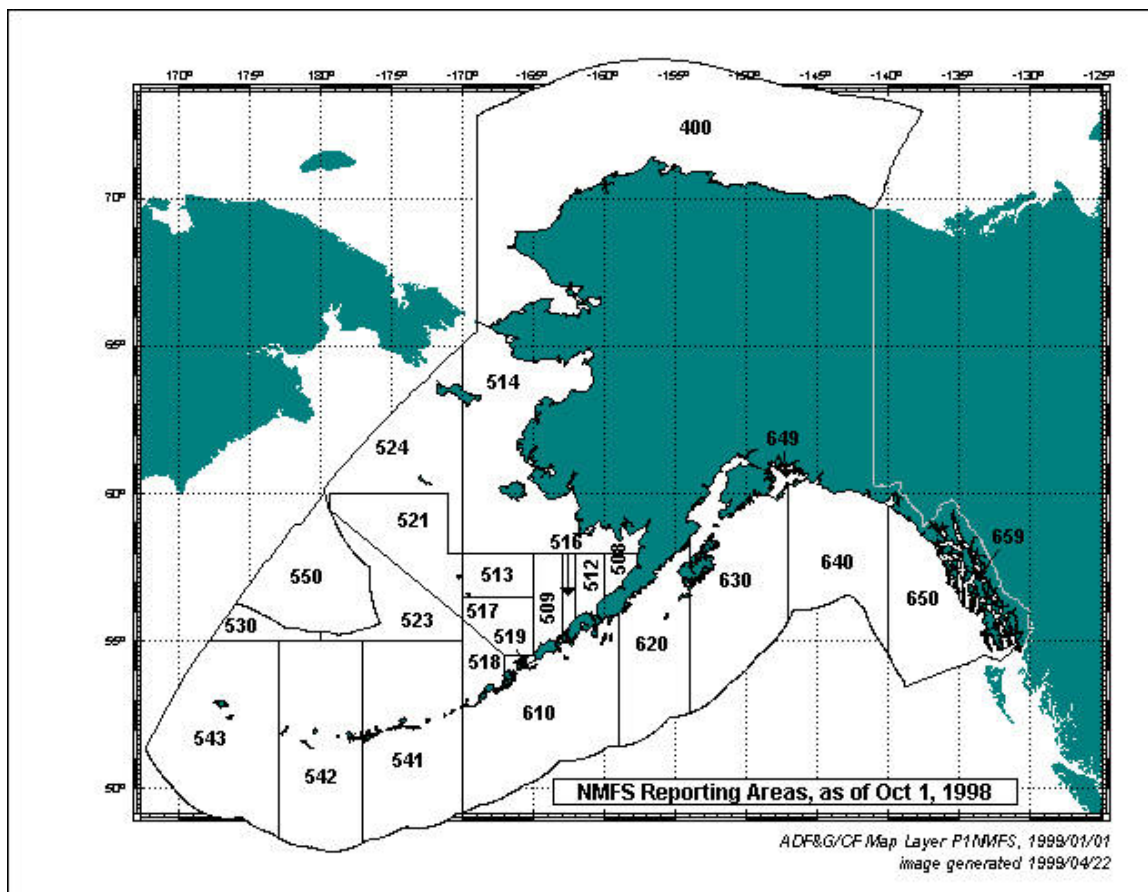


Fig. 26. Map showing National Marine Fisheries Service (NMFS) reporting areas in the Bering Sea and Aleutian Islands (BSAI; area numbers in the 500s) and Gulf of Alaska (area numbers in the 600s).

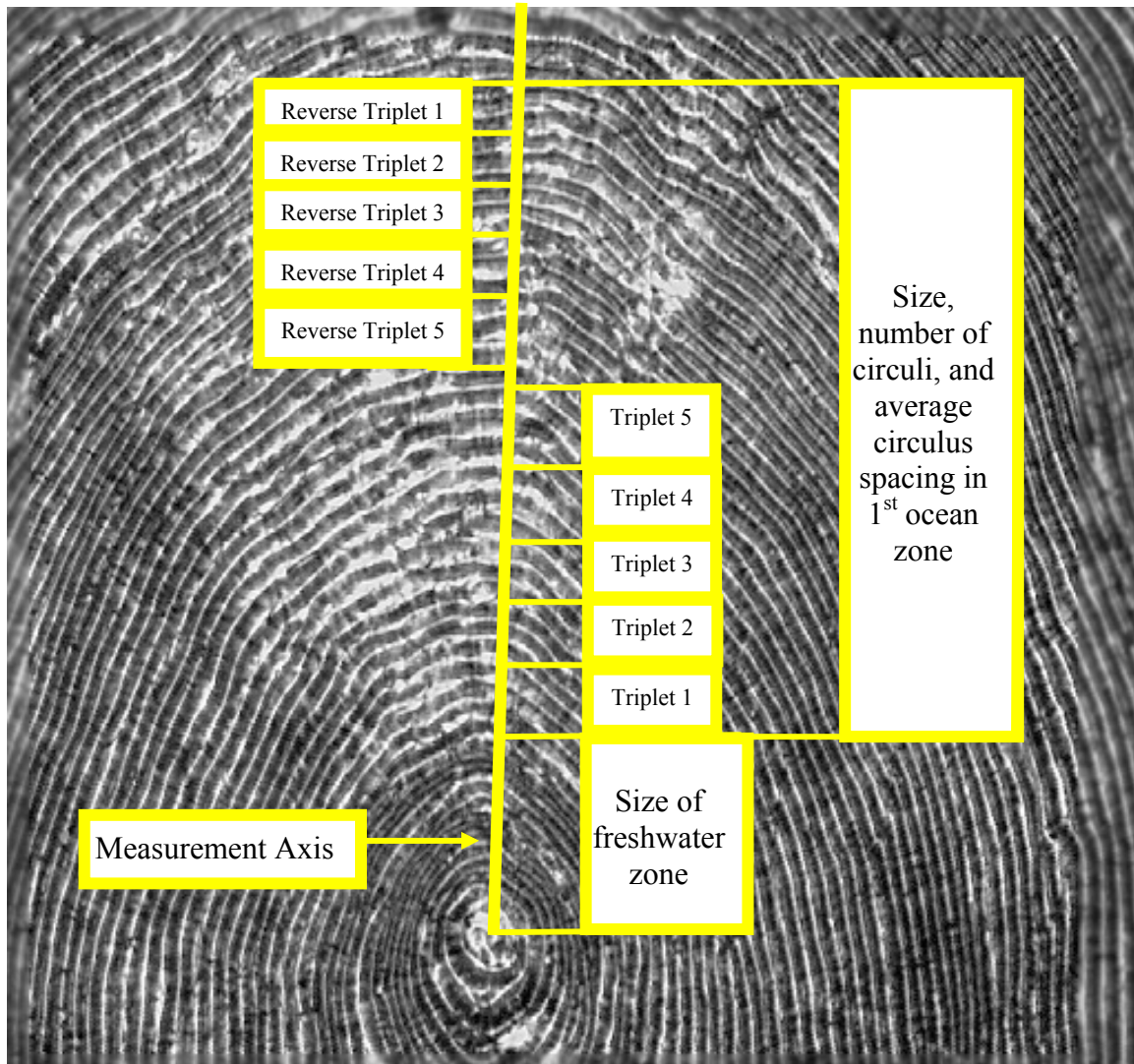


Fig. 27. Chinook salmon scale showing scale measurement axis and 14 scale pattern measurement variables used in the analysis.

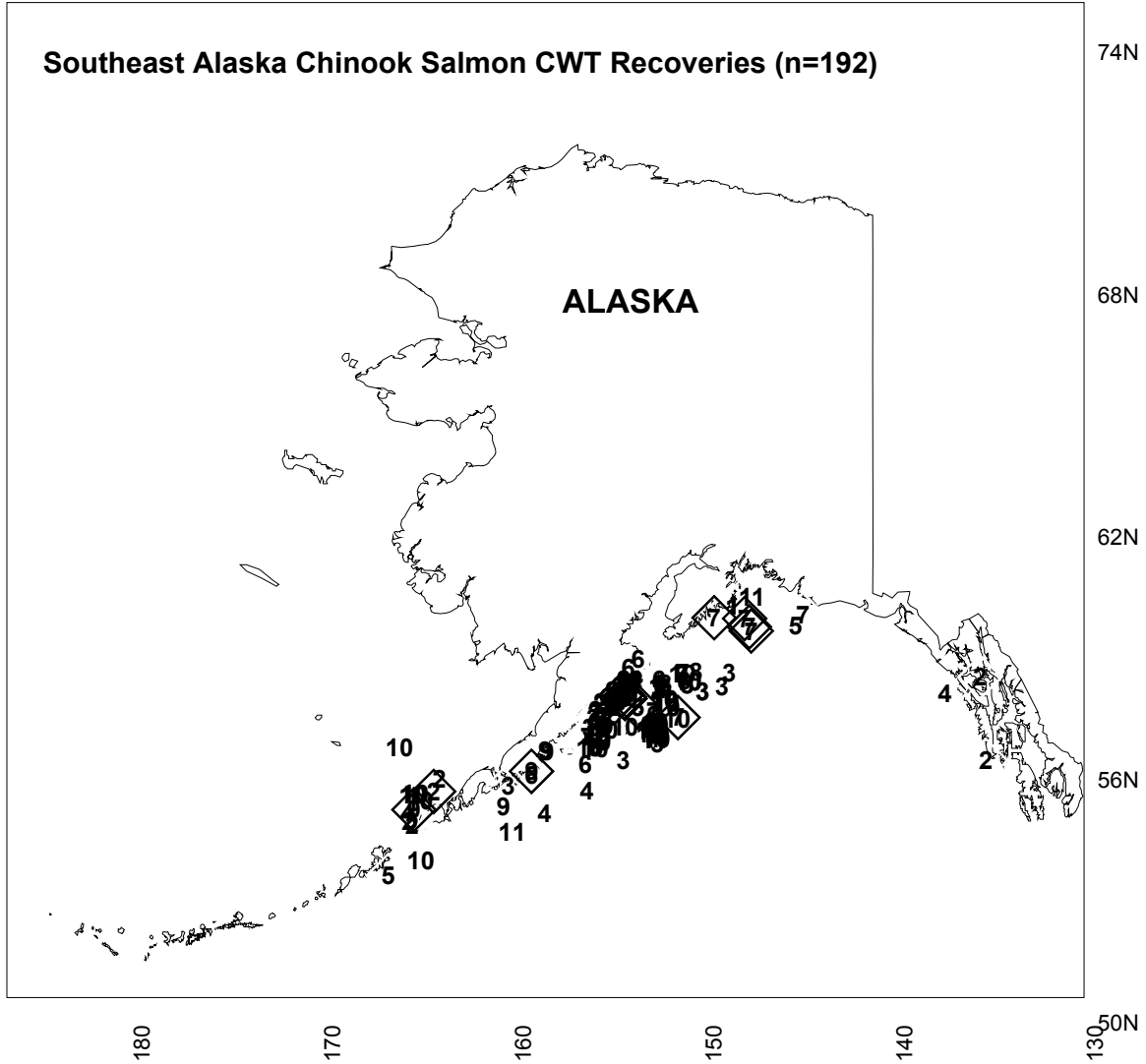


Fig. 29. Recovery locations of coded-wire tagged (CWT) southeast Alaska chinook salmon caught by U.S. research vessels and by U.S. and joint-venture groundfish (trawl) fishery vessels in the eastern Bering Sea and Gulf of Alaska, 1983-2003. The numbers at each location indicate the month of recovery. Thirteen new recoveries reported by Myers et al. (2003a) are indicated by open diamonds.

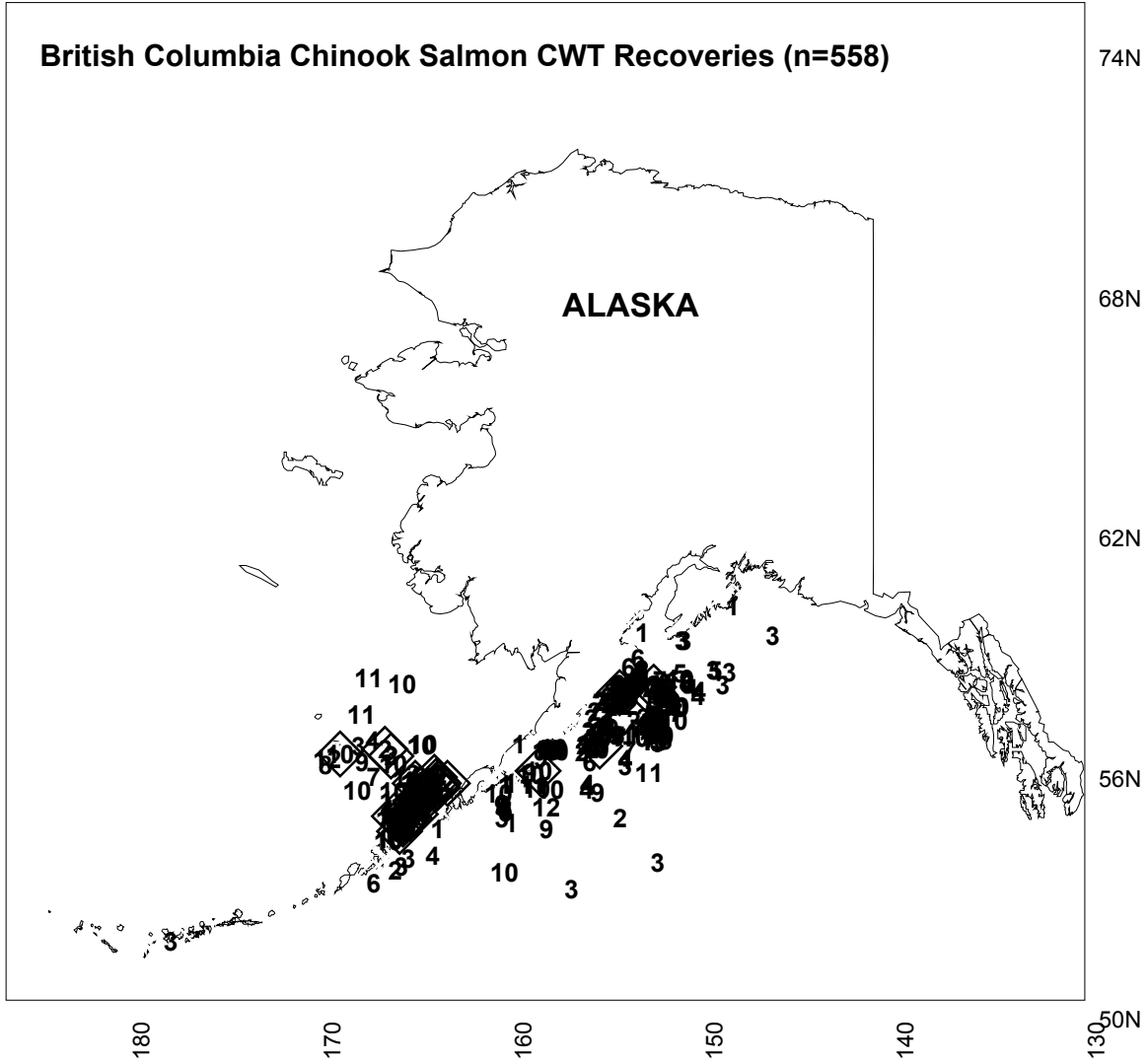


Fig. 30. Recovery locations of coded-wire tagged (CWT) British Columbia chinook salmon caught by U.S. and joint-venture groundfish (trawl) fishery vessels in the eastern Bering Sea and Gulf of Alaska (north of 50°N), 1982-2003. The numbers at each location indicate the month of recovery. Twenty-three new recoveries reported by Myers et al. (2003a) are indicated by open diamonds.

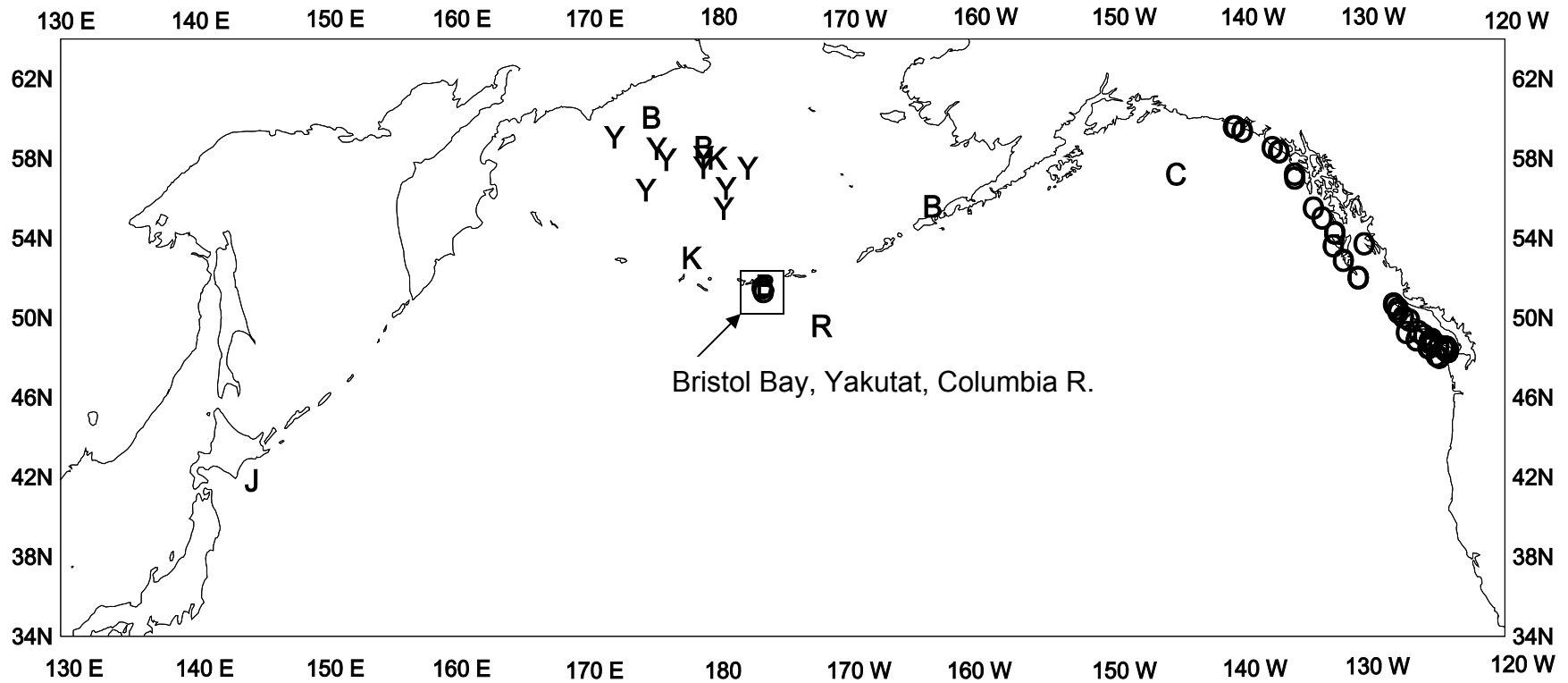


Fig. 31. Release locations of high seas tagged chinook salmon recovered in Japan (J, n=1), Russia (R, n=1), Yukon River (Y, n=9), Kuskokwim River (K, n=2), Bristol Bay (B, n=4), Cook Inlet (C, n=1), and other North American areas (O), including Yakutat (n=1), southeastern Alaska (n=7), British Columbia (n=57), Washington (n=24), Columbia River/Snake R. (n=15), and Oregon (n=2). All chinook salmon recoveries from the central and western Bering Sea were immature fish tagged in June and July and recovered as maturing fish one or more years later in western Alaska (data source: INPFC/NPAFC High Seas salmon tagging database, High Seas Salmon Research Program, SAFS, University of Washington, Seattle).

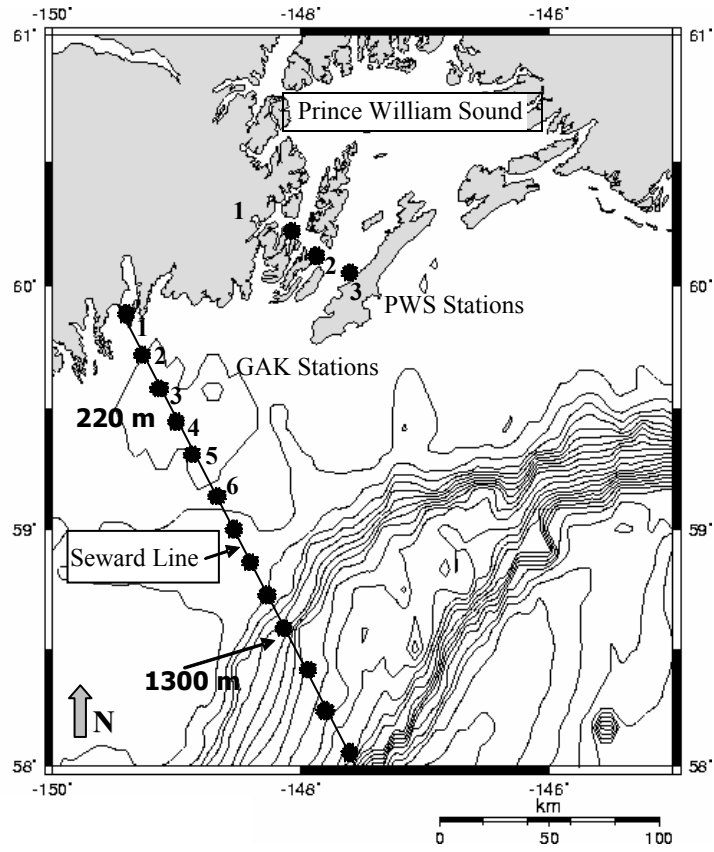


Fig. 32. Prince William Sound (PWS) and northern Gulf of Alaska (Seward line, GAK stations) sample sites for collection of juvenile pink salmon.

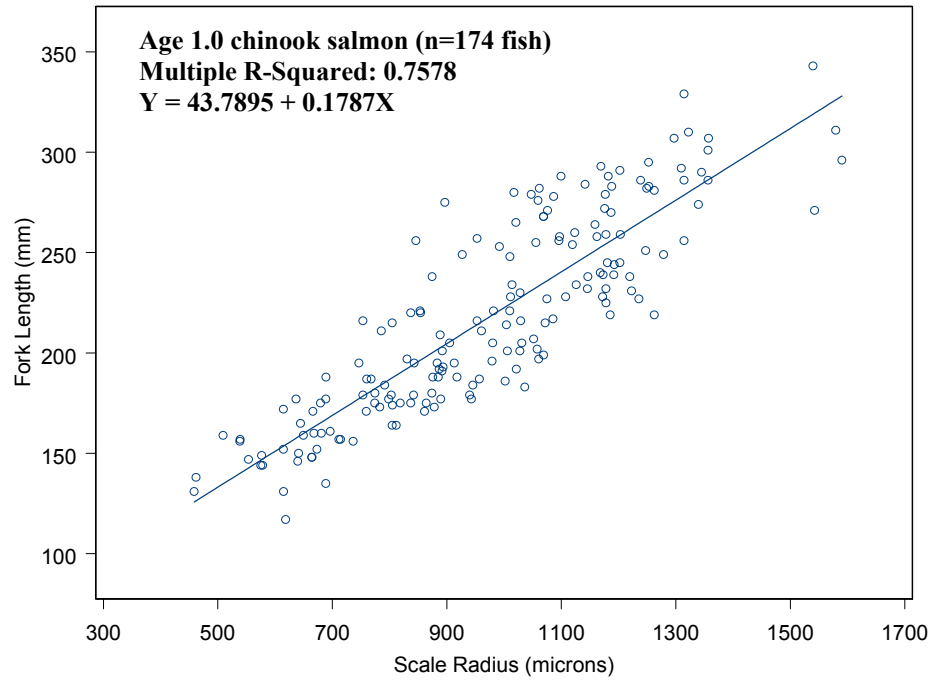


Fig. 33. The relationship between scale radius and fork length of age 1.0 chinook salmon.

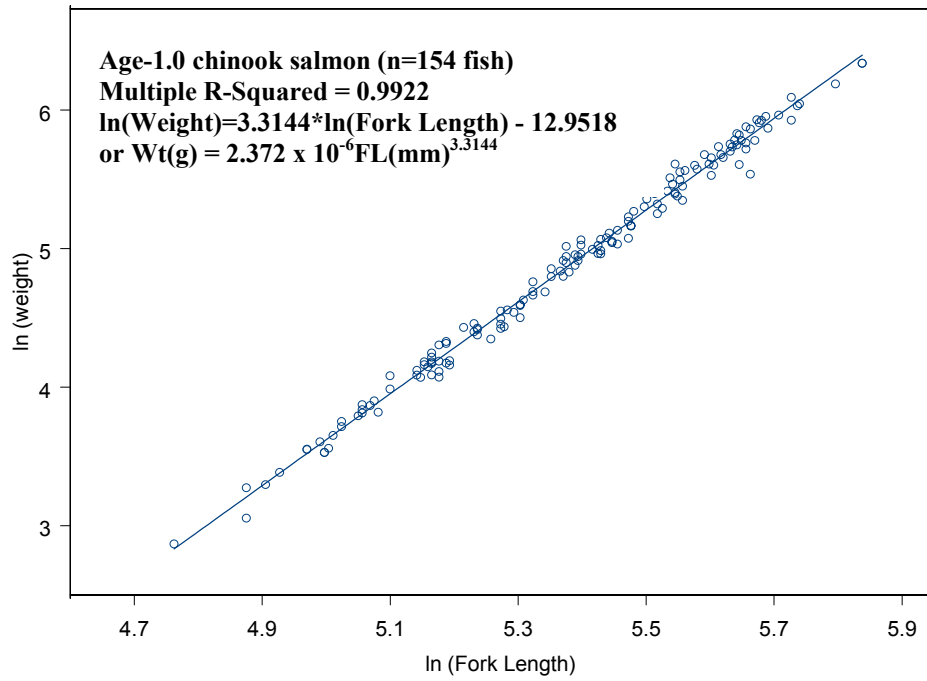


Fig. 34. The relationship between ln (fork length) and ln (weight) in age-1.0 chinook salmon caught in coastal marine waters of southeast Alaska in 1998-2000.

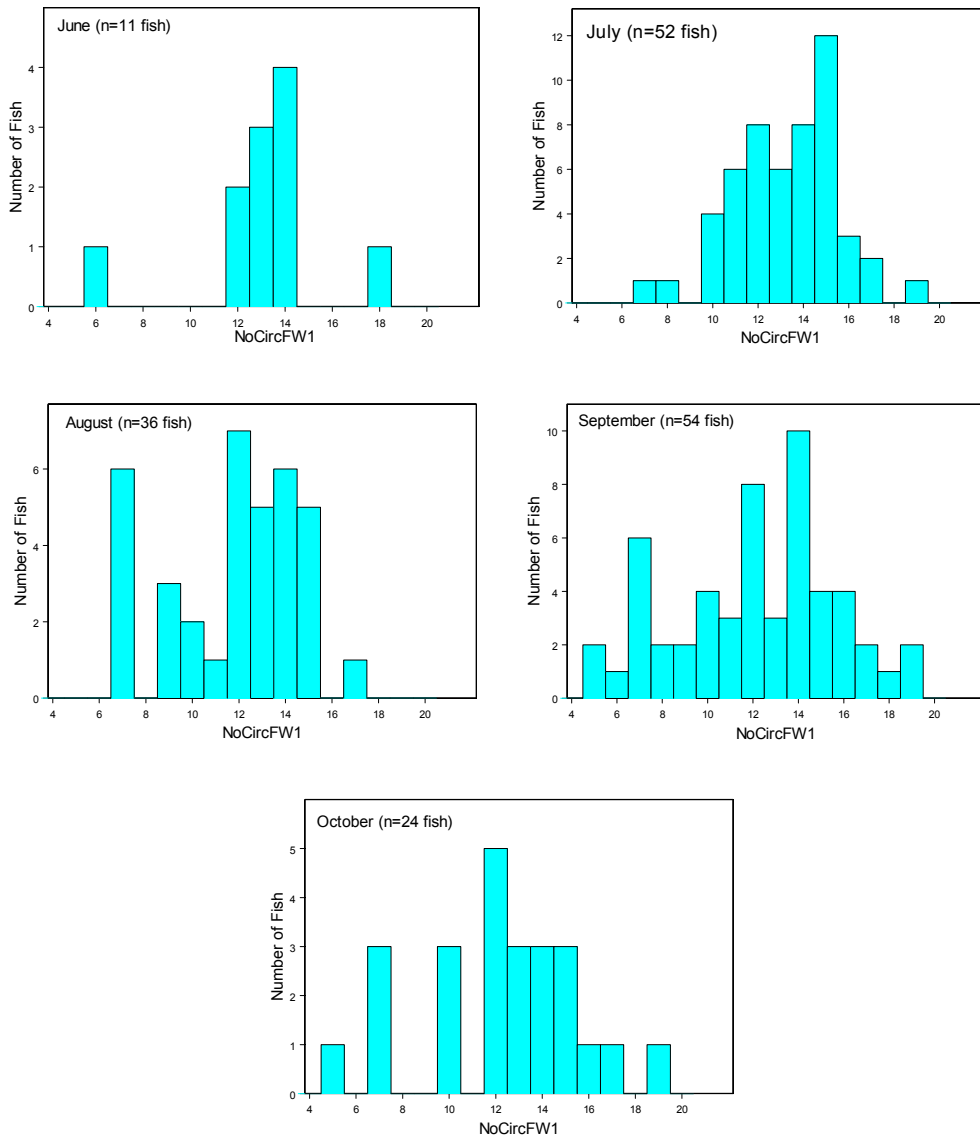


Fig. 35. Distribution of circuli counts in the freshwater zone of age-1.0 chinook salmon by month of capture in coastal marine waters of southeast Alaska in 1998-2000.

Table 1. Snout samples from salmonids without adipose fins collected from international cooperative salmon research cruises, 2003. Gear: A=commercial-mesh gillnet; C=research-mesh gillnet; followed by mesh size (mm); T=surface trawl.

Date	Research Vessel	Location		Gear	Species	Fork	Body	Sex	Gonad	Sample
		Latitude	Longitude			Length (mm)	Weight (g)		Weight (g)	Number
06/17/03	<i>Wakatake maru</i>	43°00'N	180°00'	C121	steelhead	565	1900	F	5	18-11
06/18/03	<i>Wakatake maru</i>	44°00'N	180°00'	A115	steelhead	734	4200	F	23	30-8
06/20/03	<i>Wakatake maru</i>	46°00'N	180°00'	C138	steelhead	712	3850	F	30	48-7
08/03/03	<i>Kaiyo maru</i>	52°51'N	160°10'W	T	chinook	529	2040	F	7	124-03
08/06/03	<i>Kaiyo maru</i>	54°00'N	155°13'W	T	chinook	547	2501	M	3	140-08
08/11/03	<i>Kaiyo maru</i>	53°50'N	149°59'W	T	chinook	528	2153	M	1	156-29

Table 2. Mean catch (number of salmonids) per unit (30-tans, 1500 m) of effort by C-gear (research-mesh gillnet) caught by *Wakatake maru* cruises, 1991-2003. Research-mesh gillnet is composed of 3 tans each of the following mesh sizes: 48, 55, 63, 72, 82, 93, 106, 121, 138, and 157 mm.

Year	Sampling Dates	No. of Sta.	Locations	Mean Temperature		Mean Salinity		Mean Catch per 30 tans C-gear									Total
				0 m	100 m	0 m	100 m	Sock-eye	Chum	Pink	Coho	Chi-nook	Steel-head	Dolly Varden	Masu		
Central North Pacific - Transition Domain																	
2003	14-19 Jun	6	41°N-46°N, 180°	8.8	6.7	33.4	33.6	2.0	21.2	8.3	11.3	0.0	1.0	0.0	0.0	0.0	43.8
2002	16-19 Jun	4	42°N-45°N, 180°	9.4	7.6	33.4	33.5	0.0	5.5	0.5	6.3	0.0	0.3	0.0	0.0	0.0	12.5
2001	16-18 Jun	4	42°N-45°N, 180°	8.9	6.0	33.4	33.5	0.0	14.5	1.3	32.0	0.5	2.3	0.0	0.0	0.0	50.5
2000	14-19 Jun	6	41°N-46°N, 180°	8.3	6.6	33.2	33.4	0.7	11.0	5.2	5.7	0.0	0.8	0.0	0.0	0.0	23.3
1999	16-22 Jun	6	40°N-45°N, 180°	9.1	7.4	33.3	33.4	0.0	2.5	1.0	9.0	0.0	1.0	0.0	0.0	0.0	13.5
1998	20-25 Jun	5	41°N-45°N, 180°	9.4	6.8	33.3	33.5	0.0	6.8	1.0	22.2	0.0	1.4	0.0	0.0	0.0	31.4
1997	21-25 Jun	5	41°N-45°N, 180°	10.0	7.7	33.5	33.6	0.2	11.6	1.4	21.0	0.2	2.4	0.0	0.0	0.0	36.8
1996	18-20 Jun	3	41°N-43°N, 180°	11.8	8.0	33.6	33.7	0.0	5.0	0.0	1.3	0.0	0.7	0.0	0.0	0.0	7.0
1995	22-24 Jun	3	42°N-44°N, 180°	10.6	8.4	33.7	33.9	0.0	3.7	2.0	9.0	0.0	0.3	0.0	0.0	0.0	15.0
1994	21-24 Jun	4	41°N-44°N, 180°	10.5	8.6	33.9	33.9	0.0	9.0	1.3	11.0	0.0	2.5	0.0	0.0	0.0	23.8
1993	23-25 Jun	2	43°N-44°N, 180°	9.2	7.7	33.7	33.9	0.0	27.5	0.0	8.5	0.0	1.0	0.0	0.0	0.0	37.0
1992	21-22 Jun	2	42°N-43°N, 180°	9.4	9.1	33.7	34.0	0.0	15.0	0.0	5.5	0.0	0.5	0.0	0.0	0.0	21.0
1991	15-19 Jun	5	41°N-45°N, 180°	10.4	8.3	33.5	33.8	0.0	10.6	0.4	29.2	0.0	3.2	0.0	0.0	0.0	43.4
Central North Pacific - Subarctic Current																	
2003	20-21 Jun	2	47°N, 180°	6.3	3.9	33.0	33.1	11.0	12.5	99.0	1.5	1.0	0.0	0.0	0.0	0.0	124.5
2002	20-23 Jun	3	46°N-47°N, 180°	7.0	3.7	32.9	33.1	4.3	58.7	1.0	7.7	0.7	2.7	0.0	0.0	0.0	75.0
2001	20-23 Jun	3	46°N-47°N, 180°	6.6	3.2	33.0	33.2	5.3	49.3	42.0	1.3	0.0	0.3	0.0	0.0	0.0	98.3
2000	20-22 Jun	2	47°N, 180°	6.2	3.5	32.9	33.0	6.0	53.5	8.0	1.5	0.5	4.5	0.0	0.0	0.0	74.0
1999	24-26 Jun	3	46°N-47°N, 180°	5.8	3.7	32.7	33.0	36.0	52.0	51.0	2.3	2.0	4.0	0.0	0.0	0.0	147.3
1998	26-28 Jun	3	46°N-47°N, 180°	6.8	4.1	33.0	33.1	6.0	13.3	1.0	27.3	2.3	6.7	0.0	0.3	0.0	57.0
1997	26-28 Jun	3	46°N-47°N, 180°	8.8	4.8	32.8	33.0	0.7	35.3	24.7	8.3	2.0	1.7	0.0	0.0	0.0	72.7
1996	21-26 Jun	4	44°N-47°N, 180°	9.2	5.1	33.1	33.2	0.0	53.0	1.3	19.0	0.8	1.0	0.0	0.0	0.0	75.0
1995	25-27 Jun	3	45°N-47°N, 180°	7.8	4.7	33.0	33.2	0.7	33.0	6.7	25.7	0.7	7.7	0.0	0.0	0.0	74.3
1994	25-27 Jun	3	45°N-47°N, 180°	6.5	3.9	32.9	33.0	1.3	15.3	22.0	25.0	1.0	9.0	0.0	0.0	0.0	73.7
1993	26-28 Jun	3	45°N-47°N, 180°	7.3	3.6	33.0	33.2	0.0	58.3	2.7	16.3	0.3	5.0	0.0	0.0	0.0	82.7
1992	23-25 Jun	3	44°N-46°N, 180°	7.6	4.8	33.2	33.3	0.0	12.7	0.3	19.3	0.3	1.0	0.0	0.0	0.0	33.7
1991	20-21 Jun	3	46°N-47°N, 180°	7.4	4.5	33.0	33.1	1.0	30.5	10.5	24.0	1.0	1.5	0.0	0.0	0.0	68.5
Central North Pacific - Ridge Domain																	
1992	26-Jun	1	47°N, 180°	6.7	3.1	33.0	33.1	0.0	40.0	1.0	34.0	0.0	2.0	0.0	0.0	0.0	77.0
Central North Pacific - All Areas Combined																	
2003	14-21 Jun	8	41°N-47°N, 180°	8.2	6.0	33.3	33.5	4.3	19.0	31.0	8.9	0.0	1.0	0.0	0.0	0.0	64.0
2002	15-23 Jun	8	41°N-47°N, 180°	8.5	5.4	33.3	33.5	1.9	28.3	0.7	6.9	0.3	1.3	0.0	0.0	0.0	39.3
2001	14-23 Jun	10	39°N-47°N, 180°	9.8	6.5	33.5	33.6	2.0	25.8	16.4	16.5	0.3	1.3	0.0	0.0	0.0	62.1
2000	12-22 Jun	10	39°N-47°N, 180°	9.0	6.8	33.3	33.5	1.6	17.3	4.7	3.7	0.1	1.4	0.0	0.0	0.0	28.8
1999	16-26 Jun	10	39°N-47°N, 180°	8.6	6.6	33.2	33.3	10.8	17.1	15.9	6.1	0.6	1.8	0.0	0.0	0.0	52.3
1998	17-28 Jun	10	39°N-47°N, 180°	9.7	6.9	33.4	33.5	1.8	7.4	0.8	19.3	0.7	2.7	0.0	0.1	0.0	32.8
1997	19-28 Jun	10	39°N-47°N, 180°	10.3	7.5	33.4	33.6	0.3	16.8	8.1	13.1	0.7	1.7	0.0	0.0	0.0	40.7
1996	15-27 Jun	10	38°N-47°N, 180°	11.5	7.8	33.6	33.7	0.0	22.7	0.5	8.0	0.3	0.6	0.0	0.0	0.0	32.1
1995	18-27 Jun	10	38°N-47°N, 180°	10.7	8.2	33.6	33.8	0.2	11.1	2.6	11.2	0.2	2.4	0.0	0.0	0.0	26.9
1994	18-27 Jun	10	38°N-47°N, 180°	10.4	8.1	33.7	33.7	0.4	8.2	7.1	11.9	0.3	3.7	0.0	0.0	0.0	31.6
1993	17-28 Jun	10	38°N-47°N, 180°	10.4	7.9	33.7	33.9	0.0	29.7	0.8	6.6	0.1	1.7	0.0	0.0	0.0	25.4
1992	17-25 Jun	10	38°N-47°N, 180°	9.9	7.7	33.7	33.8	0.0	10.8	0.2	10.3	0.1	0.6	0.0	0.0	0.0	22.0
1991	12-21 Jun	10	38°N-47°N, 180°	11.0	8.4	33.6	33.8	0.2	11.4	2.3	19.6	0.2	1.9	0.0	0.0	0.0	35.6
Central Bering Sea																	
2003	29 Jun-12 July	14	55°N-58°N, 178°W-176°E	7.8	2.6	32.9	33.2	22.4	67.6	227.6	0.4	4.6	0.0	0.0	0.0	0.0	322.5
2002	1-14 Jul	13	55°N-58°N, 178°W-176°E	7.0	2.2	33.1	33.2	28.5	189.5	2.2	0.2	6.9	0.0	0.0	0.0	0.0	227.2
2001	1-13 Jul	13	55°N-58°N, 178°W-176°E	5.4	1.7	33.1	33.2	60.8	136.5	164.9	0.1	2.5	0.0	0.0	0.0	0.0	364.8
2000	30 Jun-12 Jul	11	55°N-58°N, 178°W-178°E	7.9	1.8	33.0	33.2	36.1	141.5	2.2	0.0	10.2	0.0	0.0	0.0	0.0	189.9
1999	4-14 Jul	11	55°N-58°N, 178°W-178°E	6.5	1.9	32.9	33.0	25.5	64.1	357.3	0.0	4.1	0.0	0.0	0.0	0.0	450.9
1998	6-16 Jul	11	55°N-58°N, 177°W-177°E	7.0	2.5	32.3	33.0	37.7	209.6	5.6	0.4	22.7	0.0	5.0	0.0	0.0	281.1
1997	6-17 Jul	10	55°N-58°N, 177°W-177°E	8.4	3.0	32.8	32.9	57.0	143.9	379.7	0.3	3.5	0.0	0.1	0.0	0.0	584.5
1996	4-14 Jul	9	55°N-58°N, 177°W-179°E	7.5	2.9	32.8	33.0	55.1	200.7	4.8	0.1	6.8	0.0	0.2	0.0	0.0	267.7
1995	5-15 Jul	11	55°N-58°N, 177°W-177°E	7.5	2.0	32.9	33.1	37.8	63.8	174.5	0.5	6.5	0.0	0.2	0.0	0.0	283.3
1994	5-15 Jul	11	55°N-58°N, 177°W-177°E	6.7	1.8	32.9	33.2	50.3	224.0	13.1	0.0	5.2	0.0	0.2	0.0	0.0	292.7
1993	6-16 Jul	11	55°N-58°N, 177°W-177°E	7.2	2.1	33.1	33.2	58.2	111.6	141.2	0.8	1.4	0.0	0.0	0.0	0.0	313.2
1992	4-14 Jul	11	55°N-58°N, 177°W-177°E	6.4	2.5	33.0	33.3	22.8	257.5	9.0	0.3	5.4	0.0	0.5	0.0	0.0	295.5
1991	1-8 Jul	8	55°N-58°N, 180°W-177°W	7.6	2.2	33.0	33.2	22.9	53.9	365.5	0.0	9.9	0.0	0.0	0.0	0.0	452.1

Table 3. Number sampled, mean, and standard deviation of fork length (FL, mm), body weight (BW, g), and condition factor (CF=10⁶*BW/FL³) of sockeye salmon caught by the *Wakatake maru* research gillnet, 1991-2003, grouped by ocean age.

Sockeye

Year	Ocean Age .1								Ocean Age .2								Ocean Age .3								Ocean Age .4								
	% FL (mm)		B W (g)		CF		N		% FL (mm)		B W (g)		CF		N		% FL (mm)		B W (g)		CF		N		% FL (mm)		B W (g)		CF				
	Age	mean	sd	mean	sd	mean	sd	Age	mean	sd	mean	sd	mean	sd	Age	mean	sd	mean	sd	mean	sd	Age	mean	sd	mean	sd	Age	mean	sd	mean	sd		
Central North Pacific																																	
2003	27	90	323	21	377	72	11.2	1.2	3	10	443	52	1037	418	11.5	1.6	0																0
2002	6	50	364	32	493	83	10.3	1.4	6	50	469	22	1103	253	10.5	1.2	0																0
2001	5	28	322	8	326	30	9.8	0.9	11	61	458	36	1097	482	11.0	1.2	2	11	544	14	1925	205	12	0								0	
2000	6	50	310	11	308	16	10.4	0.9	6	50	419	24	817	118	11.0	0.4	0																0
1999	54	54	325	21	384	73	11.1	1.2	46	46	436	22	921	127	11.0	0.7	0																0
1998	10	59	336	23	361	80	9.4	0.7	6	35	435	22	907	55	11.1	1.2	1	6	610		3000		13.2										0
1997	0								5	100	461	41	1116	304	11.3	1.7	0																0
1996	0								0								0																0
1995	0								0								2	##	606	8	2950	354	13.2	1.0									0
1994	2	50	365	49	464	91	9.7	2.0	1	25	452		980		10.6		1	25	615		3200		13.8									0	
1993	0								0								0																0
1992	0								0								0																0
1991	2	100	315	5	295	7	9.5	0.2	0								0																0
Central Bering Sea																																	
2003	186	61	345	32	465	126	11.1	0.8	65	21	480	41	1329	463	11.6	1.1	50	17	602	39	3039	767	14	1	2	1	626	51	3250	778	13.1	0.0	
2002	125	34	324	26	366	87	10.7	1.3	200	55	476	31	1250	298	11.5	1.1	30	8	577	62	2584	1024	12.8	1.8	6	2	617	30	3258	663	13.7	1.1	
2001	622	83	308	25	314	73	10.6	1.7	44	6	463	36	1066	262	10.6	1.0	70	10	576	46	2605	744	13	2	4	1	618	30	3335	675	14.0	1.0	
2000	235	60	317	19	321	63	10.0	1.3	104	27	460	38	1099	311	11.0	1.1	53	13	603	42	3198	837	14	2	0								0
1999	121	46	300	24	254	70	9.2	1.5	104	39	477	36	1290	355	11.6	1.5	40	15	583	41	2691	661	13.3	1.7	0								0
1998	221	56	331	36	403	219	10.9	5.1	141	36	471	43	1275	471	11.8	1.8	33	8	574	44	2715	768	14.0	2.0	0								0
1997	215	41	341	25	422	97	10.5	0.9	273	53	461	28	1112	217	11.2	1.1	30	6	574	58	2489	802	12.6	1.2	0								0
1996	270	59	340	29	382	119	9.5	1.1	139	30	472	38	1250	355	11.6	1.4	48	11	585	54	2659	865	12.9	1.9	0								0
1995	37	10	330	45	399	200	10.5	1.0	292	73	495	30	1447	354	11.8	1.0	70	17	586	58	2599	792	12.6	1.8	2	0	624	63	2925	601	12.1	1.2	
1994	133	37	340	26	404	97	10.2	1.5	209	57	474	30	1189	255	11.1	1.1	23	6	583	38	2643	651	13.1	1.3	0								0
1993	297	52	351	25	430	101	9.8	1.0	246	43	483	36	1301	329	11.3	1.1	31	5	571	44	2423	773	12.6	1.8	2	0	628	20	3275	601	13.1	1.2	
1992	92	39	337	31	392	105	10.1	1.3	126	54	483	31	1364	324	12.0	1.5	16	7	584	46	2929	803	14.5	3.1	1	0	650		4500		16.4		0
1991	101	59	313	21	332	70	10.7	1.1	38	22	480	39	1335	477	11.7	1.3	30	18	595	44	2851	781	13.2	1.7	2	1	653	33	4225	460	15.2	0.6	

Table 4. Percent ocean and freshwater age composition and maturity at age of sockeye salmon caught in the central North Pacific by the *Wakatake maru* research gillnet, 1991-2003. Values indicate the percentage of fish in each age and maturity class, grouped by year. Imm=immature, Mat=mature, Tot=Total.

Sockeye, Central North Pacific																			
Ocean Age 1																			
Year N	FW Age 0			FW Age 1			FW Age 2			FW Age 3			FW X			All FW Ages			
	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	
03	27	0	0	0	43	0	43	47	0	47	0	0	0	0	0	0	90	0	90
02	6	0	0	0	8	0	8	42	0	42	0	0	0	0	0	0	50	0	50
01	5	0	0	0	11	0	11	17	0	17	0	0	0	0	0	0	28	0	28
00	6	0	0	0	17	0	17	33	0	33	0	0	0	0	0	0	50	0	50
99	54	2	0	2	25	0	25	22	0	22	0	0	0	5	0	5	54	0	54
98	10	6	0	6	6	0	6	41	0	41	6	0	6	0	0	0	59	0	59
97	0																		
96	0																		
95	0																		
94	2	0	0	0	0	0	0	50	0	50	0	0	0	0	0	0	50	0	50
93	0																		
92	0																		
91	2	0	0	0	0	0	0	100	0	100	0	0	0	0	0	0	100	0	100
Ocean Age 2																			
Year N	FW Age 0			FW Age 1			FW Age 2			FW Age 3			FW X			All FW Ages			
	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	
03	3	0	0	0	3	0	3	7	0	7	0	0	0	0	0	0	10	0	10
02	6	0	0	0	42	0	42	8	0	8	0	0	0	0	0	0	50	0	50
01	11	0	0	0	11	6	17	44	0	44	0	0	0	0	0	0	56	6	61
00	6	17	0	17	8	0	8	25	0	25	0	0	0	0	0	0	50	0	50
99	46	3	0	3	30	2	32	5	0	5	0	0	0	5	1	6	43	3	46
98	6	0	0	0	18	0	18	12	0	12	0	0	0	6	0	6	35	0	35
97	5	0	0	0	100	0	100	0	0	0	0	0	0	0	0	0	100	0	100
96	0																		
95	0																		
94	1	0	0	0	0	0	0	25	0	25	0	0	0	0	0	0	25	0	25
93	0																		
92	0																		
91	0																		
Ocean Age 3																			
Year N	FW Age 0			FW Age 1			FW Age 2			FW Age 3			FW X			All FW Ages			
	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	
03	0																		
02	0																		
01	2	0	0	0	6	0	6	0	6	6	0	0	0	0	0	0	6	6	11
00	0																		
99	0																		
98	1	0	0	0	0	6	6	0	0	0	0	0	0	0	0	0	0	6	6
97	0																		
96	2	0	0	0	0	100	100	0	0	0	0	0	0	0	0	0	0	100	100
95	0																		
94	1	0	0	0	0	25	25	0	0	0	0	0	0	0	0	0	25	0	25
93	0																		
92	0																		
91	0																		

Table 5. Percent ocean and freshwater age composition and maturity at age of sockeye salmon caught in the central Bering Sea by the *Wakatake maru* research gillnet, 1991-2003. Values indicate the percentage of fish in each age and maturity class, grouped by year. Imm=immature, Mat=mature, Tot=Total.

Sockeye, Central Bering Sea																			
Ocean Age 1																			
Year	N	FW Age 0			FW Age 1			FW Age 2			FW Age 3			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	186	1	0	1	23	0	23	31	1	32	2	0	2	3	0	3	60	1	61
02	125	1	0	1	18	0	18	14	0	14	0	0	0	1	0	1	34	0	34
01	622	2	0	2	40	0	40	38	0	38	1	0	1	3	0	3	84	0	84
00	235	1	0	1	13	0	13	43	0	43	1	0	1	2	0	2	60	0	60
99	121	0	0	0	23	0	23	15	0	15	0	0	0	6	0	6	45	0	46
98	177	2	0	2	20	0	20	26	0	26	1	0	1	3	0	3	51	0	51
97	215	0	0	0	23	0	23	16	0	16	0	0	0	2	0	2	42	0	42
96	266	1	0	1	30	0	30	25	0	25	0	0	0	3	0	3	60	0	60
95	37	1	0	1	5	0	5	1	0	1	0	0	0	1	0	1	9	0	9
94	133	0	0	0	12	0	12	22	0	22	0	0	0	2	0	2	36	0	36
93	297	0	0	0	9	0	9	38	1	39	1	0	1	3	0	3	51	1	52
92	92	1	0	1	22	0	22	13	0	13	0	0	0	3	0	3	39	0	39
91	80	0	0	0	44	0	44	13	0	13	0	0	0	2	0	2	59	0	59

Ocean Age 2																			
Year	N	FW Age 0			FW Age 1			FW Age 2			FW Age 3			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	65	1	0	1	10	1	11	7	2	9	0	0	0	0	0	0	18	3	21
02	200	1	0	1	22	1	23	27	2	29	0	0	0	1	0	1	51	3	54
01	44	0	0	0	2	0	2	4	0	4	0	0	0	0	0	0	6	0	6
00	104	0	0	0	12	0	12	13	1	14	0	0	0	1	0	1	26	1	27
99	104	0	0	0	25	4	28	9	0	9	0	0	0	1	1	2	35	5	39
98	136	1	0	1	16	1	17	15	2	17	1	1	1	2	1	3	35	5	39
97	273	0	0	0	27	3	31	16	2	18	1	0	1	3	1	4	47	6	53
96	133	0	0	0	15	1	17	11	0	12	0	0	0	1	0	1	28	2	30
95	292	0	0	0	26	5	32	26	7	33	1	0	1	5	1	6	59	14	73
94	209	0	0	0	23	2	25	27	2	29	1	0	1	2	0	3	54	4	57
93	246	0	0	0	19	2	21	16	2	17	0	0	0	4	0	4	39	3	43
92	125	0	0	1	19	3	22	23	4	27	1	0	1	2	1	3	46	8	53
91	31	0	0	0	7	1	9	10	1	12	1	0	1	1	1	1	19	4	23

Ocean Age 3																			
Year	N	FW Age 0			FW Age 1			FW Age 2			FW Age 3			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	50	0	1	1	2	4	6	0	10	10	0	0	0	0	0	0	2	15	17
02	30	0	0	0	2	1	3	2	3	5	0	0	0	0	0	0	4	4	8
01	70	0	0	0	1	3	4	2	3	5	0	0	0	0	0	0	3	7	10
00	53	0	0	0	1	7	7	1	5	6	0	0	0	0	1	1	2	12	14
99	40	0	0	1	3	5	8	1	4	5	0	0	0	0	1	1	5	11	15
98	33	0	0	0	1	3	4	1	3	4	0	0	0	1	1	1	1	7	10
97	30	0	0	0	1	2	3	0	2	2	0	0	0	0	1	1	2	4	6
96	45	0	0	1	2	3	5	1	2	3	0	0	0	0	1	1	4	7	10
95	70	0	0	0	3	5	9	1	6	7	0	0	0	1	0	1	6	12	17
94	23	0	0	0	1	3	5	0	1	1	0	0	0	0	0	0	2	5	6
93	31	0	0	0	1	2	3	1	1	1	0	0	0	0	0	0	2	3	5
92	16	0	0	0	0	3	3	0	3	3	0	0	0	0	0	0	0	6	7
91	23	0	0	0	4	5	10	1	4	5	1	1	1	1	0	1	7	10	17

Ocean Age 4																			
Year	N	FW Age 0			FW Age 1			FW Age 2			FW Age 3			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
02	6	0	0	0	0	1	1	0	2	2	0	0	0	0	0	0	0	3	3
01	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
00	0																		
99	0																		
98	0																		
97	0																		
96	0																		
95	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
94	0																		
93	0																		
92	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1

Table 7. Percent ocean age composition and maturity at age of chum salmon caught by the *Wakatake maru* research gillnet, 1991-2003. Values indicate the percentage of fish in each age and maturity class, grouped by year. Imm=immature, Mat=mature, Tot=Total.

Chum																					
Year	N	Ocean age .1			Ocean age .2			Ocean age .3			Ocean age .4			Ocean age .5			Ocean age .6			Total	
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat
Central North Pacific - Transition Domain																					
2003	121	42	0	42	42	2	44	3	11	14	0	0	0	0	0	0	0	0	0	87	13
2002	19	27	0	27	63	5	68	5	0	5	0	0	0	0	0	0	0	0	0	95	5
2001	52	6	0	6	65	0	65	21	6	27	2	0	2	0	0	0	0	0	0	94	6
2000	57	19	0	19	33	5	39	28	12	40	2	0	2	0	0	0	0	0	0	83	17
1999	8	38	0	38	50	0	50	12	0	12	0	0	0	0	0	0	0	0	0	100	0
1998	27	89	0	89	11	0	11	0	0	0	0	0	0	0	0	0	0	0	0	100	0
1997	53	13	0	13	62	17	79	6	2	8	0	0	0	0	0	0	0	0	0	81	19
1996	13	8	0	8	77	0	77	15	0	15	0	0	0	0	0	0	0	0	0	100	0
1995	12	0	0	0	33	25	58	25	17	42	0	0	0	0	0	0	0	0	0	58	42
1994	33	15	0	15	61	6	67	12	6	18	0	0	0	0	0	0	0	0	0	88	12
1993	47	9	0	9	79	0	79	8	4	12	0	0	0	0	0	0	0	0	0	96	4
1992	29	3	0	3	76	7	83	7	3	10	0	3	3	0	0	0	0	0	0	86	14
1991	48	19	0	19	65	6	71	2	8	10	0	0	0	0	0	0	0	0	0	85	15
Central North Pacific - Subarctic Current																					
2003	26	11	0	11	15	15	30	12	39	51	4	4	8	0	0	0	0	0	0	42	58
2002	161	67	1	68	24	2	26	2	3	5	0	1	1	0	0	0	0	0	0	93	7
2001	153	19	0	19	34	3	37	32	9	41	3	1	3	0	0	0	0	0	0	88	12
2000	105	19	0	19	40	2	42	32	3	35	3	1	4	0	0	0	0	0	0	94	6
1999	142	45	0	45	50	0	50	1	4	5	0	0	0	0	0	0	0	0	0	97	3
1998	38	61	0	61	24	8	32	5	0	5	0	3	3	0	0	0	0	0	0	90	10
1997	89	56	1	57	37	2	39	1	2	3	0	0	0	0	0	0	0	0	0	94	6
1996	192	56	1	57	35	2	37	5	1	6	0	1	1	0	0	0	0	0	0	96	4
1995	91	4	0	4	19	2	21	46	18	64	6	6	11	0	0	0	0	0	0	75	25
1994	43	23	0	23	49	2	51	14	9	23	2	0	2	0	0	0	0	0	0	88	12
1993	151	37	0	37	50	5	55	3	4	7	1	0	1	0	0	0	0	0	0	91	9
1992	35	31	0	31	54	6	60	3	6	9	0	0	0	0	0	0	0	0	0	89	11
1991	57	4	0	4	79	4	83	9	5	14	0	0	0	0	0	0	0	0	0	91	9
Central North Pacific - Ridge Domain																					
1992	38	47	0	47	21	11	32	8	8	16	3	3	5	0	0	0	0	0	0	79	21
Central North Pacific - All Areas																					
2003	147	37	0	37	37	5	42	4	15	19	1	1	2	0	0	0	0	0	0	79	21
2002	180	62	0	62	28	4	32	2	3	5	0	1	1	0	0	0	0	0	0	92	8
2001	205	16	0	16	42	2	44	29	8	37	2	1	3	0	0	0	0	0	0	89	11
2000	162	19	0	19	38	3	41	31	6	37	3	1	3	0	0	0	0	0	0	90	10
1999	150	45	0	45	50	0	50	2	3	5	0	0	0	0	0	0	0	0	0	97	3
1998	65	72	0	72	19	5	23	3	0	3	0	2	2	0	0	0	0	0	0	94	6
1997	142	40	1	41	47	8	54	3	2	5	0	0	0	0	0	0	0	0	0	89	11
1996	205	53	1	54	38	2	39	5	1	6	0	1	1	0	0	0	0	0	0	96	4
1995	104	4	0	4	20	5	25	44	17	62	5	5	10	0	0	0	0	0	0	73	27
1994	76	20	0	20	54	4	58	13	8	21	1	0	1	0	0	0	0	0	0	88	12
1993	253	24	0	24	64	3	67	6	3	9	0	0	0	0	0	0	0	0	0	94	6
1992	102	29	0	29	48	8	56	6	6	12	1	2	3	0	0	0	0	0	0	84	16
1991	105	11	0	11	72	5	77	6	7	12	0	0	0	0	0	0	0	0	0	89	11
Central Bering Sea																					
2003	912	22	0	22	30	2	32	12	24	36	0	9	9	0	1	1	0	0	0	64	36
2002	2225	12	0	12	37	3	40	17	16	33	3	11	14	0	1	1	0	0	0	69	31
2001	1661	34	0	34	15	2	17	10	21	31	4	13	17	0	1	1	0	0	0	63	37
2000	1551	7	0	7	20	3	23	32	16	48	6	15	21	0	1	1	0	0	0	65	35
1999	624	0	0	0	26	2	28	29	22	50	2	19	21	0	1	1	0	0	0	56	44
1998	2004	12	0	12	37	3	39	18	21	39	2	7	9	0	0	1	0	0	0	69	31
1997	1281	58	0	59	23	3	25	4	9	13	1	2	3	0	0	0	0	0	0	85	15
1996	1606	45	0	45	30	1	31	11	7	18	2	3	5	0	1	1	0	0	0	89	11
1995	642	23	2	24	13	4	17	22	18	40	3	15	18	0	1	1	0	0	0	61	39
1994	1869	17	0	18	29	2	31	30	15	44	2	5	7	0	0	0	0	0	0	78	22
1993	1064	7	0	7	45	6	51	13	20	33	1	7	8	0	1	1	0	0	0	66	34
1992	2570	36	0	36	31	3	33	13	11	25	1	5	6	0	0	0	0	0	0	80	20
1991	370	0	0	0	23	6	29	10	36	46	1	20	21	0	5	5	0	0	0	34	66

Table 8. Number sampled, mean, and standard deviation of fork length (FL, mm), body weight (BW, g), and condition factor ($CF=10^6 \cdot BW/FL^3$) of pink salmon caught by the *Wakatake maru* research gillnet, 1991-2003, grouped by ocean age.

Pink		Ocean Age .1						
Year	N	Age	% Fork length (mm)		Body weight (g)		Condition Factor	
			mean	sd	mean	sd	mean	sd
Central North Pacific - Transition Domain								
2003	48	100	448	23	1133	240	12.4	1.3
2002	2	100	409	9	745	106	10.9	0.8
2001	4	100	452	37	1060	337	11.2	1.2
2000	26	100	461	31	1124	279	11.3	0.6
1999	4	100	434	29	940	104	11.5	1.0
1998	4	100	450	20	1055	168	11.5	1.1
1997	6	100	433	25	1045	279	12.9	3.9
1996	0							
1995	6	100	467	33	1186	328	11.4	1.2
1994	7	100	469	38	1063	265	10.1	0.3
1993	0							
1992	0							
1991	1	100	416		720		10.0	
Central North Pacific - Subarctic Current								
2003	173	100	446	25	1094	233	12.2	1.3
2002	3	100	450	50	1103	474	11.6	1.6
2001	127	100	433	20	986	137	12.1	0.8
2000	17	100	444	36	1029	280	11.5	1.3
1999	148	100	410	23	776	131	11.2	1.7
1998	3	100	476	10	1193	83	11.1	0.6
1997	79	100	433	23	928	135	11.4	1.4
1996	5	100	436	45	844	349	9.6	1.4
1995	18	100	459	26	1070	360	10.8	1.7
1994	66	100	455	28	1023	210	10.8	1.0
1993	8	100	429	21	738	134	9.3	1.0
1992	2	100	458	0	920	57	9.6	0.6
1991	21	100	423	35	787	252	10.1	1.1
Central North Pacific - Ridge Domain								
1992	1	100	450		910		10.0	
Central North Pacific - All Areas Combined								
2003	221	100	446	24	1103	234	12.3	1.3
2002	5	100	434	42	960	392	11.3	1.2
2001	131	100	434	21	988	145	12.0	0.8
2000	43	100	454	34	1087	280	11.4	1.0
1999	152	100	411	23	780	132	11.2	1.6
1998	7	100	461	21	1114	148	11.3	0.9
1997	85	100	433	23	936	150	11.5	1.7
1996	5	100	436	45	844	349	9.6	1.4
1995	24	100	461	27	1099	349	11.0	1.6
1994	73	100	456	29	1027	214	10.7	1.0
1993	8	100	429	21	738	134	9.3	1.0
1992	3	100	455	5	917	40	9.7	0.5
1991	22	100	422	34	784	247	10.1	1.0
Central Bering Sea								
2003	2403	100	484	31	1484	313	13.0	1.4
2002	26	100	450	37	1086	329	11.6	1.1
2001	1882	100	461	26	1220	247	12.3	1.1
2000	27	100	455	35	1165	290	12.1	0.7
1999	2485	100	441	31	1100	260	12.7	1.3
1998	60	100	414	40	859	342	11.7	2.1
1997	1537	100	446	27	1117	244	12.5	2.0
1996	43	100	455	35	1117	275	11.7	1.4
1995	1749	100	470	29	1298	266	12.4	1.2
1994	143	100	444	30	1055	262	11.9	1.1
1993	1434	100	449	27	1106	240	12.1	1.1
1992	100	100	451	27	1153	255	12.4	1.1
1991	2621	100	447	37	1108	362	12.0	1.2

Table 9. Number sampled, mean, and standard deviation of fork length (FL, mm), body weight (BW, g), and condition factor ($CF=10^6 \cdot BW/FL^3$) of coho salmon caught by the *Wakatake maru* research gillnet, 1991-2003, grouped by ocean age.

Coho								
Ocean Age -1								
Year	N	% Age	Fork length (mm)		Body Weight (g)		Condition Factor	
			mean	sd	mean	sd	mean	sd
Central North Pacific - Transition Domain								
2003	68	100	547	38	2272	472	13.8	1.2
2002	24	100	537	39	2039	251	13.4	2.9
2001	125	100	556	34	2277	420	13.1	1.3
2000	33	100	540	58	1996	370	12.8	1.9
1999	53	100	515	32	1613	307	11.7	0.9
1998	110	100	519	34	1763	345	12.5	1.5
1997	99	100	510	37	1754	408	13.1	2.0
1996	4	100	542	20	1925	155	12.1	0.8
1995	26	100	525	40	1786	328	12.4	2.3
1994	43	100	516	39	1563	414	11.2	1.3
1993	18	100	506	58	1562	472	11.8	1.2
1992	11	100	512	55	1678	486	12.2	1.2
1991	148	100	520	40	1631	393	11.4	0.9
Central North Pacific - Subarctic Current								
2003	3	100	555	66	2420	842	13.8	0.2
2002	22	100	560	30	2249	363	12.7	0.7
2001	4	100	553	65	2380	815	13.6	0.6
2000	3	100	507	43	1780	370	13.6	0.6
1999	7	100	505	57	2006	311	16.2	0.5
1998	80	100	543	43	2122	494	13.1	1.4
1997	32	100	498	49	1468	398	11.8	2.1
1996	75	100	516	39	1653	399	11.8	1.0
1995	73	100	532	46	1836	512	11.9	1.0
1994	78	100	527	39	1829	415	12.3	1.3
1993	49	100	521	48	1755	512	12.1	1.5
1992	58	100	503	31	1514	340	11.7	1.2
1991	49	100	526	39	1821	419	12.4	1.0
Central North Pacific - Ridge Domain								
1992	34	100	507	39	1611	367	12.1	0.9
Central North Pacific - All Areas Combined								
2003	71	100	547	39	2278	484	13.8	1.1
2002	46	100	548	36	2139	324	13.1	2.2
2001	129	100	556	35	2281	432	13.1	1.3
2000	36	100	537	57	1978	370	12.9	1.8
1999	60	100	514	36	1659	330	12.2	2.4
1998	190	100	529	40	1914	450	12.7	1.5
1997	132	100	508	41	1698	450	12.8	2.1
1996	79	100	517	38	1666	394	11.8	1.0
1995	99	100	530	45	1823	469	12.0	1.5
1994	121	100	523	39	1735	432	11.9	1.4
1993	67	100	517	51	1703	505	12.0	1.5
1992	103	100	505	37	1563	367	11.9	1.1
1991	197	100	521	40	1678	407	11.7	1.0
Central Bering Sea								
2003	5	100	588	63	2656	629	13.0	1.2
2002	1	100	599		2650		12.3	
2001	1	100	582		2150		10.9	
2000	0							
1999	0							
1998	3	100	556	62	2430	725	13.8	0.4
1997	3	100	518	72	1740	1095	11.4	2.3
1996	1	100	630		3800		15.2	
1995	5	100	605	35	2910	667	12.9	1.0
1994	0							
1993	9	100	556	33	2166	581	12.4	2.1
1992	3	100	568	37	2450	492	13.3	0.1
1991	0							

Table 10. Number sampled, mean, and standard deviation of fork length (FL, mm), body weight (BW, g), and condition factor (CF=10⁶*BW/FL³) of chinook salmon caught by the *Wakatake maru* research gillnet, 1991-2003, grouped by ocean age.

Chinook																																	
		Ocean Age .1								Ocean Age .2								Ocean Age .3								Ocean Age .4							
		% FL (mm)		B W (g)		CF				% FL (mm)		B W (g)		CF		% FL (mm)		B W (g)		CF		% FL (mm)		B W (g)		CF							
Year	N	Age	mean	sd	mean	sd	mean	sd	N	Age	mean	sd	mean	sd	mean	sd	N	Age	mean	sd	mean	sd	mean	sd	N	Age	mean	sd					
Central North Pacific - Transition Domain																																	
2001	0								2	100	683	4	4650	212	14.6	0.9	0								0								
Central North Pacific - Subarctic Current																																	
2003	0								1	100	652		3920		14.1		0								0								
2002	0								1	50	602		2600		11.9		1	50	714		4400		12.1		0								
2001	0								0								0							0									
2000	0								1	100	600		3100		14.4		0							0									
1999	0								5	100	617	30	3220	448	13.6	0.6	0							0									
1998	0								6	86	582	39	2488	472	12.5	0.7	1	14	780		6850		14.4		0								
1997	0								6	86	641	47	3408	1026	12.6	2.2	1	14	700		4400		12.8		0								
1996	3	100	395	44	823	320	12.9	0.8	0								0						0										
1995	0								1	50	562		2200		12.4		1	50	832		7800		13.5		0								
1994	0								3	100	616	33	3150	477	13.4	0.3	0							0									
1993	0								1	100	624		3700		15.2		0							0									
1992	0								1	100	575		2300		12.1		0							0									
1991	0								2	100	572	82	2625	926	13.8	1.0	0							0									
Central North Pacific - Ridge Domain																																	
1992	0								0								0							0									
Central Bering Sea																																	
2003	29	46	372	32	649	179	12.3	0.8	32	51	547	42	2122	529	12.7	0.9	2	3	634	95	3485	1294	13.4	0.9	0								
2002	24	29	353	32	492	102	11.2	1.3	39	46	545	38	2026	427	12.4	1.1	21	25	695	65	4324	1136	12.5	0.9	0								
2001	24	73	345	28	476	136	11.4	1.3	5	15	492	99	1660	736	12.6	1.7	3	9	603	56	2260	754	10.1	1.7	1	3	780	6300	13.3				
2000	36	33	326	49	421	329	11.0	1.6	50	46	520	51	1779	524	12.3	0.9	22	20	671	48	4030	1122	13.1	2.0	1	1	728	5300	13.7				
1999	13	30	330	27	403	114	10.9	1.0	22	51	533	60	1936	694	12.5	2.2	8	19	658	64	3566	1236	12.1	0.8	0								
1998	140	60	348	41	528	311	11.7	1.2	62	27	545	57	2202	793	13.1	0.9	30	13	678	76	4346	1434	13.3	1.6	0								
1997	12	35	350	24	478	94	11.1	0.8	19	56	550	35	1954	390	11.6	0.8	3	9	714	100	4650	2079	12.2	0.9	0								
1996	24	43	407	31	826	221	12.0	1.0	25	45	567	46	2382	632	12.8	1.0	7	12	732	46	5121	1366	12.7	1.1	0								
1995	18	27	339	31	442	128	11.1	0.9	43	65	525	52	1813	522	12.3	1.7	4	6	726	61	4725	1300	12.2	0.8	1	2	812	6800	12.7				
1994	25	47	374	31	620	173	11.3	1.0	11	21	543	57	2179	740	13.1	1.5	17	32	720	41	4855	1129	12.8	1.0	0								
1993	1	8	352		480		11.0		7	59	573	25	2340	314	12.4	0.6	3	25	716	95	4710	2175	12.3	1.1	1	8	862	8600	13.4				
1992	17	36	356	27	525	116	11.4	0.9	23	49	567	47	2333	709	12.6	1.5	6	13	654	27	3822	648	13.6	0.8	1	2	850	7650	12.5				
1991	45	66	345	26	497	120	11.9	1.3	21	31	530	57	1816	634	11.8	0.8	2	3	715	18	4050	71	11.1	1.0	0								

Table 11. Percent ocean and freshwater age composition and maturity at age of chinook salmon caught in the central North Pacific Ocean by the *Wakatake maru* research gillnet, 1991-2003. Values indicate the percentage of fish in each age and maturity class, grouped by year. Imm=immature, Mat=Mature, Tot=Total.

Chinook, Central North Pacific																
		Ocean Age 1														
Year	N	FW Age 0			FW Age 1			FW Age 2			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	0															
02	0															
01	0															
00	0															
99	0															
98	0															
97	0															
96	3	0	0	0	33	0	33	0	0	0	67	0	67	100	0	100
95	0															
94	0															
93	0															
92	0															
91	0															
		Ocean Age 2														
Year	N	FW Age 0			FW Age 1			FW Age 2			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	1	0	0	0	100	0	100	0	0	0	0	0	0	100	0	100
02	1	0	0	0	0	0	0	0	0	0	50	0	50	50	0	50
01	2	0	0	0	50	0	50	0	0	0	50	0	50	100	0	100
00	1	0	0	0	100	0	100	0	0	0	0	0	0	100	0	100
99	5	0	0	0	80	0	80	0	0	0	20	0	20	100	0	100
98	6	0	0	0	57	0	57	0	0	0	29	0	29	86	0	86
97	6	0	0	0	71	0	71	0	0	0	14	0	14	86	0	86
96	0															
95	1	0	0	0	0	0	0	50	0	50	0	0	0	50	0	50
94	3	0	0	0	33	0	33	0	0	0	67	0	67	100	0	100
93	1	0	0	0	0	0	0	0	0	0	100	0	100	100	0	100
92	1	0	0	0	0	0	0	0	0	0	100	0	100	100	0	100
91	2	0	0	0	100	0	100	0	0	0	0	0	0	100	0	100
		Ocean Age 3														
Year	N	FW Age 0			FW Age 1			FW Age 2			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	0															
02	1	0	0	0	50	0	50	0	0	0	0	0	0	50	0	50
01	0															
00	0															
99	0															
98	1	0	0	0	14	0	14	0	0	0	0	0	0	14	0	14
97	1	0	0	0	14	0	14	0	0	0	0	0	0	14	0	14
96	0															
95	1	0	0	0	0	0	0	0	0	0	50	0	50	50	0	50
94	0															
93	0															
92	0															
91	0															

Table 12. Percent ocean and freshwater age composition and maturity at age of chinook salmon caught in the Bering Sea by the *Wakatake maru* research gillnet, 1991-2003. Values indicate the percentage of fish in each age and maturity class, grouped by year. Imm=immature, Mat=Mature, Tot=Total.

Chinook, Central Bering Sea																
Ocean Age 1																
Year	N	FW Age 0			FW Age 1			FW Age 2			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	3	0	0	0	0	0	0	0	0	0	8	0	8	8	0	8
02	24	0	0	0	19	0	19	1	0	1	9	0	9	29	0	29
01	24	0	0	0	55	0	55	0	0	0	18	0	18	73	0	73
00	36	0	0	0	27	0	27	0	0	0	6	0	6	33	0	33
99	13	5	0	5	17	0	17	2	0	2	7	0	7	31	0	31
98	98	0	0	0	36	1	37	0	0	0	15	0	15	51	1	52
97	12	0	0	0	27	0	27	3	0	3	6	0	6	35	0	35
96	19	0	0	0	24	2	27	0	0	0	16	0	16	40	2	42
95	18	0	0	0	21	0	21	0	0	0	6	0	6	27	0	27
94	24	0	0	0	40	0	40	0	0	0	6	0	6	46	0	46
93	1	0	0	0	0	0	0	0	0	0	8	0	8	8	0	8
92	17	0	0	0	23	0	23	0	0	0	13	0	13	36	0	36
91	27	0	0	0	49	0	49	0	0	0	29	0	29	77	0	77
Ocean Age 2																
Year	N	FW Age 0			FW Age 1			FW Age 2			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	32	0	0	0	62	0	62	3	0	3	22	0	22	87	0	87
02	39	0	0	0	39	0	39	0	0	0	7	0	7	46	0	46
01	5	0	0	0	15	0	15	0	0	0	0	0	0	15	0	15
00	50	0	0	0	38	0	38	0	0	0	8	0	8	46	0	46
99	22	0	0	0	33	0	33	0	0	0	19	0	19	52	0	52
98	62	2	0	2	22	0	22	0	0	0	10	0	10	33	0	33
97	19	0	0	0	32	0	32	3	0	3	22	0	22	56	0	56
96	19	0	0	0	31	0	31	0	0	0	11	0	11	42	0	42
95	43	0	0	0	53	0	53	0	0	0	12	0	12	65	0	65
94	11	0	0	0	15	0	15	0	0	0	6	0	6	21	0	21
93	7	0	0	0	50	0	50	0	0	0	8	0	8	58	0	58
92	23	0	0	0	36	0	36	0	0	0	13	0	13	49	0	49
91	8	0	0	0	17	0	17	0	0	0	6	0	6	23	0	23
Ocean Age 3																
Year	N	FW Age 0			FW Age 1			FW Age 2			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	2	0	0	0	5	0	5	0	0	0	0	0	0	5	0	5
02	21	0	0	0	21	0	21	0	0	0	4	0	4	25	0	25
01	3	0	0	0	9	0	9	0	0	0	0	0	0	9	0	9
00	22	0	0	0	16	0	16	0	0	0	5	0	5	20	0	20
99	7	0	0	0	14	0	14	0	0	0	2	0	2	17	0	17
98	29	0	0	0	11	0	11	0	0	0	4	0	4	15	0	15
97	3	0	0	0	3	0	3	0	0	0	6	0	6	9	0	9
96	7	0	0	0	7	2	9	2	0	2	4	0	4	13	2	16
95	4	0	0	0	5	0	5	0	0	0	2	0	2	6	0	6
94	17	0	0	0	19	2	21	0	0	0	11	0	11	31	2	33
93	3	0	0	0	17	0	17	0	0	0	8	0	8	25	0	25
92	6	0	0	0	6	0	6	0	0	0	6	0	6	13	0	13
91	0															
Ocean Age 4																
Year	N	FW Age 0			FW Age 1			FW Age 2			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	0															
02	0															
01	1	0	0	0	3	0	3	0	0	0	0	0	0	3	0	3
00	1	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
99	0															
98	0															
97	0															
96	0															
95	1	0	0	0	0	0	0	0	0	0	2	0	2	2	0	2
94	0															
93	1	0	0	0	8	0	8	0	0	0	0	0	0	8	0	8
92	1	0	0	0	2	0	2	0	0	0	0	0	0	2	0	2
91	0															

Table 13. Number sampled, mean, and standard deviation of fork length (FL, mm), body weight (BW, g), and condition factor (CF=10⁶*BW/FL³) of steelhead trout caught by the *Wakatake maru* research gillnet, 1991-2003, grouped by ocean age.

Steelhead																										
Year	Ocean Age .1								Ocean Age .2								Ocean Age .3									
	N	Age	% FL (mm)		B W (g)		CF		N	Age	% FL (mm)		B W (g)		CF		N	Age	% FL (mm)		B W (g)		CF			
			mean	sd	mean	sd	mean	sd			mean	sd	mean	sd	mean	sd			mean	sd	mean	sd	mean	sd	mean	sd
Central North Pacific - Transition Domain																										
2003	3	50	544	63	1743	571	10.5	0.1	3	50	752	35	3960	524	9.4	1.5	0									
2002	1	100	540		1620		10.3		0								0									
2001	5	39	586	17	1928	101	9.6	0.8	8	62	698	44	3263	950	9.4	1.1	0									
2000	2	40	557	1	1645	7	9.5	0.0	2	40	694	117	3450	1909	9.7	0.8	1	20	752		4050		9.5			
1999	5	71	544	45	1492	375	9.2	0.8	2	29	704	76	3275	1096	9.2	0.1	0									
1998	5	71	539	52	1684	245	11.1	3.0	2	29	708	76	3425	1167	9.5	0.2	0									
1997	7	64	549	63	1717	644	9.9	1.1	4	36	697	17	3323	349	9.8	0.6	0									
1996	2	100	555	11	1770	212	10.4	0.6	0								0									
1995	0								1	100	682		3000		9.5		0									
1994	9	100	564	16	1812	189	10.1	0.7	0								0									
1993	1	50	540		1520		9.7		1	50	656		2650		9.4		0									
1992	0								1	100	718		4000		10.8		0									
1991	8	73	542	49	1608	434	9.9	1.2	3	27	741	24	4533	797	11.1	1.4	0									
Central North Pacific - Subarctic Current																										
2003	0								0								0									
2002	3	37	554	23	1713	261	10.0	0.7	5	63	752	83	4530	1449	10.3	1.0	0									
2001	0								1	100	756		4250		9.8		0									
2000	0								7	78	670	18	3929	305	11.5	0.8	2	22	749	2	4425	672	10.5	1.5		
1999	3	25	615	108	2177	844	9.3	1.3	7	58	684	75	3124	992	9.5	0.6	2	17	747	57	4155	771	10.0	0.4		
1998	10	50	556	52	1726	543	9.7	0.8	8	40	645	28	2488	330	9.3	1.0	2	10	692	28	3350	71	10.1	1.0		
1997	1	16	536		1750		11.4		4	67	685	47	3005	308	9.4	1.1	1	17	800		4850		9.5			
1996	4	100	555	12	1608	116	9.4	0.5	0								0									
1995	16	73	574	41	1791	317	9.4	0.6	5	23	672	51	3050	752	9.9	0.9	1	4	700		3000		8.7			
1994	21	84	551	44	1850	231	11.4	3.1	4	16	692	61	3538	1090	10.5	1.1	0									
1993	4	40	563	24	1695	93	9.6	1.2	6	60	688	70	2975	424	9.4	2.5	0									
1992	0								3	100	663	49	2867	569	9.8	0.5	0									
1991	2	75	522	60	1315	403	9.1	0.3	1	25	712		3800		10.5		0									
Central North Pacific - Ridge Domain																										
1992	1	50	548		1530		9.3		1	50	658		2350		8.2		0									
Central North Pacific - All areas																										
2003	3	50	544	63	1743	571	10.5	0.1	3	50	752	35	3960	524	9.4	1.5	0									
2002	4	44	551	20	1690	218	10.1	0.6	5	56	752	83	4530	1449	10.3	1.0	0									
2001	5	50	586	17	1928	101	9.6	0.8	5	50	709	46	3460	934	9.5	1.0	0									
2000	2	15	557	1	1645	7	9.5	0.0	9	64	698	44	3822	755	11.1	1.1	3	21	750	3	4300	522	10.2	1.2		
1999	8	42	571	76	1749	640	9.2	0.9	9	47	689	71	3158	945	9.4	0.6	2	11	747	57	4155	771	10.0	0.4		
1998	15	56	550	51	1712	455	10.2	1.8	10	37	657	44	2675	626	9.3	0.9	2	7	692	28	3350	71	10.1	1.0		
1997	8	47	547	59	1721	597	10.1	1.1	8	47	691	33	3164	349	9.6	0.8	1	6	800		4850		9.5			
1996	6	100	555	11	1662	155	9.7	0.7	0								0									
1995	16	70	574	41	1791	317	9.4	0.6	6	26	674	46	3042	673	9.8	0.9	1	4	700		3000		8.7			
1994	30	88	555	38	1839	216	11.0	2.7	4	12	692	61	3538	1090	10.5	1.1	0									
1993	5	42	558	23	1660	112	9.6	1.1	7	58	683	65	2929	406	9.4	2.3	0									
1992	1	17	548		1530		9.3		5	83	673	43	2990	728	9.7	1.0	0									
1991	10	71	538	49	1549	424	9.7	1.1	4	29	734	24	4350	747	10.9	1.1	0									

Table 14. Percent ocean and freshwater age composition and maturity at age of steelhead trout caught in the central North Pacific by the *Wakatake maru* research gillnet, 1991-2003. Values indicate the percentage of fish in each age and maturity class, grouped by year. Imm=immature, Mat=Mature, Tot=Total.

Steelhead, Central North Pacific																			
Ocean Age 1																			
Year	N	FW Age 1			FW Age 2			FW Age 3			FW 4			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	3	17	0	17	0	0	0	0	17	17	16	0	16	0	0	0	33	17	50
02	4	22	11	33	0	0	0	0	0	0	11	0	11	0	0	0	33	11	44
01	5	10	0	10	10	0	10	20	0	20	0	0	0	0	10	10	40	10	50
00	2	0	7	7	0	0	0	0	7	7	0	0	0	0	0	0	0	14	14
99	7	0	22	22	0	6	6	0	6	6	0	0	0	0	6	6	0	39	39
98	15	7	11	18	0	4	4	4	15	19	0	15	15	0	0	0	11	44	56
97	8	0	6	6	6	0	6	0	0	0	0	0	0	12	24	35	18	29	47
96	6	17	17	33	17	0	17	0	0	0	0	0	0	50	0	50	83	17	100
95	16	0	13	13	0	22	22	4	0	4	0	0	0	4	26	30	9	61	70
94	30	27	3	29	6	0	6	0	0	0	0	0	0	32	21	53	65	24	88
93	5	8	0	8	8	0	8	8	0	8	0	0	0	17	0	17	42	0	42
92	1	0	0	0	17	0	17	0	0	0	0	0	0	0	0	0	17	0	17
91	10	0	0	0	14	0	14	0	0	0	0	0	0	36	21	57	50	21	71

Ocean Age 2																			
Year	N	FW Age 1			FW Age 2			FW Age 3			FW 4			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	3	0	17	17	0	0	0	0	33	33	0	0	0	0	0	0	0	50	50
02	5	0	22	22	0	23	23	0	0	0	0	11	11	0	0	0	0	56	56
01	5	20	30	50	0	0	0	0	0	0	0	0	0	0	0	0	20	30	50
00	9	0	29	29	0	0	0	0	36	36	0	0	0	0	0	0	0	64	64
99	9	0	6	6	0	0	0	0	17	17	0	0	0	0	28	28	0	50	50
98	10	0	11	11	0	4	4	0	11	11	0	11	11	0	0	0	0	37	37
97	8	0	12	12	0	6	6	0	0	0	0	0	0	12	18	29	12	35	47
96	0																		
95	6	0	9	9	0	4	4	0	0	0	0	0	0	0	13	13	0	26	26
94	4	0	6	6	0	0	0	0	0	0	0	0	0	3	3	6	3	9	12
93	7	8	8	17	8	8	17	0	0	0	0	0	0	8	17	25	25	33	58
92	5	0	17	17	17	33	50	0	0	0	0	0	0	0	17	17	17	67	83
91	4	0	0	0	0	14	14	0	0	0	0	0	0	7	7	14	7	21	29

Ocean Age 3																			
Year	N	FW Age 1			FW Age 2			FW Age 3			FW 4			FW X			All FW Ages		
		Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot	Imm	Mat	Tot
03	0																		
02	0																		
01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
00	3	0	7	7	0	0	0	0	14	14	0	0	0	0	0	0	0	21	21
99	2	0	0	0	0	6	6	0	0	0	0	0	0	0	6	6	0	11	11
98	2	0	4	4	0	0	0	0	0	0	0	4	4	0	0	0	0	7	7
97	1	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6	0	6	6
96	0																		
95	1	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	4	0	4
94	0																		
93	0																		
92	0																		
91	0																		

Table 15. Mean percent composition of stomach contents of salmonids caught in the central North Pacific by the *Wakatake maru*, 1991-2003. % empty=percent of stomachs that did not contain stomach contents. Empty stomachs were not included in other table entries. PW=prey weight, SCI=PW*100/body weight, SD=standard deviation. Prey composition based on visual estimates. Prey categories are EU=euphausiids, CO=copepods, AM=amphipods, CR=crab larvae, SQ=squids, PT=pteropods, FI=fish, PO=polychaetes, GE=gelatinous zooplankton (coelenterates, ctenophores, and salps), OTH=other groups, and UNID=unidentified material.

41°-50°N, 180° Central North Pacific Ocean

Species	Year	N	% empty	Mean PW	SD PW	Mean SCI	SD SCI	Mean % composition by volume												
								EU	CO	AM	CR	SQ	PT	FI	PO	CH	GE	OTH	UNID	
Sockeye	2003	30	33	21	55	1.21	1.58	6	1	24	0	32	15	2	5	12	0	3	0	
	2002	20	15	12	14	0.80	0.94	4	3	36	0	37	10	0	6	1	0	3	0	
	2001	32	13	12	20	0.70	0.67	3	6	45	0	13	18	3	0	1	0	9	2	
	2000	16	50	23	36	1.45	1.79	0	2	4	0	57	24	13	0	0	0	0	0	
	1999	34	38	2	3	0.34	0.52	10	15	31	0	10	10	0	11	8	0	1	4	
	1998	18	33	12	17	0.78	0.86	0	10	13	0	61	0	8	2	0	0	6	0	
	1997	27	0	18	23	0.98	1.01	24	26	9	0	27	2	0	3	7	0	2	0	
	1996	10	10	20	14	0.82	0.34	30	7	23	0	21	10	6	0	1	0	2	0	
	1995	15	0	40	34	1.50	1.12	35	16	11	0	33	2	1	0	2	0	0	0	
	1994	26	4	25	24	0.91	0.76	15	10	12	0	54	8	1	0	0	0	0	0	
	1993	2	0	11	7	0.39	0.14	0	0	65	0	0	0	0	35	0	0	0	0	
	1992	3	0	9	8	0.65	0.78	7	0	33	0	43	17	0	0	0	0	0	0	
	1991	22	32	7	9	0.46	0.47	19	5	24	0	5	35	0	0	1	0	0	11	
Chum	2003	79	9	11	11	0.74	0.50	0	3	1	0	4	2	0	4	10	61	13	2	
	2002	88	2	15	15	1.40	0.81	0	2	20	0	1	27	0	0	12	33	5	0	
	2001	84	5	14	14	0.92	0.69	3	1	3	0	2	19	1	4	0	65	2	0	
	2000	51	4	9	8	0.83	0.70	0	2	2	0	6	9	0	8	1	61	9	2	
	1999	47	15	7	11	0.60	0.50	3	5	12	0	0	14	1	0	14	36	0	15	
	1998	87	18	6	13	0.64	0.46	1	4	8	0	0	18	2	7	11	21	5	23	
	1997	94	4	8	7	0.82	0.64	17	5	7	0	1	8	2	5	32	19	2	2	
	1996	103	4	10	10	0.83	0.72	4	3	9	0	5	15	1	4	10	31	9	9	
	1995	98	1	9	8	0.80	0.60	36	2	6	0	5	8	3	0	5	33	0	2	
	1994	106	5	9	8	0.92	0.68	6	1	3	0	2	20	1	0	12	27	2	26	
	1993	117	3	11	7	1.27	0.72	1	3	4	0	1	16	3	7	8	11	37	9	
	1992	42	7	6	4	0.71	0.49	13	3	27	0	3	4	2	1	12	9	0	26	
	1991	134	5	11	9	1.36	0.78	4	3	5	0	1	8	1	0	3	1	0	74	
Pink	2003	55	9	48	32	4.02	2.31	7	0	1	0	81	6	5	0	0	0	0	0	
	2002	12	0	32	30	2.43	2.15	0	6	21	0	55	8	2	0	0	3	5	0	
	2001	32	3	16	10	1.54	0.98	14	26	17	0	24	12	3	0	4	0	0	0	
	2000	13	8	32	23	2.44	1.56	8	0	1	0	74	0	4	0	1	0	12	0	
	1999	40	13	9	8	1.02	0.84	5	52	7	0	12	9	3	0	10	0	2	0	
	1998	12	0	18	21	1.57	1.74	5	22	21	0	26	1	4	0	0	0	21	0	
	1997	60	3	15	14	1.52	1.42	14	60	7	0	2	5	3	0	8	0	1	0	
	1996	8	13	7	7	0.48	0.49	3	14	29	0	19	17	1	0	0	7	9	1	
	1995	34	9	18	10	1.75	0.89	12	24	15	0	22	6	10	0	8	0	3	0	
	1994	62	2	18	21	1.56	1.61	8	27	10	0	25	14	2	0	8	0	3	3	
	1993	6	0	12	10	1.29	1.09	11	1	17	0	11	36	20	1	0	2	1	0	
	1992	2	0	4	1	0.39	0.09	2	5	68	0	0	0	25	0	0	0	0	0	
	1991	101	4	13	9	1.56	0.99	24	14	13	0	8	35	3	0	1	0	1	1	
Coho	2003	52	12	59	56	2.19	1.70	0	0	0	0	88	12	0	0	0	0	0	0	
	2002	48	33	52	56	2.21	2.32	0	0	17	0	73	0	3	0	0	6	1	0	
	2001	45	13	54	57	2.38	2.38	0	0	4	0	92	0	4	0	0	0	0	0	
	2000	43	19	52	46	2.72	2.75	0	0	1	0	84	1	14	0	0	0	0	0	
	1999	18	67	37	50	1.83	2.46	0	0	1	0	82	0	2	0	0	0	15	0	
	1998	88	20	45	41	2.14	1.76	0	0	1	0	94	2	3	0	0	0	0	0	
	1997	130	26	26	25	1.68	1.59	6	1	6	0	64	5	18	0	0	0	0	0	
	1996	82	24	24	36	1.28	1.45	3	0	12	0	74	6	1	0	0	3	1	0	
	1995	61	3	46	32	2.65	1.75	2	0	3	0	86	2	7	0	0	0	0	0	
	1994	45	11	44	46	2.30	2.11	3	0	8	0	73	9	7	0	0	0	0	0	
	1993	36	8	23	25	1.30	1.20	0	0	4	0	65	27	3	0	0	1	0	0	
	1992	20	0	16	23	0.95	1.23	5	1	43	0	45	1	2	0	1	2	0	0	
	1991	83	6	34	30	1.78	1.45	3	0	16	0	71	7	2	0	0	1	0	0	
Chinook	2003	6	17	41	32	1.24	1.05	0	0	0	0	100	0	0	0	0	0	0	0	
	2002	3	33	39	43	1.42	1.74	0	0	0	0	100	0	0	0	0	0	0	0	
	2001	9	33	36	25	0.88	0.61	0	0	0	0	100	0	0	0	0	0	0	0	
	2000	4	25	51	47	1.41	1.47	0	0	0	0	100	0	0	0	0	0	0	0	
	1999	3	33	36	26	1.25	0.95	0	0	0	0	50	0	50	0	0	0	0	0	
	1998	9	22	50	37	1.45	0.82	0	0	0	0	100	0	0	0	0	0	0	0	
	1997	26	31	27	28	1.06	1.17	17	0	0	0	78	0	5	0	0	0	0	0	
	1996	2	0	19	25	0.26	0.30	0	0	0	0	100	0	0	0	0	0	0	0	
	1995	4	25	40	34	1.12	0.95	0	0	0	0	100	0	0	0	0	0	0	0	
	1994	3	0	13	6	0.28	0.07	0	0	0	0	100	0	0	0	0	0	0	0	
	1993	3	33	74	80	1.94	1.91	0	0	0	0	100	0	0	0	0	0	0	0	
	1992	0																		
	1991	2	0	23	29	0.48	0.57	0	0	2	0	63	0	0	0	0	0	0	35	
Steelhead	2003	12	25	85	77	2.38	1.46	0	0	0	0	76	0	24	0	0	0	0	0	
	2002	23	4	84	62	2.60	1.40	0	0	0	0	85	0	12	1	0	0	2	0	
	2001	25	16	17	20	0.75	1.02	0	0	3	0	27	0	51	16	0	0	1	2	
	2000	28	4	51	48	1.41	1.07	0	0	0	0	54	0	31	14	0	0	1	0	
	1999	9	11	17	15	0.48	0.40	0	1	4	0	12	1	81	0	0	0	1	0	
	1998	21	14	31	36	1.48	1.82	0	0	0	0	69	1	20	0	0	0	10	0	
	1997	55	18	10	11	0.51	0.62	2	0	9	0	16	1	29	18	0	0	25	0	
	1996	21	10	19	29	0.80	1.32	0	0	6	0	40	0	45	0	0	0	9	0	
	1995	10	30	36	70	0.94	1.37	0	0	8	0	33	1	51	0	0	0	7	0	
	1994	18	0	33	38	1.05	0.94	0	0	4	0	62	5	29	0	0	0	0	0	
	1993	14	25	20	20	0.91	0.86	2	0	35	0	60	3	0	0	0	0	0	0	
	1992	8	0	35	50	1.10	1.43	14	0	13	0	50	0	23	0	0	0	0	0	
	1991	14	0	33	35	1.56	1.75	0	0	15	0	70	2	11	0	0	0	2	0	

Table 16. Mean percent composition of stomach contents of salmonids caught in the central Aleutian Islands by the *Wakatake maru*, 1991-2003. % empty=percent of stomachs that did not contain stomach contents. Empty stomachs were not included in other table entries. PW=prey weight, SCI=PW*100/body weight, SD=standard deviation. Prey composition based on visual estimates. Prey categories are EU=euphausiids, CO=copepods, AM=amphipods, CR=crab larvae, SQ=squids, PT=pteropods, FI=fish, PO=polychaetes, CH=chaetognaths, GE=gelatinous zooplankton (coelenterates, ctenophores, and salps), OTH=other groups, and UNID=unidentified material.

51°30N, 180° Central Aleutian Islands

Species	Year	N	% empty	Mean PW	SD PW	Mean SCI	SD SCI	Mean % composition by volume														
								EU	CO	AM	CR	SQ	PT	FI	PO	CH	GE	OTH	UNID			
Sockeye	2003	0																				
	2002	2	0	2	1	0.15	0.10	0	0	73	0	0	0	2	0	0	21	4	0	0		
	2001	0																				
	2000	0																				
	1999	3	33	1	1	0.11	0.05	0	7	15	0	0	25	53	0	0	0	0	0	0	0	
	1998	0																				
	1997	3	0	8	5	0.50	0.34	26	0	2	0	0	4	3	20	0	15	30	0	0	0	
	1996	4	25	14	16	0.56	0.52	12	0	35	0	40	12	1	0	0	0	0	0	0	0	
	1995	14	0	10	7	0.51	0.40	1	5	21	0	6	30	5	6	3	20	3	0	0	0	
	1994	7	14	14	9	0.96	0.58	0	0	70	2	2	8	0	0	0	0	0	18	0	0	
	1993	7	57	1	0	0.11	0.03	7	3	17	0	33	7	0	0	0	0	0	0	0	33	
	1992	3	0	5	4	0.44	0.31	3	3	47	0	0	0	24	0	23	0	0	0	0	0	
	1991	3	67	7	-	0.41	-	0	5	10	0	0	0	5	0	0	0	0	0	0	80	
Chum	2003	4	0	22	16	1.32	0.42	0	1	0	0	0	0	0	2	52	45	0	0	0		
	2002	7	0	26	20	1.41	0.41	0	1	2	0	0	1	0	7	69	20	0	0	0		
	2001	0																				
	2000	0																				
	1999	2	0	13	2	1.26	0.33	0	0	1	0	0	2	0	1	96	0	0	0	0		
	1998	10	0	17	12	1.05	0.55	0	1	9	0	1	26	2	24	0	27	0	10	0		
	1997	2	0	16	1	2.29	0.30	0	0	1	0	0	3	0	0	48	0	48	0	0		
	1996	10	20	19	33	0.56	0.73	9	0	25	0	8	4	16	1	23	13	0	0	0		
	1995	8	0	18	10	1.25	0.58	1	0	1	0	0	8	1	33	0	56	0	0	0		
	1994	20	0	9	4	1.23	0.85	24	4	22	0	18	1	9	0	15	5	2	0	0		
	1993	19	0	14	7	1.52	0.76	0	0	0	0	0	1	0	0	0	99	0	0	0		
	1992	8	13	14	5	1.42	0.75	1	2	22	0	9	0	1	0	65	0	0	0	0		
	1991	20	0	10	7	1.19	0.87	0	0	2	0	0	4	1	0	11	0	82	0	0		
Pink	2003	10	0	6	7	0.46	0.46	0	1	2	0	27	12	34	0	1	0	23	0	0		
	2002	0																				
	2001	4	0	2	1	0.12	0.07	0	2	3	0	6	39	50	0	0	0	0	0	0		
	2000	0																				
	1999	9	0	3	3	0.36	0.26	0	16	37	2	2	13	9	0	20	0	1	0	0		
	1998	0																				
	1997	0																				
	1996	0																				
	1995	10	0	10	6	0.89	0.45	2	0	19	0	13	28	33	4	0	0	1	0	0		
	1994	2	0	12	9	0.96	0.47	0	0	25	0	0	20	15	0	0	0	40	0	0		
	1993	20	10	4	4	0.39	0.38	2	1	37	1	8	0	39	0	0	0	12	0	0		
	1992	0																				
	1991	20	5	6	5	0.72	0.68	9	19	9	0	1	22	7	0	0	0	1	32	0		
Coho	2003	0																				
	2002	0																				
	2001	0																				
	2000	0																				
	1999	0																				
	1998	0																				
	1997	1	0	68	-	3.82	-	0	0	0	0	0	0	100	0	0	0	0	0	0		
	1996	0																				
	1995	0																				
	1994	0																				
	1993	0																				
	1992	0																				
	1991	1	0	3	-	0.10	-	0	0	0	0	100	0	0	0	0	0	0	0	0		
Chinook	2003	0																				
	2002	0																				
	2001	0																				
	2000	0																				
	1999	0																				
	1998	0																				
	1997	0																				
	1996	0																				
	1995	0																				
	1994	0																				
	1993	0																				
	1992	0																				
	1991	0																				
Steelhead	2003	0																				
	2002	0																				
	2001	0																				
	2000	0																				
	1999	0																				
	1998	0																				
	1997	0																				
	1996	0																				
	1995	0																				
	1994	0																				
	1993	0																				
	1992	0																				
	1991	0																				

Table 17. Mean percent composition of stomach contents of salmonids caught in the central Bering Sea by the *Wakatake maru*, 1991-2003. % empty=percent of stomachs that did not contain stomach contents. Empty stomachs were not included in other table entries. PW=prey weight, SCI=PW*100/body weight, SD=standard deviation. Prey composition based on visual estimates. Prey categories are EU=euphausiids, CO=copepods, AM=amphipods, CR=crab larvae, SQ=squids, PT=pteropods, FI=fish, PO=polychaetes, CH=chaetognaths, GE=gelatinous zooplankton (coelenterates, ctenophores, and salps), OTH=other groups, and UNID=unidentified material.

52°-58°N Central Bering Sea

Species	Year	N	% empty	Mean PW	SD PW	Mean SCI	SD SCI	Mean % composition by volume											
								EU	CO	AM	CR	SQ	PT	FI	PO	CH	GE	OTH	UNID
Sockeye	2003	155	37	11	13	0.68	0.62	20	2	8	1	33	6	23	3	0	0	4	0
	2002	139	12	11	15	0.87	0.87	19	10	34	0	19	4	14	0	0	0	0	0
	2001	195	17	8	10	0.66	0.65	26	14	13	0	10	17	16	0	3	1	0	0
	2000	133	8	16	29	0.84	0.92	12	11	28	1	17	4	25	0	1	0	1	0
	1999	117	15	7	10	0.64	0.64	12	8	29	1	29	9	9	0	0	2	1	0
	1998	113	19	12	17	1.21	1.42	28	18	19	2	14	8	10	0	0	1	0	0
	1997	114	11	7	7	0.51	0.47	9	21	25	9	10	11	11	0	0	0	4	0
	1996	134	16	12	14	0.70	0.77	23	13	16	1	15	12	19	0	0	1	0	0
	1995	144	1	10	8	0.67	0.55	9	6	36	6	22	12	8	0	0	1	0	0
	1994	115	10	11	11	0.90	0.90	15	20	30	0	21	5	7	0	0	1	1	0
	1993	72	11	10	10	0.68	0.69	3	10	19	1	31	3	29	0	0	0	3	1
	1992	33	15	14	28	0.70	1.13	12	33	19	0	20	0	13	0	0	3	0	0
	1991	66	12	9	8	0.56	0.49	13	5	7	0	33	13	14	0	0	5	3	7
Chum	2003	183	0	21	16	1.34	0.98	21	2	1	0	7	23	5	1	1	30	8	1
	2002	242	5	15	14	1.01	0.87	31	4	14	0	7	20	6	0	1	12	4	1
	2001	199	3	35	24	1.51	0.86	18	1	1	0	2	46	2	0	0	29	1	0
	2000	184	4	18	12	1.10	0.90	28	4	7	0	3	9	8	0	1	40	0	0
	1999	226	4	15	12	0.71	0.47	11	2	2	0	3	21	3	1	0	53	1	3
	1998	316	5	13	11	1.02	0.79	19	9	14	1	4	19	7	10	0	11	1	5
	1997	174	3	14	12	1.05	0.79	20	2	6	1	5	28	5	5	2	8	16	2
	1996	238	6	15	15	1.00	0.88	39	3	9	0	2	20	10	0	0	13	4	0
	1995	216	2	14	9	1.01	0.69	23	1	12	1	7	9	22	0	0	23	0	2
	1994	279	1	11	9	0.99	0.65	13	6	13	0	5	7	2	0	3	39	1	11
	1993	272	4	16	10	1.41	0.76	6	2	4	0	10	6	16	1	0	29	24	2
	1992	227	1	19	11	1.32	0.84	26	18	13	0	13	0	5	0	1	4	0	20
	1991	291	1	24	16	1.54	0.76	9	2	4	0	3	4	1	0	0	10	24	43
Pink	2003	168	6	21	18	1.35	1.15	17	4	2	1	40	2	30	0	1	0	3	0
	2002	40	10	14	12	1.23	1.00	34	8	10	0	10	2	36	0	0	0	0	0
	2001	185	3	19	17	1.49	1.19	32	7	3	0	20	10	26	0	1	0	1	0
	2000	5	0	24	14	2.22	1.28	0	0	0	0	19	0	81	0	0	0	0	0
	1999	271	8	10	10	0.89	0.83	13	19	7	1	17	10	31	1	0	0	1	0
	1998	31	13	12	14	1.46	1.44	12	16	11	4	15	6	36	0	0	0	0	0
	1997	181	16	10	8	0.88	0.75	9	14	16	6	15	10	27	0	0	0	3	0
	1996	52	8	19	19	1.43	1.28	21	5	5	3	14	2	50	0	0	0	0	0
	1995	186	0	15	12	1.19	0.83	9	8	14	5	26	12	26	0	0	0	0	0
	1994	28	0	17	17	1.37	1.39	23	12	8	4	28	2	23	0	0	0	0	0
	1993	139	1	17	15	1.49	1.21	2	7	6	0	30	3	51	0	0	0	1	0
	1992	14	0	27	25	1.94	1.65	14	12	6	0	40	0	21	0	0	0	4	3
	1991	292	8	18	17	1.56	1.92	14	5	11	0	36	4	22	0	0	2	1	5
Coho	2003	9	22	13	5	0.74	0.44	39	0	0	0	40	0	21	0	0	0	0	0
	2002	4	0	29	32	0.97	1.02	49	2	0	0	25	0	24	0	0	0	0	0
	2001	1	100																
	2000	0																	
	1999	0																	
	1998	1	100																
	1997	8	50	16	13	0.94	0.89	15	0	0	0	36	0	49	0	0	0	0	0
	1996	2	0	76	41	2.07	1.38	0	0	0	0	0	0	100	0	0	0	0	0
	1995	0																	
	1994	0																	
	1993	0																	
	1992	2	0	9	2	0.63	0.46	88	0	5	0	5	0	2	0	0	0	0	0
	1991	1	0	18	-	0.50	-	100	0	0	0	0	0	0	0	0	0	0	0
Chinook	2003	77	43	14	22	0.67	0.73	11	0	0	0	61	2	26	0	0	0	0	0
	2002	89	30	23	35	0.73	0.79	34	1	0	0	44	0	21	0	0	0	0	0
	2001	40	35	4	4	0.50	0.60	6	0	0	0	34	2	58	0	0	0	0	0
	2000	60	27	35	82	1.10	1.58	29	1	0	0	36	0	34	0	0	0	0	0
	1999	22	32	4	6	0.38	0.41	9	0	6	0	36	4	45	0	0	0	0	0
	1998	96	34	15	20	0.82	0.86	12	3	2	0	66	0	16	0	0	0	0	1
	1997	53	34	13	22	0.54	0.66	29	0	0	0	52	0	19	0	0	0	0	0
	1996	72	19	25	38	1.03	1.00	18	0	2	0	47	1	32	0	0	0	0	0
	1995	44	16	10	9	0.63	0.55	16	0	0	0	52	0	29	0	0	0	0	3
	1994	26	31	11	12	0.51	0.42	20	0	10	0	58	0	8	0	1	3	0	0
	1993	12	17	12	12	0.54	0.52	27	0	0	0	39	0	34	0	0	0	0	0
	1992	37	19	18	26	0.78	0.97	43	4	0	0	44	0	9	0	0	0	0	0
	1991	30	13	19	40	0.83	0.87	32	1	0	0	43	0	23	0	0	0	0	1
Steelhead	2003	0																	
	2002	0																	
	2001	0																	
	2000	0																	
	1999	0																	
	1998	0																	
	1997	0																	
	1996	0																	
	1995	0																	
	1994	0																	

Table 18. Locations, sea surface temperatures (°C), and catches for 2003 *Kaiyo maru* fishing stations. Stations are ordered by transect (west to east) and latitude (north to south), not by date of operation. Catches are for 1-hour tows of surface trawl.

Transect	Station	Date	Latitude	Longitude	SST	Sockeye	Chum	Pink	Coho	Chinook	Steelhead	Total
160°W	B38	8/4	53°50	160°05	12.2	27	153	42	2	5	0	229
	B39	8/3	52°51	160°10	12.7	5	52	5	1	1	0	64
	B40	8/3	51°54	160°15	12.0	57	172	1	1	2	0	232
	B41	8/2	50°50	160°10	11.4	63	145	0	0	0	0	208
	B42	8/2	49°49	160°00	11.9	5	28	0	0	0	0	33
155°W	B43	8/5	55°39	154°49	12.5	0	25	48	1	11	0	85
	B44	8/5	55°03	155°15	13.6	6	91	64	3	2	0	166
	B45	8/6	54°00	155°13	11.5	14	53	1	1	1	0	70
	B46	8/6	53°03	155°13	12.9	44	90	0	0	0	0	134
	B47	8/7	52°08	154°52	11.9	37	49	0	0	1	0	87
	B48	8/7	51°09	154°59	12.7	12	31	0	1	0	2	46
	B49	8/8	50°07	154°59	13.0	0	142	0	0	0	0	142
150°W	B52	8/12	55°52	150°15	13.4	10	241	3	0	2	0	256
	B53	8/11	53°50	149°59	12.7	8	20	0	0	1	0	29
	B54	8/10	51°49	149°57	12.5	0	4	0	0	0	0	4
	B55	8/9	49°50	150°02	13.2	0	160	0	0	0	0	160
145°W	B50	8/13	57°50	144°59	14.8	0	20	2	0	0	0	22
	B56	8/13	56°53	144°45	15.0	0	75	3	1	0	0	79
	B57	8/14	55°50	145°05	13.2	0	20	10	0	0	0	30
	B58	8/14	54°50	145°03	13.0	0	2	0	0	0	0	2
	B59	8/15	53°55	145°15	13.2	0	4	0	0	0	0	4
	B60	8/15	52°54	145°13	12.9	0	0	0	0	0	0	0
	B61	8/16	51°54	145°13	12.6	0	0	0	0	0	0	0
	B62	8/16	51°04	144°47	13.0	0	0	0	0	0	0	0
	B63	8/17	50°00	145°15	13.0	0	0	0	0	0	0	0
Total						288	1577	179	11	26	2	2,082

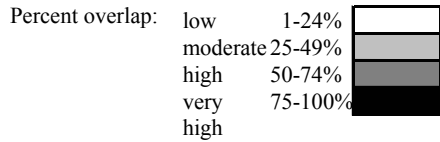
Table 19. Recoveries of iButton tags released in 2003. All fish were tagged in the Bering Sea, near 180° longitude.

Tag Number	Species	Tagging Latitude	Release Date	Recovery Date	Recovery Area
W-31	Sockeye	58°30N	7/2/03	7/21/03	Naknek, Bristol Bay, Alaska
W-32	Chum	56°30N	7/6/03	7/21/03	Russian EEZ, E Kamchatka
W-64	Pink	54°30N	6/28/03	7/23/03	Olyutorsky Bay, NE Kamchatka
W-65	Pink	54°30N	6/28/03	8/9/03	Karaginsky Bay, NE Kamchatka
W-75	Pink	57°30N	7/1/03	7/26/03	Karaginsky Bay, NE Kamchatka

Table 20. Recoveries of temperature-depth tags released in 2003. All fish were tagged in the Bering Sea, between 177°E and 180° longitude.

Tag Number	Species	Tagging Latitude	Release Date	Recovery Date	Recovery Area
1685	Sockeye	54°30N	6/28/03	7/31/03	North Alaska Peninsula, Alaska
1396	Chum	57°30N	7/10/03	9/12/03	Kalininsky Hatchery, Sakhalin
1603	Chum	56°30N	7/9/03	10/11/03	Nemuro Coast, Hokkaido
1688	Sockeye	55°30N	6/29/03	8/7/03	S tip of Kamchatka
1709	Chum	56°30N	7/7/03	9/23/03	Okhotsk Coast, Hokkaido

Table. 21. Percent diet overlap of sockeye, chum, and chinook salmon collected in the Bering Sea basin, shelf, and Aleutian Islands in fall 2002. Empty stomachs are not included in calculation of overlap values. Bold values highlight major prey components of diet overlap. Overlap values calculated for salmon species if sample size is > 15.



BASIN

Prey Group	Pairwise Comparison																			
	sockeye- chum	sockeye- chinook	chum- chinook																	
Euphausiids	17	4	4																	
Copepods	0	0	0																	
Amphipods	12	0	0	<table border="1"> <thead> <tr> <th></th> <th>sockeye</th> <th>chum</th> <th>chinook</th> </tr> </thead> <tbody> <tr> <th>sockeye</th> <td style="text-align: center;">4</td> <td></td> <td style="text-align: center;">21</td> </tr> <tr> <th>chum</th> <td></td> <td style="text-align: center;">9</td> <td style="text-align: center;">28</td> </tr> <tr> <th>chinook</th> <td></td> <td></td> <td style="text-align: center;">0</td> </tr> </tbody> </table>		sockeye	chum	chinook	sockeye	4		21	chum		9	28	chinook			0
	sockeye	chum	chinook																	
sockeye	4		21																	
chum		9	28																	
chinook			0																	
Squid	0	0	2																	
Pteropods	0	0	0																	
Fish	17	17	22																	
Gelatinous	2	0	0																	
Other	1	0	0																	
Total	49	21	28																	

ALEUTIAN ISLANDS

Prey Group	Pairwise Comparison											
	sockeye- chum											
Euphausiids	44											
Copepods	2											
Amphipods	27		<table border="1"> <thead> <tr> <th></th> <th>sockeye</th> <th>chum</th> </tr> </thead> <tbody> <tr> <th>sockeye</th> <td style="text-align: center;">8</td> <td></td> </tr> <tr> <th>chum</th> <td></td> <td style="text-align: center;">0</td> </tr> </tbody> </table>		sockeye	chum	sockeye	8		chum		0
	sockeye	chum										
sockeye	8											
chum		0										
Squid	0											
Pteropods	0											
Fish	5											
Gelatinous	0											
Other	2											
Total	80											

SHELF

Prey Group	Pairwise Comparison											
		chum- chinook										
Euphausiids		5										
Copepods		0										
Amphipods		0										
Squid		2	<table border="1"> <thead> <tr> <th></th> <th>chum</th> <th>chinook</th> </tr> </thead> <tbody> <tr> <th>chum</th> <td style="text-align: center;">3</td> <td></td> </tr> <tr> <th>chinook</th> <td></td> <td style="text-align: center;">0</td> </tr> </tbody> </table>		chum	chinook	chum	3		chinook		0
	chum	chinook										
chum	3											
chinook		0										
Pteropods		0										
Fish		23										
Gelatinous		0										
Other		0										
Total		30										

Table 22. Major brood year (BY) groups in the North Pacific Groundfish Observer Program scale samples from chinook salmon caught by U.S. groundfish fisheries in the eastern Bering Sea in 1997-1999. Bold font indicates brood year groups for which scale pattern baselines were established.

Age group	Observer Program Sample Year		
	1997	1998	1999
Age 1.0	BY95	BY96	BY97
Age 1.1	BY94	BY95	BY96
Age 1.2	BY93	BY94	BY95
Age 1.3	BY92	BY93	BY94
Age 1.4	BY91	BY92	BY93
Age 1.5	BY90	BY91	BY92

Table 23. Evaluation of the accuracies of the 4-group maximum likelihood estimate (MLE) models for brood year 1991-1995 chinook salmon, as indicated by computer simulations. Simulations are from 1000 iterations of randomly sampled scales in the model (with replacement), and include specified cases of equal representation of all groups or 100% representation by one group only. Numbers in parentheses are 95% confidence intervals (CI) derived from the 1000 simulations. Percentages represented by 0.0 are small numbers, less than 0.05 but greater than 0. N = number of scales in the simulated sample. Bold font indicates correct regional stock group for 100% simulations.

Brood year	Brood year and stock composition of simulated mixture sample	N	Maximum likelihood estimates (MLE) of stock composition (%)							
			<u>Kamchatka</u>		<u>Western Alaska</u>		<u>Cook Inlet</u>		<u>SE Alaska/BC</u>	
			MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
1991	Equal proportions (25%)	150	24.2	(19.1-30.1)	25.2	(20.4-30.1)	24.9	(18.2-31.1)	25.7	(20.3-31.4)
	100% Kamchatka	150	96.2	(88.5-99.9)	0.0	(0-0)	3.8	(0.0-11.5)	0.0	(0-0.0)
	100% Western Alaska	150	0.1	(0-0.7)	99.8	(97.9-99.9)	0.1	(0-1.4)	0.0	(0-0.8)
	100% Cook Inlet	150	0.0	(0-0.0)	0.5	(0-4.4)	98.4	(92.0-99.9)	1.1	(0-6.6)
	100% British Columbia	150	0.1	(0-1.6)	0.0	(0-0.0)	0.3	(0-3.8)	99.6	(95.8-99.9)
1992	Equal proportions (25%)	200	25.2	(16.8-33.3)	23.6	(16.1-32.5)	24.3	(15.0-34.7)	26.9	(18.9-35.3)
	100% Kamchatka	200	95.8	(90.1-99.8)	1.9	(0-5.3)	2.3	(0-7.3)	0	(0-0)
	100% Western Alaska	200	4.1	(0-11.2)	95.5	(88.3-100)	0.0	(0-0.0)	0.4	(0-2.7)
	100% Cook Inlet	200	0.8	(0-4.0)	1.6	(0-5.7)	97.5	(92.5-100)	0.1	(0-1.4)
	100% British Columbia	200	0	(0-0)	0.2	(0-1.2)	0	(0-0.0)	99.8	(98.8-100)
1993	Equal proportions (25%)	200	24.2	(16.3-32.1)	23.8	(14.3-34.3)	28.8	(16.8-41.1)	23.2	(15.3-31.5)
	100% Kamchatka	200	94.9	(88.9-99.5)	2.8	(0-7.8)	1.9	(0-7.4)	0.4	(0-2.1)
	100% Western Alaska	200	0.9	(0-5.6)	96.8	(88.5-99.9)	2.1	(0-9.7)	0.2	(0-1.7)
	100% Cook Inlet	200	0.0	(0-0.0)	0.1	(0-1.1)	99.8	(98.1-99.9)	0.1	(0-1.0)
	100% SE Alaska	200	0.0	(0-0.3)	1.5	(0-5.4)	0.2	(0-2.4)	98.3	(93.5-99.9)

Table 23. Evaluation of the accuracies of the 4-group maximum likelihood estimate (MLE) models for brood year 1991-1995 chinook salmon, as indicated by computer simulations (continued).

Brood year	Brood year and stock composition of simulated mixture sample	N	Maximum likelihood estimates (MLE) of stock composition (%)							
			<u>Kamchatka</u>		<u>Western Alaska</u>		<u>Cook Inlet</u>		<u>SE Alaska/BC</u>	
			MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
1994	Equal proportions (25%)	200	24.4	(16.5-32.8)	24.0	(15.6-33.2)	29.0	(18.2-40.6)	22.6	(15.4-29.7)
	100% Kamchatka	200	94.6	(87.9-100)	0	(0-0.0)	4.9	(0.0-10.7)	0.5	(0-3.4)
	100% Western Alaska	200	0.0	(0-0.5)	90.0	(81.0-98.5)	10.0	(1.0-18.9)	0	(0-0)
	100% Cook Inlet	200	0.7	(0-4.7)	2.7	(0-9.9)	96.1	(88.0-100)	0.5	(0-2.7)
	100% SE Alaska	200	0.2	(0-2.0)	0.2	(0-1.6)	6.3	(0.3-12.9)	93.3	(87.0-99.0)
1995	Equal proportions (25%)	200	25.0	(16.4-34.6)	23.8	(14.3-33.8)	28.4	(17.2-40.4)	22.8	(14.8-31.4)
	100% Kamchatka	200	96.5	(89.6-100.0)	3.0	(0-9.7)	0.4	(0-4.0)	0.1	(0-0.9)
	100% Western Alaska	200	2.2	(0-9.4)	97.0	(89.2-100.0)	0.4	(0-4.2)	0.4	(0-2.5)
	100% Cook Inlet	200	0	(0-0)	1.2	(0-6.7)	98.0	(91.4-100.0)	0.8	(0-5.6)
	100% Southeast Alaska	200	0.5	(0-4.0)	0.6	(0-4.4)	3.3	(0-11.2)	95.6	(88.1-100.0)

Table 24. Evaluation of the accuracies of the 4-group stock identification models for brood year 1991-1995 chinook salmon, as indicated by maximum likelihood estimates (MLE) of the stock composition of test samples. Test samples are scales not included in the final 4-group models. Numbers in parentheses are 95% confidence intervals (CI) derived from 1000 bootstrap runs (random sampling with replacement). The results for the correct regional stocks are indicated in bold font. Percentages represented by 0.0 are small numbers, less than 0.05 but greater than 0. N = number of scales in test sample. The Copper River is located geographically between the Cook Inlet region and the Southeast Alaska-British Columbia region. Bold font indicates correct regional stock group.

Brood year	Stock composition of test sample	Maximum likelihood estimates (MLE) of stock composition (%)								
		N	<u>Kamchatka</u>		<u>Western Alaska</u>		<u>Cook Inlet</u>		<u>SE Alaska/BC</u>	
			MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
1991	Yukon (100%)	97	13.8	(4.0-27.0)	86.2	(70.5-95.1)	0	(0-3.1)	0.0	(0-7.2)
	Kuskokwim (100%)	103	0.0	(0-1.9)	100	(97.2-100)	0.0	(0-1.1)	0	(0-0)
	Bristol Bay (100%)	97	0	(0-0.0)	99.4	(94.3-100)	0.0	(0-2.5)	0.6	(0-5.4)
	Cook Inlet (100%)	49	0	(0-4.9)	6.3	(0-17.4)	85.0	(61.5-98.1)	8.7	(0-29.4)
	Copper River (100%)	84	0	(0-0)	33.4	(14.2-53.0)	9.4	(0.0-27.8)	57.2	(32.6-77.1)
1992	Kamchatka (100%)	26	95.6	(73.7-100)	4.0	(0-13.3)	0.4	(0-20.2)	0	(0-0)
	Yukon (100%)	65	18.0	(3.9-33.8)	75.6	(59.1-89.8)	6.4	(0-16.2)	0	(0-1.8)
	Kuskokwim (100%)	126	0	(0-4.6)	100	(91.1-100)	0	(0-7.6)	0	(0-0.0)
	Bristol Bay (100%)	117	0	(0-0)	97.8	(93.2-100)	0.2	(0-3.8)	2.0	(0-5.8)
	Cook Inlet (100%)	19	0	(0-0)	4.1	(0-33.4)	95.9	(66.4-100)	0	(0-0)
	Copper River (100%)	60	0	(0-0)	0	(0-7.0)	39.2	(10.9-70.5)	60.8	(29.5-87.3)
	SE Alaska (100%)	137	7.3	(0-17.3)	0.4	(0-4.2)	2.6	(0-18.5)	89.7	(71.9-97.5)
1993	Yukon (100%)	129	7.0	(0.0-18.9)	93.0	(80.5-100)	0	(0-0)	0	(0-0)
	Kuskokwim (100%)	126	0.1	(0-5.7)	99.9	(87.9-100)	0	(0-9.8)	0	(0-0)
	Bristol Bay (100%)	124	0	(0-0)	100	(93.4-100)	0	(0-3.4)	0	(0-0)
	Copper River (100%)	49	0	(0-0)	0	(0-0)	100	(78.0-100)	0	(0-0)
	British Columbia (100%)	135	0	(0-0)	0	(0-0)	3.1	(0-18.2)	96.9	(82.0-100)

Table 24. Evaluation of the accuracies of the 4-group stock identification models for brood year 1991-1995 chinook salmon, as indicated by maximum likelihood estimates (MLE) of the stock composition of test samples (continued).

Brood year	Stock composition of test sample	Maximum likelihood estimates (MLE) of stock composition (%)								
		N	Kamchatka		Western Alaska		Cook Inlet		SE Alaska/BC	
			MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
1994	Yukon (100%)	128	3.7	(0-9.2)	80.0	(64.0-91.8)	16.3	(3.4-33.1)	0	(0-0)
	Kuskokwim (100%)	123	0	(0-0)	89.8	(73.6-100)	10.2	(0.0-26.4)	0	(0-0)
	Bristol Bay (100%)	128	0	(0-0)	100	(100-100)	0	(0-0.0)	0	(0-0)
	Copper River (100%)	49	0	(0-1.3)	0	(0-31.7)	100	(64.4-100)	0	(0-9.6)
	British Columbia (100%)	78	0	(0-0)	0	(0-0)	33.0	(6.5-67)	67.0	(33-93.5)
1995	Yukon (100%)	125	18.4	(0.0-42.0)	73.7	(42.4-96.8)	7.9	(0.0-25.7)	0	(0-0)
	Kuskokwim (100%)	131	0	(0-0)	100	(97.9-100)	0	(0-0.2)	0	(0-1.9)
	Nushagak (100%)	127	0	(0-0)	98.0	(85.4-100)	0.4	(0-11.2)	1.6	(0-9.5)
	Togiak (100%)	75	0	(0-0)	95.6	(84.0-100)	0	(0-0.0)	4.4	(0-16.1)
	Copper River (100%)	61	0	(0-0)	0	(0-0)	35.1	(11.2-66.6)	64.9	(33.4-88.8)
	British Columbia (100%)	58	0	(0-0)	0	(0-4.9)	31.4	(3.9-62.8)	68.6	(37.2-95.3)

Table 25. Age composition (% of total sample size, n) of chinook salmon in incidental catches by U.S. commercial groundfish fisheries in the eastern Bering Sea in 1997, 1998, and 1999. Fishery area: East = east of 170°W longitude, West = west of 170°W longitude. Fishery season: winter = January-June, most samples from January (50.0%) and February (41.5%), n=2,432; fall = July-November, most samples from September (61.2%) and October (34.7%), n=2,255. Total n = total number of fish in the fishery observer samples with scales that could be assigned both freshwater and ocean ages.

Fishery year	Fishery area	Fishery season	Age Group														Total n
			0.1	0.2	0.3	0.4	0.5	1.0	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	
1997	East	Winter	0.0	0.1	1.5	0.9	0.1	0.0	0.1	9.6	35.0	48.7	3.8	0.1	0.1	0.0	822
		Fall	1.3	6.9	0.8	0.0	0.0	0.0	12.9	68.7	9.2	0.2	0.0	0.0	0.0	0.0	651
	East total		0.6	3.1	1.1	0.5	0.1	0.0	5.8	35.7	23.6	27.2	2.1	0.1	0.1	0.0	1,473
	West	Winter	0.0	0.0	0.0	2.0	0.0	0.0	0.0	19.2	53.8	23.1	1.9	0.0	0.0	0.0	52
		Fall	0.0	0.0	0.7	0.0	0.0	0.0	0.6	63.9	30.4	4.4	0.0	0.0	0.0	0.0	158
	West total		0.0	0.0	0.5	0.4	0.0	0.0	0.5	52.9	36.2	9.0	0.5	0.0	0.0	0.0	210
1997 Total			0.5	2.7	1.1	0.4	0.1	0.0	5.1	37.8	25.2	25.0	1.9	0.1	0.1	0.0	1,683
1998	East	Winter	0.0	0.3	1.6	0.8	0.1	0.0	1.0	9.5	61.1	19.8	5.0	0.1	0.6	0.1	885
		Fall	0.8	3.0	0.7	0.2	0.0	0.8	29.9	50.0	14.5	0.1	0.0	0.0	0.0	0.0	730
	East total		0.3	1.5	1.1	0.5	0.1	0.4	14.1	27.8	40.1	10.9	2.7	0.1	0.3	0.1	1,615
	West	Winter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.4	4.8	4.8	0.0	0.0	0.0	21
		Fall	0.0	0.0	0.7	0.0	0.0	0.0	0.0	16.7	81.2	1.4	0.0	0.0	0.0	0.0	138
	West total		0.0	0.0	0.6	0.0	0.0	0.0	0.0	14.5	82.4	1.9	0.6	0.0	0.0	0.0	159
1998 Total			0.3	1.4	1.1	0.4	0.1	0.3	12.8	26.6	43.9	10.1	2.5	0.1	0.3	0.1	1,774
1999	East	Winter	0.0	0.5	0.1	0.0	0.1	0.0	3.1	16.3	56.4	22.4	0.8	0.3	0.0	0.0	644
		Fall	0.0	2.0	0.2	0.2	0.0	0.0	9.2	67.5	20.0	0.9	0.0	0.0	0.0	0.0	456
	East total		0.0	1.0	0.2	0.1	0.1	0.0	5.6	37.5	41.3	13.5	0.5	0.2	0.0	0.0	1,100
	West	Winter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	50.0	25.0	0.0	0.0	0.0	0.0	8
		Fall	0.0	0.8	0.0	0.0	0.0	0.0	1.6	41.0	54.1	2.5	0.0	0.0	0.0	0.0	122
	West total		0.0	0.9	0.0	0.0	0.0	0.0	1.5	40.0	53.8	3.8	0.0	0.0	0.0	0.0	130
1999 Total			0.0	1.0	0.2	0.1	0.1	0.0	5.2	37.8	42.6	12.4	0.4	0.2	0.0	0.0	1,230
Grand Total			0.3	1.8	0.9	0.4	0.1	0.1	8.0	33.6	36.8	16.0	1.8	0.1	0.1	0.0	4,687

Table 26. Maximum likelihood estimates (MLE) of the regional stock composition of chinook salmon in incidental catches by U.S. commercial groundfish fisheries in the eastern Bering Sea 1997-1999. The estimates are summarized by (a) brood year (BY) 1991-1995, (b) fishery year and age group, and (c) for the fishery area east of 170°W by fishery season, year, and age group. Fishery season: fall = July-December, winter = January-June. Numbers in parentheses are 95% confidence intervals (CI) derived from 1000 bootstrap runs (random sampling with replacement). An estimate of zero without a confidence interval indicates that the stock was not present. Percentages represented by 0.0 are small numbers, less than 0.05 but greater than zero.

Sample Description	Age(s)	N	Kamchatka		Western Alaska		Cook Inlet		SE Alaska-British Columbia	
			MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
(a) Summary by brood year:										
BY91, 1997-1998	1.4-1.5	373	9.5	(4.2-16.6)	59.5	(48.4-68.4)	31.0	(19.5-41.6)	0.0	(0-4.1)
BY92, 1997-1999	1.3-1.5	530	6.5	(3.3-10.9)	55.8	(47.6-63.0)	32.2	(23.5-40.5)	5.5	(2.4-9.2)
BY93, 1997-1999	1.2-1.4	1111	7.4	(3.5-12.3)	53.6	(44.9-62.2)	30.1	(21.9-39.0)	8.9	(5.9-11.8)
BY94, 1997-1999	1.1-1.3	762	0		65.3	(56.3-73.3)	25.7	(16.6-35.5)	9.0	(5.8-13.4)
BY95, 1998-1999	1.1-1.2	481	3.1	(0.0-8.6)	43.6	(33.6-52.1)	36.4	(24.3-48.5)	16.9	(9.6-24.5)
(b) Summary by fishery year and age group:										
1997	1.2	426	2.6	(0-7.0)	51.7	(42.6-60.4)	37.9	(28.1-47.0)	7.8	(3.8-13.1)
	1.3	345	3.8	(0.7-7.6)	56.8	(47.8-64.8)	31.2	(21.5-41.3)	8.2	(4.4-13.1)
	1.4	342	7.6	(2.6-14.6)	60.4	(50.2-70.3)	32.0	(19.5-42.4)	0.0	(0-5.2)
1998	1.1	141	0		14.6	(5.0-24.9)	52.5	(34.3-70.9)	32.9	(18.1-47.5)
	1.2	316	0		55.5	(44.8-66.3)	34.4	(21.4-46.9)	10.1	(4.3-18.0)
	1.3	559	8.9	(4.3-15.0)	59.0	(49-68.4)	20.8	(11.2-31.6)	11.3	(7.4-15.0)
	1.4	181	13.5	(6.3-22.4)	53.7	(41.2-64.9)	32.7	(19.7-43.5)	0.1	(0-4.3)
1999	1.2	340	5.4	(0.5-12.6)	57.6	(44.5-68.3)	25.7	(13.0-40.4)	11.3	(5.1-18.2)
	1.3	381	0		75.4	(65.8-82.8)	17.2	(9.4-26.7)	7.4	(4.2-11.1)
	1.4	126	27.8	(14.1-42.4)	31.4	(12.5-52.6)	37.3	(17.4-55.5)	3.5	(0-9.6)

Table 26. Maximum likelihood estimates (MLE) of the regional stock composition of chinook salmon in incidental catches by U.S. commercial groundfish fisheries in the eastern Bering Sea 1997-1999 (continued).

Sample Description	Age(s)	N	Kamchatka		Western Alaska		Cook Inlet		SE Alaska-British Columbia	
			MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
(c) Summary for the fishery area east of 170°W by fishery season, year, and age group:										
Fall 1998	1.1	134	0		11.2	(1.5-21.5)	53.1	(34.1-71.7)	35.7	(20.3-52.0)
Fall 1997	1.2	286	3.9	(0.0-9.2)	33.1	(23.7-43.5)	53.1	(40.4-63.9)	9.9	(4.9-16.3)
Fall 1998	1.2	249	0		54.3	(42.6-65.8)	35.6	(21.1-49.6)	10.1	(3.8-17.5)
Fall 1999	1.2	222	3.4	(0.0-10.5)	62.9	(47.0-74.9)	28.2	(14.8-42.2)	5.5	(0.6-11.7)
Winter 1997	1.3	240	6.0	(1.7-10.9)	59.5	(49.1-68.7)	26.8	(16.8-38.2)	7.7	(3.0-13.1)
Winter 1998	1.3	428	8.0	(3.0-14.2)	58.7	(45.9-68.9)	20.7	(11.3-33.1)	12.6	(8.2-17.1)
Winter 1999	1.3	279	0		72.8	(63.2-81.2)	17.5	(8.9-27.0)	9.7	(5.6-14.5)
Winter 1997	1.4	327	8.3	(2.7-15.5)	59.4	(49.0-68.6)	32.3	(19.5-43.4)	0.0	(0-5.6)
Winter 1998	1.4	178	12.7	(4.9-21.9)	54.3	(41.4-66.0)	32.9	(19.0-44.9)	0.1	(0-4.5)
Winter 1999	1.4	122	27.9	(13.5-43.5)	32.0	(15.5-53.6)	36.3	(14.9-55.6)	3.8	(0-10.5)

Table 27. Maximum likelihood estimates (MLE) of the western Alaska subregional (Yukon, Kuskokwim, and Bristol Bay) stock composition of chinook salmon in incidental catches by U.S. commercial groundfish fisheries in the eastern Bering Sea portion of the U.S. exclusive economic zone in 1997-1999. The estimates are summarized by (a) brood year (BY) 1991-1995 and (b) for the fishery area east of 170°W by fishery season, year, and age group. Fishery season: fall = July-December, winter = January-June. Numbers in parentheses are 95% confidence intervals (CI) derived from 1000 bootstrap runs (random sampling with replacement). An estimate of zero without a confidence interval indicates that the stock was not present and the data were re-analyzed without those baseline groups. Percentages represented by 0.0 are small numbers, less than 0.05 but greater than zero. Dashes indicate that no baseline data were available for that regional stock group. Bold font emphasizes results for western Alaska subregional stocks.

Sample description	Age(s)	N	<u>Kamchatka</u>		<u>Yukon</u>		<u>Kuskokwim</u>		<u>Bristol Bay</u>		<u>Cook Inlet</u>		<u>SE Alaska</u>		<u>British Columbia</u>	
			MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)	MLE	(95% CI)
(a) Summary by brood year:																
BY91	1.4-1.5	373	4.1	(0.0-10.0)	37.2	(17.2-56.1)	27.0	(4.4-47.4)	4.2	(0.0-12.1)	27.5	(18.3-37.5)	-	-	0	
BY92	1.3-1.5	530	6.0	(2.5-9.6)	29.7	(16.6-39.9)	5.5	(0.0-22.1)	21.0	(12.4-29.2)	33.4	(24.6-41.3)	-	-	4.4	(1.5-8.2)
BY93	1.2-1.4	1111	5.9	(3.0-9.5)	12.7	(4.0-23.2)	24.5	(11.4-37.3)	17.9	(11.1-25.3)	28.5	(21.8-34.1)	8.5	(5.7-11.2)	2.0	(0.0-4.1)
BY94	1.1-1.3	762	0		20.2	(12.3-30.4)	0		41.7	(33.9-49.7)	30.0	(20.5-37.5)	8.1	(5.1-11.8)	-	-
BY95	1.1-1.2	481	4.4	(0.1-10.2)	12.2	(4.2-20.7)	15.8	(6.7-24.1)	10.6	(0.0-28.1)	41.9	(28.4-52.4)	15.1	(9.2-22.0)	-	-
(b) Summary for the fishery area east of 170°W by fishery season, year, and age group:																
Fall 1998	1.1	134	0		6.1	(0-15.0)	3.9	(0-9.4)	0		57.7	(37.1-74.8)	32.3	(16.5-47.9)	-	-
Fall 1997	1.2	286	3.8	(0.0-8.7)	0.0	(0-13)	16.1	(1.7-25.4)	17.6	(9.5-28.5)	49.2	(37.1-58.5)	8.5	(3.7-14.5)	4.8	(0.2-10.5)
Fall 1998	1.2	249	0		10.2	(2.5-21.4)	0		41.4	(29.8-51.6)	38.7	(25.5-50.2)	9.7	(4.7-16.2)	-	-
Fall 1999	1.2	222	5.8	(0.0-12.9)	13.0	(2.0-25.3)	18.3	(5.6-33.3)	27.2	(4.5-50.2)	31.3	(16.3-44.7)	4.4	(0.0-9.8)	-	-
Winter 1997	1.3	240	5.7	(1.5-10.4)	24.6	(10.2-38.3)	5.9	(0.0-27.6)	28.0	(14.5-39.5)	30.0	(18.2-40.8)	-	-	5.8	(1.3-11.3)
Winter 1998	1.3	428	4.6	(0.8-9.7)	23.1	(11.2-36.9)	22.8	(6.7-38.8)	17.3	(8.8-27.3)	18.2	(9.9-26.4)	11.9	(7.5-16.3)	2.1	(0-6.3)
Winter 1999	1.3	279	0		34.7	(23.0-47.4)	0		37.6	(27.4-47.8)	18.5	(8.9-28.3)	9.2	(5.3-13.5)	-	-
Winter 1997	1.4	327	3.9	(0.0-9.7)	34.6	(14.8-53.7)	28.4	(6.8-48.9)	4.7	(0.0-13.4)	28.4	20.3-34.6)	-	-	0	
Winter 1998	1.4	178	10.9	(3.8-18.6)	35.0	(17.4-49.9)	12.8	(0.0-34.9)	10.1	(0.0-21.0)	31.2	(19.3-41.9)	-	-	0	
Winter 1999	1.4	122	22.0	(9.1-36.4)	9.9	(0.0-31.2)	32.2	(8.6-50)	2.9	(0-13.5)	28.2	(11.2-44.4)	4.8	(0-10.4)	0	

Table 28. Estimates of the average rate of circulus formation in age-1.0 chinook salmon in June-October in coastal marine waters of southeast Alaska in 1998-2000.

Month	Sample Size*	Number of circuli year to date		360 Days**		Circulus formation rate (no/day)	No. days/circulus
		Mean	s.d.	Mean	s.d.		
June	10	5.7	1.95	173.6	2.06		
July	55	9.5	2.33	200.2	1.37		
Aug	36	14.4	2.76	235.1	2.72		
Sept/Oct	79	18.6	3.44	269.5	3.77		
Difference June-July		3.8		26.6		0.14	7.0
Difference July-Aug		4.9		34.9		0.14	7.1
Difference August-Sept/Oct		4.2		34.4		0.12	8.1

*Note: 2 outliers removed from analysis

** number of days from Jan 1 to capture based on 360 day year

Appendix 1.

Davis, N.D. 2003. Feeding ecology of Pacific salmon (*Oncorhynchus* spp.) in the central North Pacific Ocean and central Bering Sea, 1991-2000. Ph.D. Dissertation. Hokkaido University, Hakodate, Japan. 190 p.

Abstract

The food habits and feeding ecology of salmon in the North Pacific Ocean and Bering Sea in summer (June-July) were investigated using a historical database of food habits data collected during a decade of *Wakatake maru* salmon surveys. The food habits of salmon in the southern area (41°-44°N) of the central North Pacific Ocean were characterized by low consumption of the squid, *Berryteuthis anonychus*. Chum consumed gelatinous zooplankton including intact salps, and both chum and coho salmon fed upon salp barrels containing the hyperiid amphipod, *Phronima sedentaria*. Steelhead consumed polychaetes and floating debris (plastic sheet, bits of wood). Salmon feeding conditions in the southern area of the central North Pacific Ocean were the poorest of the three areas studied.

Salmonids in the northern area of the central North Pacific (45°-51°N) were characterized by high levels of stomach fullness. Large (>1000 g body weight) immature and maturing sockeye, pink, coho, and chinook salmon, and steelhead consumed a high proportion of large-sized *B. anonychus* (40-125 mm mantle length), a calorically-rich prey item. In addition, fish prey such as *Gasterosteus aculeatus*, *Pleurogrammus monopterygius*, and *Tarletonbeania crenularis* (30-85 mm SL) were consumed by large coho and chinook salmon, and steelhead. In this area, chum salmon, greater than 1000 g body weight, occasionally fed on large *B. anonychus*, in addition to the more common gelatinous zooplankton, pteropods, heteropods, appendicularia, and ostracods found in their stomach contents. Due to relatively high consumption of *B. anonychus* by salmon in the northern area of the central North Pacific Ocean (45°-51°N), this region was a particularly favorable feeding area for large immature and maturing salmon.

Feeding conditions in the central Bering Sea were characterized by young sockeye, chum, pink, and chinook salmon (<1000 g body weight) that ingested a diverse diet with relatively high proportions of juvenile fish and juvenile squid, in addition to euphausiids and other large zooplankton. The juvenile fish prey were approximately 12-30 mm SL, and the juvenile squid were in the 9-30 mm ML size range. The summertime feeding environment in the central Bering Sea seems to be critically important to small, young (age-.1) immature sockeye, chum, and chinook salmon.

Reduction of high quality prey in the stomach contents of sockeye, chum, and pink salmon was substantial when pink salmon were abundant in the central Bering Sea. Reduction in the proportion of high quality prey was 53% in sockeye, 50% in chum, and 33% in pink salmon during odd-numbered years when pink salmon was abundant. There were substantial decreases in the weight of euphausiids, a high caloric-density prey, and increases in pteropods and hyperiid amphipods, a lower caloric-density prey, in the stomach contents of sockeye, chum, and pinks when pink salmon was abundant. The shift in prey composition observed in chum, sockeye, and pink salmon was due primarily

to resource limitation stemming from feeding competition among salmon. Density-dependent interactions occur in odd-numbered years when abundant maturing pink salmon migrate through the central Bering Sea on their return migration to the rivers of eastern Kamchatka, which negatively affect energy consumed by sockeye, chum, and pink salmon. Chum salmon have a unique alimentary system that enables them to exploit abundant, slow moving gelatinous zooplankton when availability of crustacean prey is reduced by feeding competition.

Diel catches and food habits analysis of sockeye, pink, and chum salmon were investigated between 57°33'N, 178°41'W and 57°27'N, 178°20'W in the central Bering Sea. Eight operations were conducted in a 24-hour period using a surface gillnet. Sockeye, chum, and pink salmon were caught at the surface during each of the six daylight gillnet operations, evidence these species spent some time at the surface during daylight periods. More sockeye salmon were caught during daylight and less during the night than would be expected with equal catches in every time period. Pink salmon catches were small in the afternoon and early evening, however, increased dramatically after sunset and remained at a high level until after sunrise. Chum catches increased shortly after sunrise and after noon, however, catches were independent of daytime or nighttime. Food habits of sockeye salmon illustrated a diel pattern where stomach fullness was significantly greater during the night than during the day (ANOVA, $p < 0.001$, $df = 1$). However, stomach fullness of pink and chum salmon was not significantly different between day and night (ANOVA, $p = 0.07$; $p = 0.90$, $df = 1$). There was a distinct change in the prey composition in sockeye and pink salmon stomach contents over the diel period, as euphausiids and copepods were consumed at night and fish was consumed during the day. Chum salmon consumed euphausiids during nighttime and fish during daylight, however, gelatinous zooplankton was consumed throughout the diel period. At night, competition for euphausiids may intensify when pink salmon are abundant and the period of darkness is short, as is the case during summer at high latitudes. Therefore, a daytime switch to feeding on fish by sockeye, pink, and chum salmon may be a mechanism to decrease food competition.

Caloric density determinations were determined by bomb calorimetry on a variety of salmonids, salmon prey organisms, and salmon stomach contents. Caloric density ranged from 470 to approximately 1000 calories per g wet weight for pteropods, hyperiid amphipods, small flat fish juveniles (approximately 20 mm SL), and small squid (<20 mm ML). Slightly larger fish (21-44 mm SL), and middle-sized squid (40 mm ML) had caloric densities ranging from approximately 1100 to 1500 calories per g wet weight. Prey containing the highest caloric density (>1500 calories per g wet weight) included large *B. anonychus* (80-90 mm ML), deep sea smelt, *Leuroglossus schmidtii*, and northern lampfish, *Stenobranchius leucopsarus* (43-112 mm SL). Caloric values were reported for the first time for small squid (13-22 mm ML; 850-1010 calories per g wet weight) and juvenile flatfish including *Atheresthes* sp. (20 mm SL; 624 calories per g wet weight) and *Hippoglossus stenolepis* (19 mm SL; 853 calories per g wet weight), which were important prey of sockeye, chum, pink, and chinook salmon in the central Bering Sea.

Bomb calorimetry indicated juvenile chum (age 0.0) and pink salmon (age 0.0), and young steelhead (age 2.0) had lower energy density than older steelhead (age 3.0) and sockeye that had spent one year at sea (age 1.1). Caloric determinations of stomach contents collected from similar-sized sockeye, chum, and pink salmon showed energy

density was lowest in chum salmon (270 to 739 calories per g wet weight). A comprehensive table of energy densities was compiled for species ecologically-related to Pacific salmon. Caloric values were listed for cnidarians (n=14), ctenophorans (n=14), polychaetes (n=7), pteropods (n=8), squids (n=22), copepods (n=20), euphausiids (n=34), amphipods (n=12), ostracods (n=1), mysids (n=5), decapods (n=11), chaetognaths (n=6), salps (n=3), appendicularia (n=1), and fish (n=122). Tabulated caloric values increase the accessibility of this information to researchers involved in studies of bioenergetics and feeding ecology of salmonids and other animals inhabiting the North Pacific and Bering Sea.

Salmon growth and prey consumption were estimated for a two-month summer period using field observations on sea surface temperatures, salmon food habits in the central North Pacific Ocean and central Bering Sea, data on caloric density of salmon and salmon prey, and a published fish bioenergetic model. Growth estimates from the model were compared with summer monthly mean weights of high-seas caught salmon to evaluate daily ration. Model consumption estimates indicated an ocean age .1 sockeye needed to consume 16-19 g of prey per day, the equivalent of 3.57 to 4.09% body weight per day, depending on temperature (5°-9°C). The specific energy requirements for small sockeye salmon were the first available for young ocean age .1 sockeye in the Bering Sea. Simulation results showed an immature chum salmon required a daily consumption rate of 42 to 49 g prey per day (3.28-3.86% body weight per day) and a daily prey consumption of 30-35 g per day for a maturing pink salmon (2.73-3.14% body weight per day), depending on temperature (5°-9°C). A maturing coho salmon would require 63-68 g of prey (2.64-2.86% body weight per day) at 9° to 11°C. My estimates of daily ration for maturing coho salmon were the first determined for adult coho in offshore marine habitats.

Simulation results suggested salmon feeding rate was close to their physiological maximum (85 to 93% of the maximum for immature sockeye and chum, 86 to 96% of the maximum for maturing pink and coho salmon). Therefore, small decreases in the daily ration can cause significant decreases in growth over a relatively short time period, and prey consumption was more important than temperature for determining salmon growth at summertime temperatures. When salmon prey is abundant, an upper thermal limit favorable for salmon growth may be bounded by large metabolic requirements at high temperatures, and a lower limit favorable for salmon growth may be bounded by decreased capacity for prey consumption at low temperatures.

In summer, the central Bering Sea is critical habitat for salmon because it serves as a nursery area for juvenile fish and juvenile squid, and these small prey organisms provide a rich forage base for feeding of Asian and North American stocks of young sockeye, chum, and chinook, and maturing chum and pink salmon. Recent reductions in productivity suggest important environmental changes may be occurring in the Bering Sea. Therefore, monitoring year-round conditions of prey availability and salmon feeding and growth is advised so we may best manage the future of our salmon resources.