

**COOPERATIVE JAPAN-U. S. HIGH SEAS SALMONID RESEARCH
IN 1991: SUMMARY OF RESEARCH ABOARD THE JAPANESE
RESEARCH VESSEL *WAKATAKE MARU*,
4 JUNE TO 23 JULY**

by

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COOPERATIVE JAPAN-U. S. HIGH SEAS SALMONID RESEARCH IN 1991: SUMMARY OF RESEARCH ABOARD THE JAPANESE RESEARCH VESSEL WAKATAKE MARU, 4 JUNE TO 23 JULY

ABSTRACT

Two Japanese and one U. S. scientist participated in the cruise of the Japanese research vessel *Wakatake maru* from 4 June to 23 July, 1991. Salmonids (*Oncorhynchus* spp.) and neon flying squid (*Ommastrephes bartramii*) were collected by longline (31 stations), midwater trawl (31 stations), squid jigs (23 stations), and gillnet (18 stations) in the North Pacific Ocean and Bering Sea along a transect at 179°30'W longitude from 38°N to 58°N latitude. In total, 19,875 salmonids and 225 neon flying squid were caught. Pink salmon (*O. gorbuscha*) were the most abundant species (72% of the salmonid catch) followed by chum (*O. keta*, 16%), coho (*O. kisutch*, 7%), and sockeye salmon (*O. nerka*, 3%). Chinook salmon (*O. tshawytscha*) and steelhead (*O. mykiss*) were in low abundance (each equaled 1% of the catch), and two Dolly Varden (*Salvelinus malma*) were caught (less than 1%). A total of 293 salmonids was tagged and released (mostly pink and chum salmon). Six coho salmon were caught coincident with neon flying squid in the vicinity of the subarctic boundary, but their distributions did not substantially overlap. The transition zone was characterized by an abundance of coho salmon and steelhead. Chum, pink, chinook, and sockeye salmon were also distributed in the transition domain, but these species were more abundant in the Bering Sea. Stomach contents from 579 chum, 531 pink, 128 coho, 93 sockeye, and 33 chinook salmon, and 14 steelhead trout, 115 Pacific pomfret (*Brama japonica*), 8 Atka mackerel (*Pleurogrammus monopterygius*), and 7 walleye pollock (*Theragra chalcogramma*) were identified to major taxonomic groups. The stomachs of chum salmon most often contained unidentifiable, heavily-digested material, but amphipods were also common. Pink salmon had the most diverse diet, which was commonly comprised of pteropods, amphipods, euphausiids, copepods, and squids. Pteropods, euphausiids, and amphipods were also common in the stomachs of sockeye salmon. Squid, fish, and euphausiids were commonly found in the stomachs of chinook salmon. Coho salmon and steelhead frequently consumed squid. Digestion rates were 20% of stomach content weight per hour for chum salmon and 15% of stomach content weight per hour for pink salmon. Recommendations for future high seas salmonid research include investigating the factors affecting the distribution of neon flying squid and salmonids, examining whether or not density-dependent effects influence salmon survival and growth at sea, estimating the daily ration of salmonids, and studying the distribution and abundance of squids that are an important prey of coho salmon and steelhead trout.

INTRODUCTION

In 1990, the Sub-Committee on Salmon recommended, in part, to the International North Pacific Fisheries Commission (INPFC) that research "with respect to oceanographic conditions, distributions of salmonids and squid and their prey ... and the incidence of salmonids in the area of the squid driftnet fishery" be continued in 1991. In partial response to this recommendation, the Fisheries Agency of Japan (FAJ) chartered the research vessel, *Wakatake maru*, and invited a U.S. scientist to participate cooperatively in the research cruise.

Research objectives were to identify oceanographic conditions, investigate distributions of squid (*Ommastrephes bartramii*) and salmonids (*Oncorhynchus* spp.), examine food

habits of salmonids and other pelagic fishes, identify species and abundance of plankton, and measure primary productivity. This report summarizes research on oceanography, phytoplankton biomass, squid and salmonid distribution, and fish feeding habits. Analysis of plankton collected by Norpac net and a fish larval net, and measurements of primary productivity require detailed post-cruise laboratory analysis, and therefore, results from these studies will not be included in this summary. In addition, this vessel served as a sampling platform of opportunity for other researchers who will report results of their studies elsewhere. These studies included, chum stock identification using gel electrophoresis, DNA analysis of salmonids, infestation of salmonids by the salmon louse, *Lepeophtheirus salmonis*, collection of sea birds incidentally taken in fishing operations, and marine mammal sighting surveys.

METHODS

OCEANOGRAPHIC CONDITIONS

The cruise track of the *Wakatake maru* included a total of 31 stations. Twenty-one stations were located along a transect at 179°30'W longitude from 38°30'N to 58°30'N latitude (Stations 1-23, excluding Stations 14 and 15, Fig. 1). Ten stations did not fall along this transect. These 10 stations were located at 50°30'N (Stations 14 and 15), 57°30'N (Stations 24 and 25), and 56°30'N (Stations 26-31). At each of the 31 stations, oceanographic data including temperature and salinity were recorded at 1-m intervals to a depth of 400 m, or more, using an Alec Memory S. T. D. sensor (Alec Electronics Co. Ltd., Japan).

ESTIMATES OF PHYTOPLANKTON BIOMASS

Chlorophyll *a* ($\mu\text{g/l}$) was measured as an index of phytoplankton biomass at the 21 stations located along the transect at 179°30'W longitude (Stations 1-23, excluding Stations 14 and 15). A 500-ml sample of surface seawater (prefiltered to remove large zooplankters) was suctioned through a glass fiber filter (Whatman GF/F) and kept frozen at -20°C. Several weeks later, in the laboratory, pigments were extracted from the phytoplankton cells and the chlorophyll *a* estimated fluorometrically.

DISTRIBUTION OF SALMONIDS AND SQUID

Salmonids and squid were collected using four types of fishing gear that included longline, gillnet, midwater trawl, and hand-operated squid jigs.

Longline

Longline operations were conducted every evening at one of 31 stations between June 12 and July 12 (Fig. 1). The crew set the longline before sunset, and allowed 30 minutes to elapse after they finished setting the line before they started to haul it aboard. Thirty hachi (units of longline, each unit contains 120 m of longline and 49 hooks) were fished at all operations.

The sampling routine for salmonids included counting the presence and location of salmon lice, measuring fork length and body weight, and collecting scale samples. If the fish was not frozen whole, the gonads were weighed and other tissues were collected, such as stomach (for stomach content analysis), muscle, heart, liver, and retina (for gel

electrophoresis) from up to 100 chum salmon (*O. keta*), and liver (for DNA analysis) from up to 10 fish of each salmonid species caught. Sampling routine for non-salmonids included measuring fork length and body weight, and removing the stomach (for stomach content analysis). In the case where more salmonids were caught than were needed for digestion experiments, a disk tag was applied immediately anterior to the dorsal fin and the fish was released.

Gillnet

Gillnet operations were conducted at 14 stations along those portions of the transect outside the U.S. 200-mile exclusive economic zone (EEZ), and four additional sets were made at stations in the central Bering Sea at 56°30'N and 57°30'N (Fig. 1, Appendix Table 1). The gillnet was set in the early evening and allowed to fish until after sunrise the following morning. The gillnet was 80 tans in overall length. Thirty tans comprised of variable research-mesh (three tans each of 48 mm, 55 mm, 63 mm, 72 mm, 82 mm, 93 mm, 106 mm, 121 mm, 138 mm, and 157 mm) and the remaining 50 tans comprised of commercial-mesh (115 mm). Salmonid catch was sorted by mesh size. Appendix Table 2 summarizes the numbers of salmonids sampled and the items measured. In addition, up to 100 salmonids of each species were inspected for the location and abundance of salmon lice. Catches of other fish, squid, sea birds, and marine mammals were also sorted by mesh size and counted. Catch per unit of effort (CPUE) was calculated separately for research-mesh (catch in research-mesh divided by 30) and for commercial-mesh (catch in commercial-mesh divided by 50).

Midwater Trawl

Trawling operations were conducted at 31 stations shortly before sunset, except Station 31 where the trawl was set in the early morning (Fig. 1, Appendix Table 3). The general procedure was to tow the trawl once at each station for one hour. Net depth (distance between the surface of the water and the bottom of the net) was 20 meters and net height (vertical size of the net opening) was 16 meters. Deviation from this procedure at Stations 15, 20, and 29 included additional tows or longer tows (Appendix Table 3). The stretched mesh size of the codend liner was 20 mm (Appendix Figure 1). Fish caught in the trawl were measured for body length and weight, and the stomachs were removed for stomach content analysis.

Squid Jigging

At night, hand jigging was done at 21 stations along the transect at 179°30'N (Fig. 1, Appendix Table 3). Five people jigged for 30 minutes except at Stations 5, 9, 11, and 13 where fishing time varied from 20 to 45 minutes. The catch was identified to species, the number counted, and total wet weight measured for each species.

SALMONID FOOD HABITS

Fish Stomach Content Analysis

A maximum of 20 fish stomachs were collected from each species of salmonid and other species of pelagic fish caught in longline and trawl operations. The fish's stomach was removed from the esophagus to the pyloric valve. The procedure used for stomach examination was similar to that of Davis (1990). Each stomach was weighed to the nearest gram; the contents were removed, and the stomach was weighed again. Weight of stomach contents was determined by subtraction. Stomach contents were examined visually without magnification and identified to major prey categories that included the following: fishes, squids, copepods, euphausiids, amphipods, pteropods, appendicularia, chaetognaths, gelatinous zooplankton, other, and unidentified material. "Other" category included the following groups: mysids, zoea, polychaetes, shrimps, and isopods. "Unidentified

material" was composed of material that could not be identified confidently to taxonomic group without magnification, or that was too heavily digested to identify. Percent volume of each prey category was estimated by eye; the fullness of the stomach and the degree of digestion were also noted. After data were collected on individual stomach contents, contents were combined from each species and stored in 10% formalin solution for examination in the laboratory, where the contents will later be identified to the genus or species level.

Fish were caught on longlines baited with salted anchovy (*Engraulis japonicus*). If bait was present in the stomach, bait weight was subtracted from the weight of stomach contents because it was not considered as prey. Likewise, a stomach containing only bait was considered empty. Percent occurrence of each major prey category and the index of stomach content weight (stomach content weight X 100/ body weight) was calculated for sockeye (*O. nerka*), chum, pink (*O. gorbuscha*), coho (*O. kisutch*), and chinook salmon (*O. tshawytscha*), steelhead trout (*O. mykiss*), Pacific pomfret (*Brama japonica*), walleye pollock (*Theragra chalcogramma*), and Atka mackerel (*Pleurogrammus monopterygius*).

Chum and Pink Salmon Digestion Experiments

Rate of digestion was estimated by measuring the decrease in the index of stomach content weight over time. Approximately 20 live pink or chum salmon were collected from the longline catch and put into a tank. Although the temperature of the sea water supplied to the tank was not monitored, the sea surface temperature measured at the stations where these experiments were conducted varied from 6.6°C to 8.5°C. Approximately 5 fish were sacrificed at predetermined times of the day, i. e., 2300, 0200, 0500, and 1000 hours. The fish's stomach was examined as just described, and the index of stomach content weight was calculated. Five experiments each on chum and pink salmon were conducted, and the data from the five experiments was pooled together.

Several digestion rates (10%, 15%, and 20% loss of stomach content weight per hour) were simulated to determine which rate matched the observed decrease in the stomach content weight over time. The rate that matched the observed values was used as the estimate of digestion rate.

RESULTS

OCEANOGRAPHIC CONDITIONS

Vertical profiles of temperature (°C) and salinity (parts per thousand) were plotted from oceanographic data collected at 21 stations along the transect at 179°30'W (Figs. 2 and 3). The vertical 34.0 isohaline at 40°30'N indicated this was the vicinity of the the subarctic boundary (Fig. 3, Station 3, Dodimead et al. 1963, Favorite et al. 1976). The subarctic boundary is believed to be the southern limit of salmonid distribution, and Station 3 was the most southerly station where salmonids were caught (six coho, Appendix Table 1, Favorite et al. 1976).

The northern boundary of the transition domain is difficult to discern (Favorite et al. 1976), but the temperature profile indicates that at 46°30'N cold water (less than 4°C) rose to less than 150 m from below 500 m, indicating the boundary with the subarctic current (Fig. 2). Between 46°30' and 50°30'N, temperature and salinity had a homogeneous horizontal component indicating the eastward flowing subarctic current (Stations 9 through 13, Figs. 2 and 3).

The cruise track crossed the Aleutian Islands at Amchitka Pass (51°30'N and 52°30'N, Stations 16 and 17, Figs. 1, 2, and 3). Temperature and salinity profiles showed abrupt changes over short distances, as water masses mixed horizontally around islands and vertically over shallow banks (Petrel Bank, Station 17). In the Bering Sea, cold water (less than 3.0°C) appeared close to the surface (less than 100 m) and a cold core of water (2.0° to 2.5°C) occurred between 50 and 200 meters with warmer water (3.5°C) at greater depths (53°30'N to 58°30'N, Stations 18 through 23).

ESTIMATES OF PHYTOPLANKTON BIOMASS

Chlorophyll *a* was estimated to range almost twenty-fold from a low in the North Pacific Ocean at 44°30'N to a high in the central Bering Sea at 57°30'N latitude (0.08-1.58 µg/l, Fig. 4). Concentrations were consistently at or below 0.30 µg/l south of the subarctic current (Station 11, 48°30'N), except for the high value found at the subarctic boundary (0.76 µg/l at Station 3, 40°30'N). North of 48°30'N in the North Pacific Ocean and Bering Sea, chlorophyll *a* concentrations ranged between 0.44 and 0.97 µg/l, except where large concentrations (greater than 1.50 µg/l) were found in Amchitka Pass and the central Bering Sea (Stations 16 and 22).

DISTRIBUTION OF SALMONIDS AND SQUID

In total, 19,875 salmonids and 225 neon flying squid were caught by longline, gillnet, trawl, and squid jigs (Table 1). Pink salmon were the most abundant species (72% of the salmonid catch) followed by chum (16%), coho (7%), and sockeye salmon (3%). Chinook salmon and steelhead were in low abundance (each equaled 1% of the catch), and two Dolly Varden were caught (less than 1%). A total of 293 salmonids (mostly pink and chum salmon) was tagged and released (Table 2). This number is small because tagging was a low priority for this vessel and many fish were sacrificed for digestion experiments.

Longline catch was used as a measure of abundance along the transect because fishing duration and the number of hooks were kept constant at all stations and because operations were conducted in the U.S. 200-mile EEZ, where gillnet operations were prohibited (48°30' to 54°30'N, Stations 11-19, Fig. 5). The only station where neon flying squid and salmon occurred together was at Station 3, 40°30'N, where squid was abundant and six coho salmon were caught (sea surface temperature [SST]=12.6°C, Figs. 5 and 6, Appendix Table 1). Coho were most abundant at 45°30'N (SST=9.4°C), but three coho salmon were caught north of 47°30'N (SST=7.1°C). Steelhead were most abundant at 44°30'N (SST=10.3°C), but were caught as far south as 42°30'N (Station 5, SST=10.7°C) and as far north as 47°30'N (SST=7.1°C, Figs. 5 and 6, Appendix Table 1). Chum salmon were caught at all stations north of 42°30'N (SST=10.7°C) and were abundant south of the Aleutian Islands at 50°30'N (SST=6.5°C) and also in the Bering Sea, north of 53°30'N (Figs. 4 and 5, Appendix Table 1). A few chinook salmon were caught between 42°30'N (SST=10.7°C) and 47°30'N (SST=7.1°C), but were most abundant in the Bering Sea north of 55°30'N (SST=6.3°C). Sockeye salmon were most abundant north of 53°30'N (SST=6.6°C). Pink salmon were caught at all stations north of 45°30'N (SST=9.4°C) and were abundant north of 50°30'N (SST=6.5°C, Figs. 5 and 6, Appendix Table 1).

SALMONID FOOD HABITS

Stomach Content Analysis

A total of 1,253 fish stomachs were examined from longline and trawl catches (Table 3). Chum (n=469), pink (n=430), sockeye (91), coho (n=86), and chinook salmon (n=33), and steelhead (n=14) were examined, and other fish including pomfret (n=115), Atka mackerel (n=8), and walleye pollock (n=7) were examined.

The data from longline-caught fish examined for stomach content analysis were summarized by species and by grouping the stations along the transect (Tables 4-12). The groupings were based on a combination of oceanographic (subarctic boundary, subarctic current) and geographic features (Aleutian Islands and the Bering Sea), and a biological consideration that 47°30'N (Station 10) was the northern extent of major coho salmon and steelhead catches. The result was five groups: south of the subarctic boundary (Stations 1-2), transition area (Stations 3-10), subarctic current area (Stations 13-15), Aleutian Islands (Stations 16-17) and Bering Sea (Stations 18-23).

Pteropods, euphausiids, and amphipods were a major component of the prey of sockeye salmon ranging from 49% to 77% of the prey found (Table 4). Fishes and squids were eaten more frequently in the Aleutian Islands and Bering Sea than in the subarctic current area. The index of stomach content weight in the subarctic area, Aleutian Islands, or Bering Sea, was small as compared to chum, pink, and coho salmon (range 0.50 to 0.61).

In all areas, "unidentified material" was a common prey category of chum salmon (18% to 57%, Table 5). Amphipods were an important prey category in the transition, subarctic, and Aleutian Islands area, but their diet was more diverse in the Bering Sea where appendicularia was abundant in their stomachs. The index of stomach content weight was two to three times higher than that of sockeye salmon (range 1.19 to 1.55).

Pink salmon had a diverse diet; pteropods, amphipods, euphausiids, copepods, and squids were commonly found in pink salmon stomachs collected from all areas (Table 6). Fishes became more frequent with increasing latitude, and squids were particularly common in pink salmon stomachs examined from the Bering Sea. Mean index of stomach content weight ranged from 1.27 to 1.70 in the transition, subarctic current area, and Bering Sea, but was smaller in the Aleutian Islands area (0.59).

Squids, amphipods, and pteropods were common in the stomachs of coho salmon caught in the transition area (Table 7). One coho was caught in the Aleutian Islands area, and one coho salmon was caught in the Bering Sea, so it is difficult to generalize about coho prey preferences with increasing latitude. The index of stomach content weight for coho salmon in the transition area was larger than any of the other salmonid fishes examined (1.80).

Squids, fishes, and euphausiids were common in chinook salmon stomachs collected in the Bering Sea (Table 8). In the transition area, amphipods were also common, but very few fish were examined. The index of stomach content weight was low (0.48 to 0.69) and similar to that of sockeye.

Steelhead were caught only in the transition area, where they were commonly found feeding on squids, amphipods, and fishes (Table 9). The mean index of stomach content weight was similar to the value found for chum and pink salmon (1.56).

Pacific pomfret stomachs were collected from south of the subarctic boundary and in the transition area (Table 10). Pomfret were found with fishes, euphausiids, pteropods, amphipods, squids, and gelatinous zooplankton (mostly ctenophores or jellyfish) in their stomachs in both areas. Euphausiids were more common in the transition area than south of the boundary. The mean index of stomach content weight in the transition area was almost twice the value south of the boundary (0.98 as compared to 0.42).

A few walleye pollock stomachs were examined from fish caught in the Aleutian Islands and Bering Sea ($n=4$, Table 11). In both areas, pollock had euphausiids and amphipods in their stomachs, and in the Bering Sea appendicularia and copepods were also found. One pollock examined from the Aleutian Islands area also contained gelatinous zooplankton. The index of stomach content weight was much lower in samples from the Aleutian Islands area than in samples from the Bering Sea (0.28 as compared to 1.24).

A few Atka mackerel stomachs were examined from fish caught in the Aleutian Islands and Bering Sea ($n=8$, Table 12). In both areas, copepods, euphausiids, squids, and gelatinous zooplankton were found in the stomachs, and fishes were also found in Atka mackerel stomachs collected from the Bering Sea. The mean index of stomach content weight was large in both areas, ranging from 2.05 to 2.46 (Table 12).

Chum and Pink Salmon Digestion Rates

The standard deviation around the mean index of stomach content weight of the five experiments was quite large and in some cases larger than the mean (Table 13). The rate of digestion (d) that best matched the rate observed was $d=0.20$ for chum salmon and $d=0.15$ for pink salmon (Table 13 and Figure 7). This indicates that during the experiment 20% of the weight of stomach contents was removed by digestion every hour from the stomachs of chum salmon and 15% of the weight of stomach contents was removed by digestion every hour from the stomachs of pink salmon.

DISCUSSION

Neon flying squid were found at the southern end of the transect between $38^{\circ}30'N$ and $40^{\circ}30'N$, but were most abundant in the vicinity of the subarctic boundary (Station 3, $40^{\circ}30'N$, SST= $12.6^{\circ}C$, Fig. 6). Coho salmon were the most southerly distributed of the salmonids because they were the only salmonid caught in the vicinity of the subarctic boundary and coincident with neon flying squid. The abundance of coho this far to the south however, was small (six fish caught, Figs 5 and 6, Appendix Table 1). The greatest abundance of squid and coho salmon occurred at Stations 3 and 8, respectively, and they did not substantially overlap.

The transition zone was characterized by large abundances of coho salmon and steelhead trout ($43^{\circ}30'N$ and $45^{\circ}30'N$, Stations 6-8, SST= $9.4-10.8^{\circ}C$, Fig 5 and 6, Appendix Table 1). Chum, pink, and chinook salmon were distributed in the transition domain as far south as $42^{\circ}30'N$ (Station 5, SST= $10.7^{\circ}C$). Sockeye was the most northerly distributed salmonid because it was found only in catches north of $46^{\circ}30'N$ (Station 9, SST= $7.7^{\circ}C$). The area where the distributions of all the salmonids overlapped was the northern area of the transition domain ($46^{\circ}30'N$ to $47^{\circ}30'N$, Stations 9 and 10, Fig. 5 and 6, Appendix Table 1).

Sockeye, pink, and chum salmon were distributed throughout the vicinity of the subarctic current and the Aleutian Islands, but it was in the Bering Sea, north of $53^{\circ}30'N$, that these species and chinook salmon were found in greatest abundance (Appendix Table 1).

Prey commonly found to occur in salmonid stomachs was similar to that listed in the review of Brodeur (1990) and a recent study of high seas salmonid food habits (Davis 1990). The "unidentified" prey category occurred frequently in chum salmon, and amphipods were an important secondary prey category in all these studies. However, we also found a high occurrence of appendicularia (=larvacea) in the stomachs of chum salmon (Table 5). All studies indicated a high frequency of squid and amphipods in coho diets, but we found that euphausiids occurred more frequently and fish less frequently in the stomachs of coho salmon than was found by Davis (1990, Table 7). The index of stomach content weight of chum and pink salmon was generally smaller in our study than in Davis's study (Tables 5 and 6). Methods used to collect data were similar in both studies. Whether or not these differences reflect real biological differences, geographical differences (Davis's study only examined fish from 43°30' to 46°30'N latitude), or annual changes is uncertain.

Rate of digestion depends on several factors including temperature, size and composition of the item to be digested, and the fullness of the stomach. The large variance in the index of stomach content weight may reflect some of these conditions (Fig. 7, Table 13). We combined the data from five digestion experiments to estimate digestion rates. The temperature of the sea water circulated to the live tank may have varied enough (6.6°C to 8.5°C) to cause some variation in the rate of digestion in the five experiments that were pooled together. A further uncertainty associated with the digestion experiments was that initial stomach fullness of the individual fish was unknown at the beginning of the experiment, unlike laboratory experiments where it is possible to start the experiment having fed the fish on a supplied prey item and to feed until satiation or a predetermined amount of time. We used fish caught in evening longline operations in order to minimize the number of fish that would start the experiment with empty stomachs because fish caught in morning longline operations are more likely to have empty stomachs (Davis 1990). The disadvantages of doing digestion experiments in the field may have resulted in increased variability in our observed estimates of stomach content weights. However, our estimates are based on fresh prey that fish are actually eating.

The daily feeding chronology, daily ration, and rate of digestion may be quite different for chum salmon than for the other salmonids. The index of stomach content weight was consistently high for chum salmon in all areas and the digestion rate of chum was slightly faster than that of pink salmon (Tables 5 and 13). Although chum salmon stomachs were not always full, they often contained heavily digested material, and they were rarely completely empty. To compensate for nutritionally low quality prey, e.g., gelatinous zooplankton, chum may increase the frequency of their feeding and digest food items quickly.

RECOMMENDATIONS

1. Research should continue to further elucidate the biotic and abiotic factors affecting the distribution of neon flying squid and salmonids, especially coho and chum salmon, and steelhead trout, in the vicinity of the subarctic boundary.
2. Researchers should investigate whether or not density-dependent effects influence salmon survival and growth at sea, although such effects may be difficult to prove. Return of smaller fish to hatcheries have led some to wonder if density-dependent effects are possibly the cause (Kaeriyama, in press). In 1991, pink salmon were very abundant in the catch of the *Wakatake maru*. If the large abundance of pink salmon affects the feeding ecology of other salmonids, then a survey of feeding habits in

1992, an off-year for Asian pink salmon, might show changes in salmonid feeding ecology associated with reduced pink salmon abundance.

3. Research toward estimating the daily ration of salmonids should be continued to evaluate whether or not there is food limitation for salmonids at sea. To estimate the daily ration, data must be collected on the salmonid diel feeding cycle, in addition to data on digestion rates. Hauling gillnets at short time intervals and longlines during the day and night will provide information on this cycle. It is important to continue the digestion experiments, and to expand them to include other salmonids, especially coho salmon and steelhead trout.
4. Squids are important prey items for coho salmon and steelhead trout. Investigations of important squid species and the factors affecting their distribution will help in the overall understanding of growth and distribution of salmonids in the transition domain.

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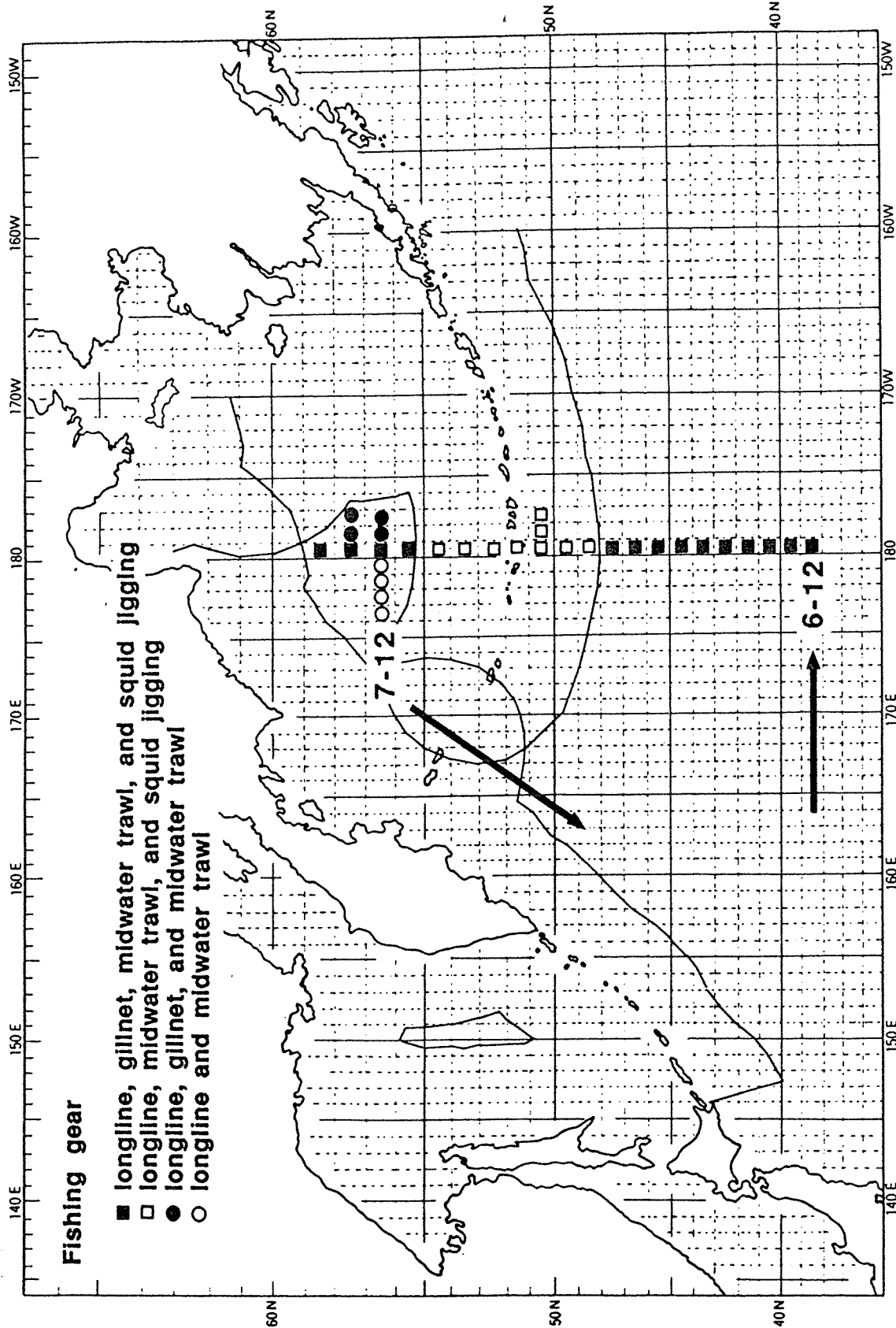


Figure 1. Station locations for the summer 1991 salmon research cruise of the *Wakatake maru*. The cruise track included 31 stations: 21 stations along a transect at 179°30'W longitude (Stations 1-23, excluding Stations 14 and 15), and 10 additional stations located at 50°30'N (Stations 14 and 15), 57°30'N (Stations 24 and 25), and 56°30'N latitude (Stations 26-31).

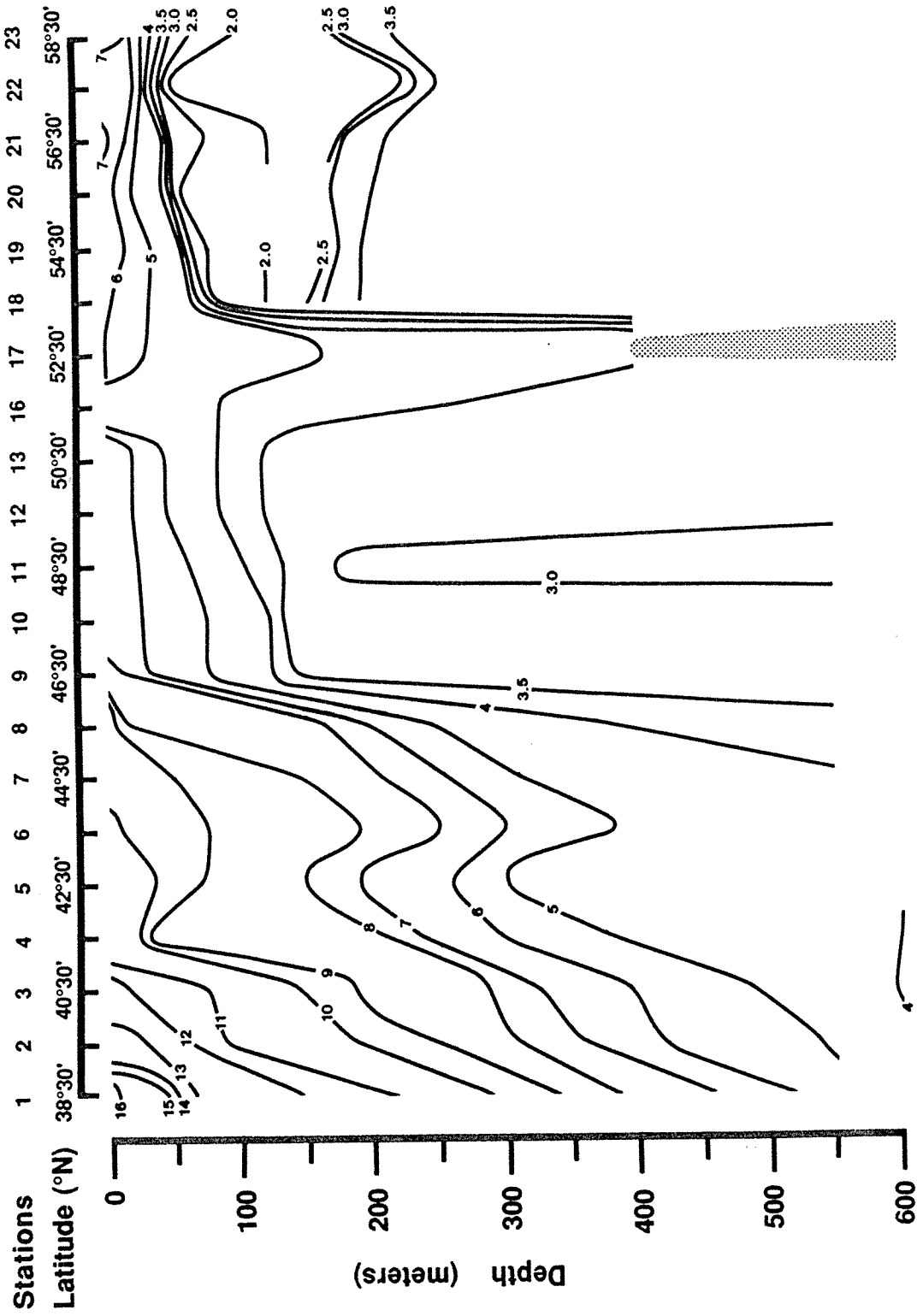


Figure 2. Vertical profile of temperature (°C) at depth (meters) along a transect at 179° 30'W longitude (Stations 1-23, excluding Stations 14 and 15). Stippled area indicates the sea bottom (Petrel Bank).

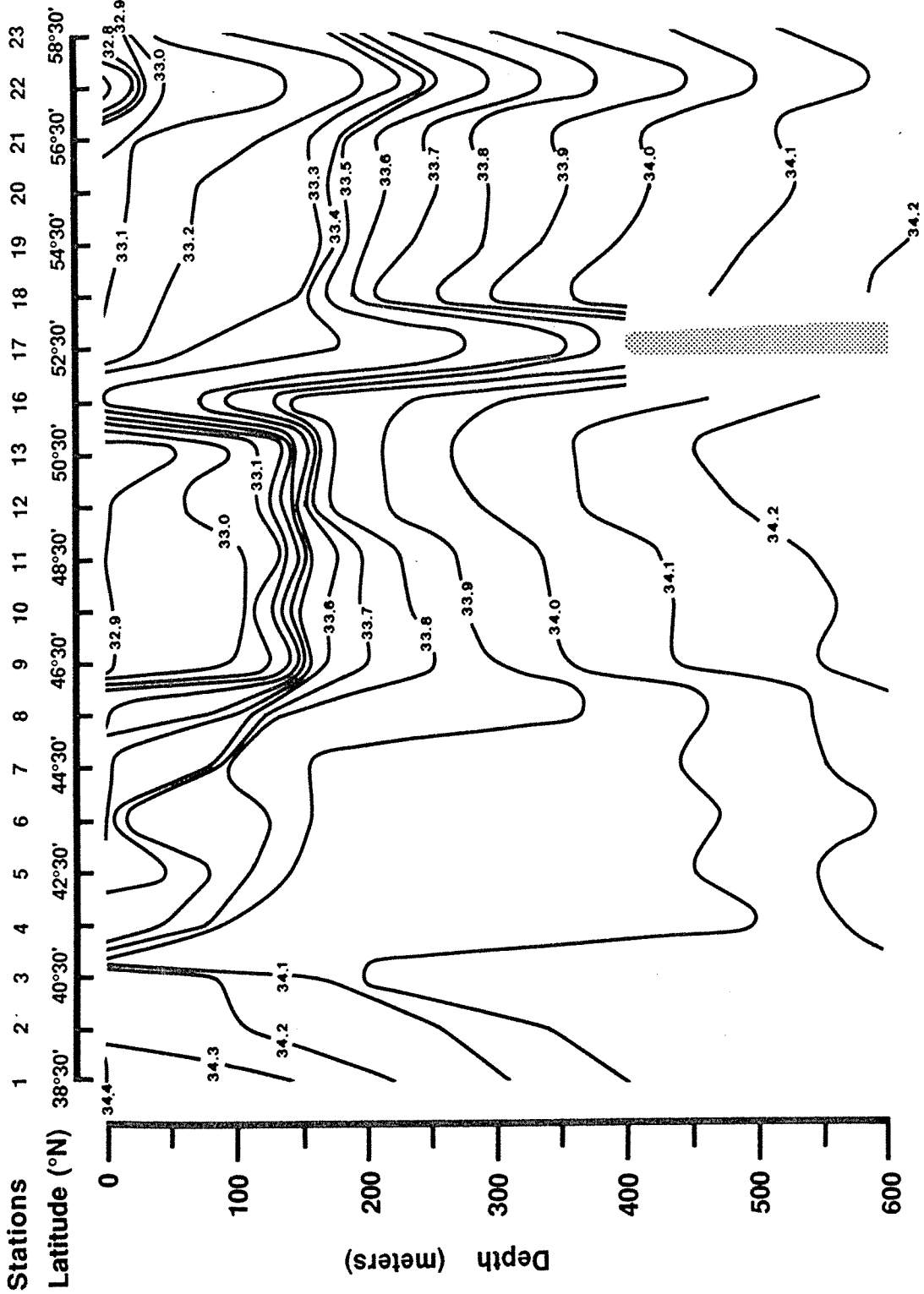


Figure 3. Vertical profile of salinity (parts per thousand) at depth (meters) along a transect at 179° 30'W longitude (Stations 1-23, excluding Stations 14 and 15). Stippled area indicates the sea bottom (Petrel Bank).

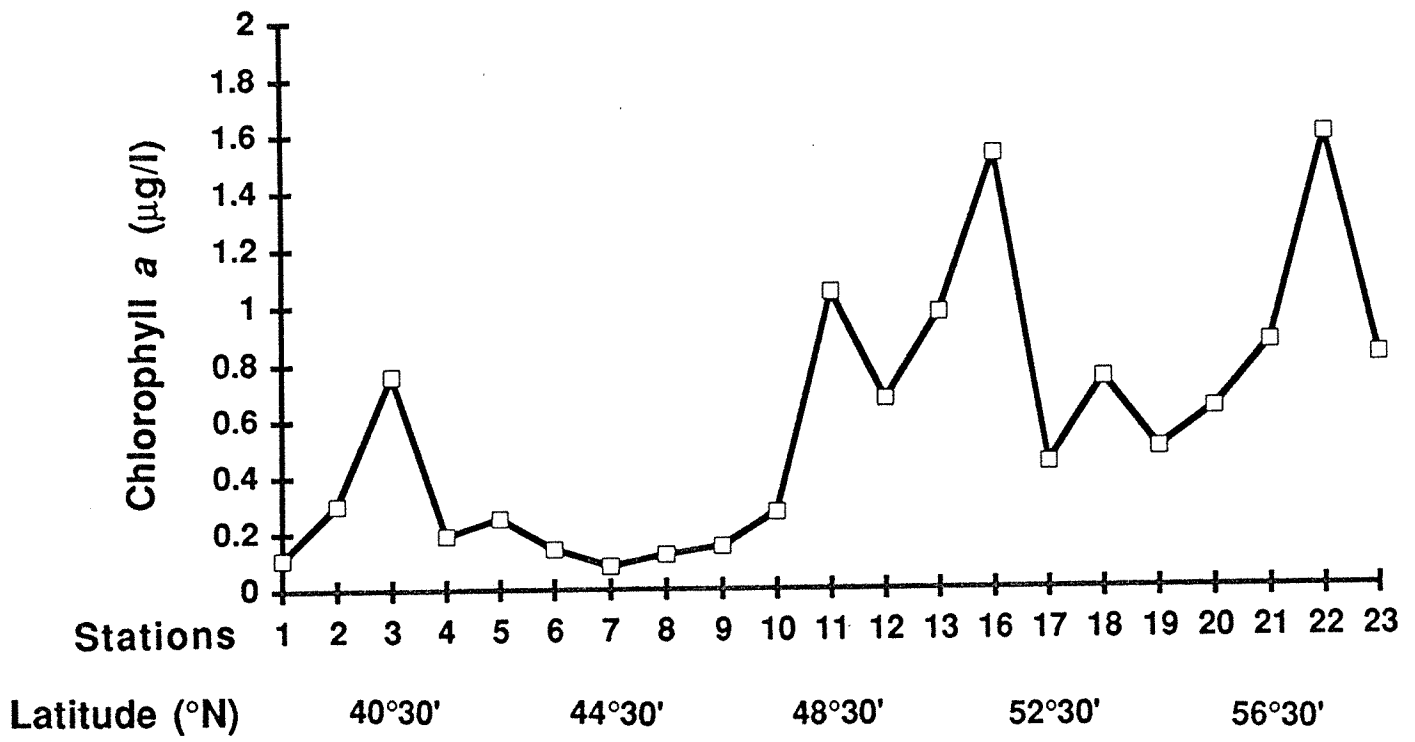


Figure 4. Chlorophyll-*a* ($\mu\text{g/l}$) found in surface water samples taken along a transect at 179°W longitude (Stations 1-23, excluding Stations 14 and 15).

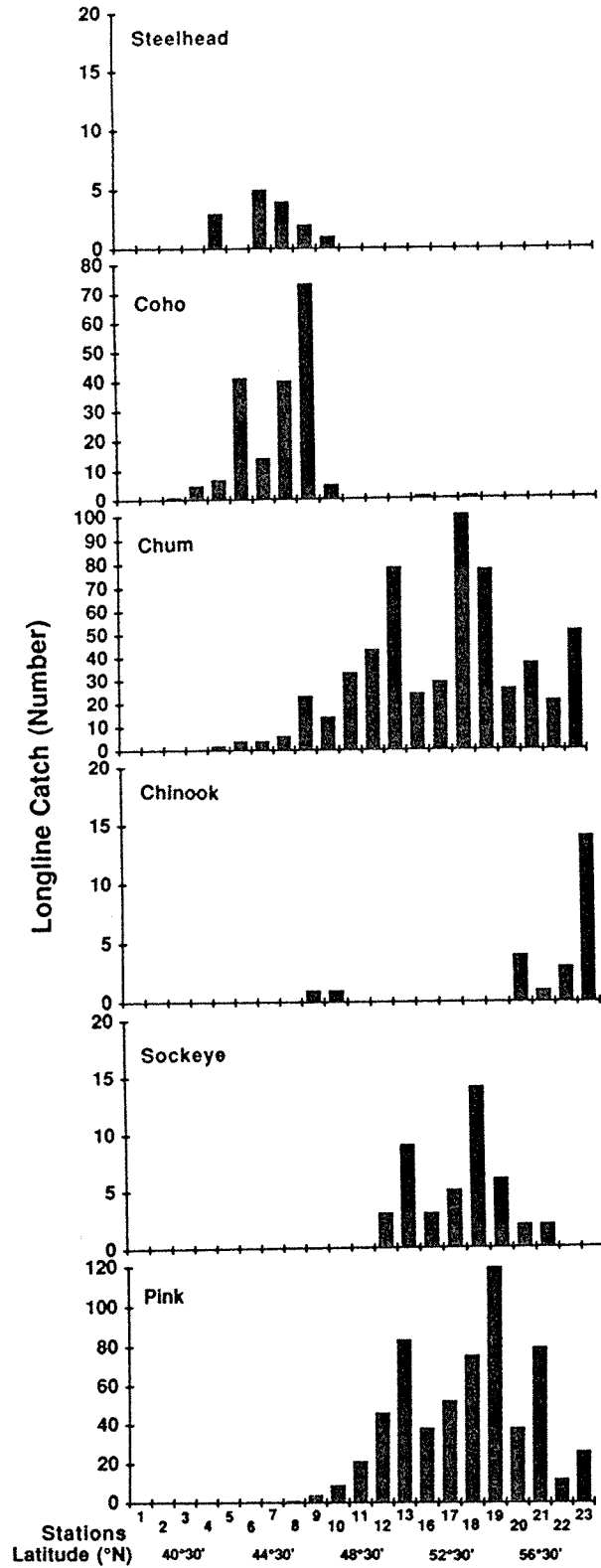


Figure 5. Number of salmonids caught by longline at stations along a transect at 179°30'W longitude (Stations 1-23, excluding Stations 14 and 15). Longline fishing effort is the same for all stations. Set duration is 30 minutes (time from end of setting the longline until the start of retrieval). The longline is 30 hachi in length (hachi are units of longline and each unit is 120 m long and has 49 hooks).

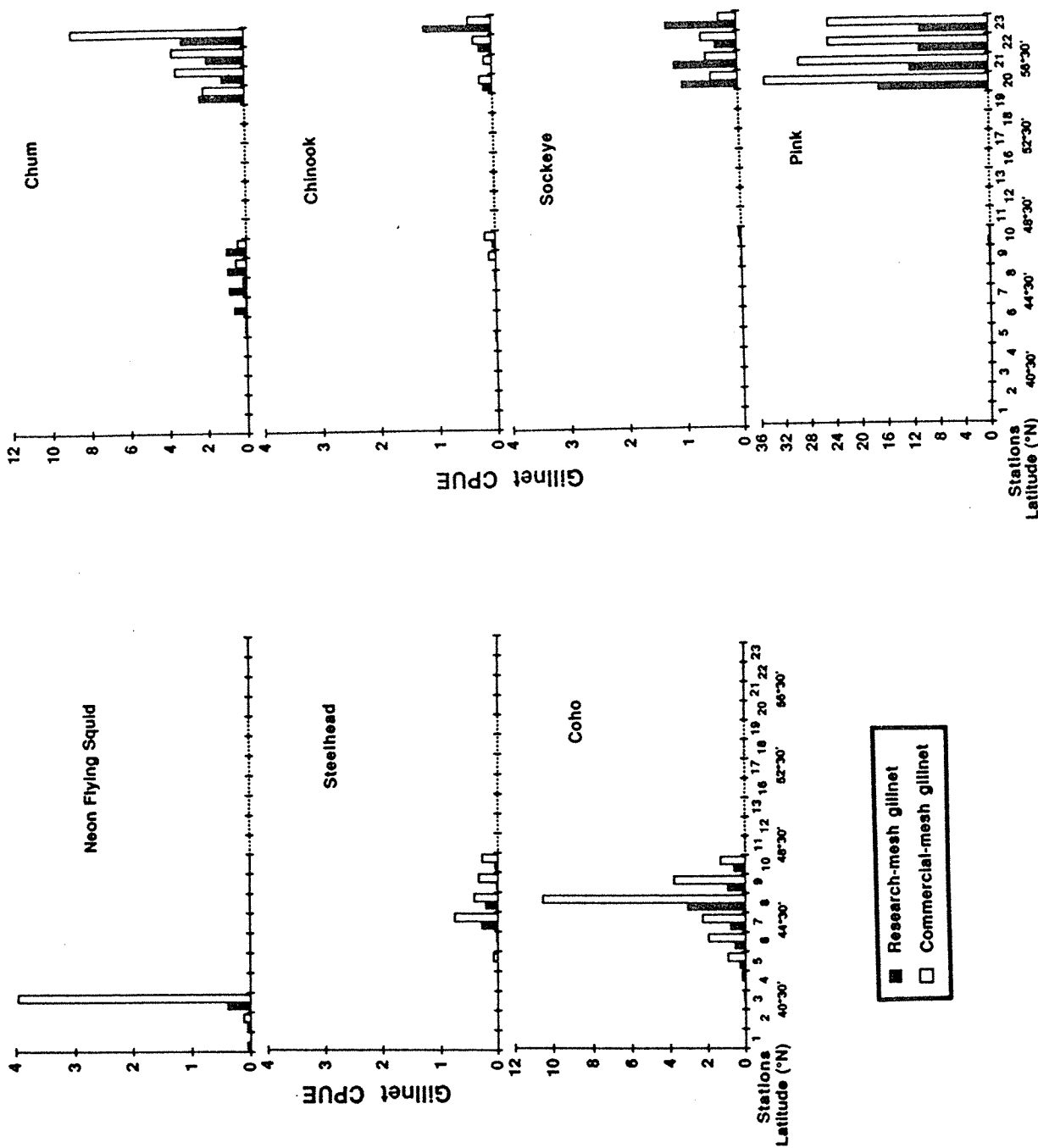


Figure 6. Catch per unit of effort (CPUE) of salmonids and neon flying squid caught at stations along a transect at 179°30'W longitude (Stations 1-23, excluding Stations 14 and 15). Gillnets were not fished between 48°30'N and 54°30'N (Stations 11-19, inclusive, stippled area of axis) because these stations were within the U. S. 200-mile EEZ. Commercial-mesh is 50 tans long with 115 mm mesh size. Research-mesh gillnet is 30 tans long and comprises 3 tans each of the following mesh sizes: 48 mm, 55 mm, 63 mm, 72 mm, 82 mm, 93 mm, 106 mm, 121 mm, 138 mm, and 157 mm.

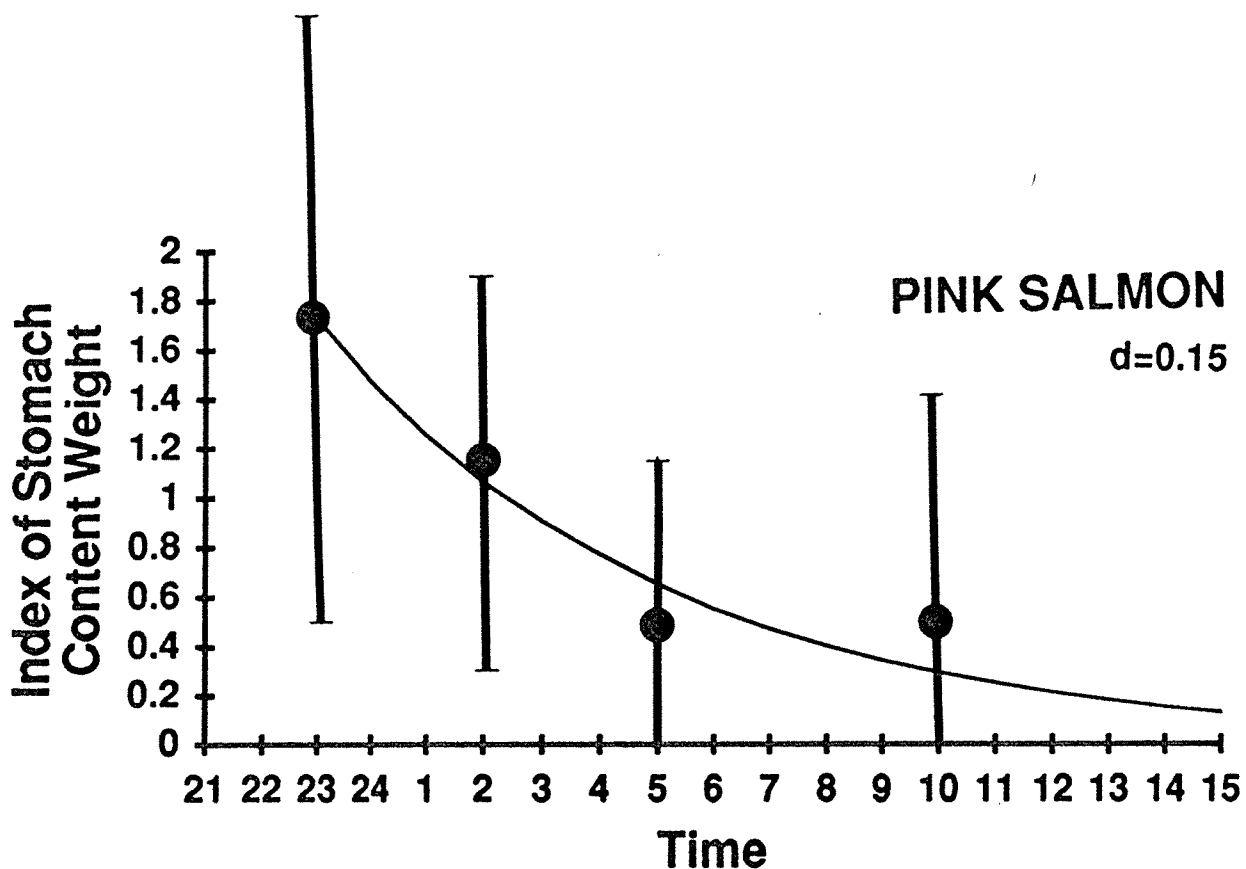
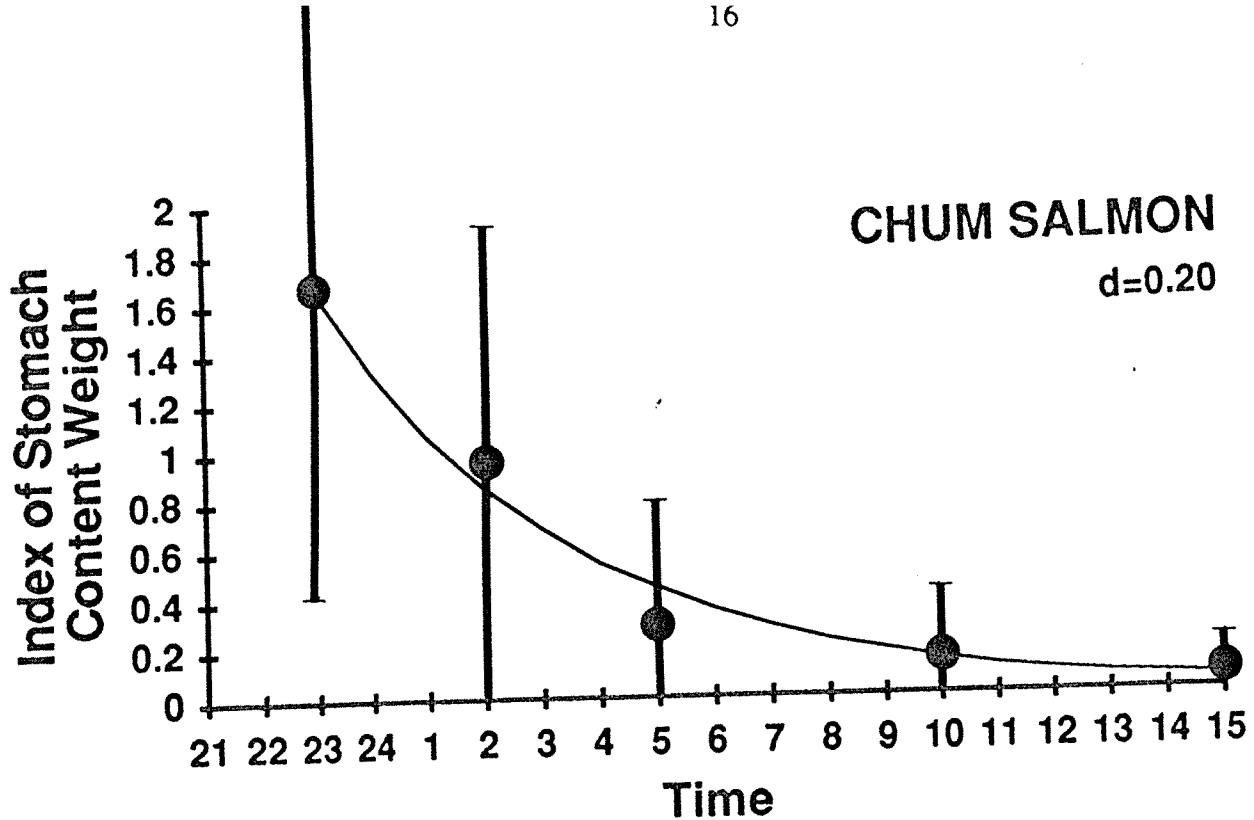


Figure 7. Points are the observed index of stomach content weight (mean and standard deviation) and the curves are fitted to the estimated index of stomach content weight when the digestion rate (d) equals 0.20 for chum and equals 0.15 for pink salmon. The estimated index values are listed on Table 13. Time is hour of the day. Index of stomach content weight equals weight of stomach contents \times 100/body weight.

Table 1. Number of salmonids and neon flying squid caught by longline (B), research-mesh gillnet (C), commercial-mesh gillnet (A), midwater trawl, and squid jigs.

Gear	Catch										Total Salmonids	Neon Flying Squid
	Sockeye	Chum	Pink	Coho	Chinook	Steelhead	Dolly Varden					
B	99	1,037	1,114	189	33	15	1				2,488	0
C	185	545	2,947	196	81	19	0				3,973	16
A	222	1,662	10,214	1,049	112	95	1				13,355	204
subtotal	506	3,244	14,275	1,434	226	129	2				19,816	220
Trawl	1	32	22	0	4	0	0				59	0
Squid jigs	0	0	0	0	0	0	0				0	5
Total	507	3,276	14,297	1,434	230	129	2				19,875	225

Table 2. Number of salmonids tagged and released by species and general area. North Pacific Ocean defined as Stations 1 through 15. Bering Sea defined as Stations 16 through 31.

Area	Sockeye	Chum	Pink	Coho	Chinook	Steelhead	Total
North Pacific Ocean	0	0	0	5	0	0	5
Bering Sea	3	74	211	0	0	0	288
Total	3	74	211	5	0	0	293

Table 3. Number of fish stomachs examined for stomach content analysis and digestion experiments by species and gear.

Gear	Sockeye	Chum	Pink	Coho	Chinook	Steelhead	Pacific Pomfret	Atka Mackerel		Walleye Pollock	Total
								Atka Mackerel	Walleye Pollock		
Longline stomach contents	90	446	413	86	32	14	115	8	8	5	1209
digestion experiments	2	110	101	42	0	0	0	0	0	0	255
Trawl stomach contents	1	23	17	0	1	0	0	0	0	2	44
Total	93	579	531	128	33	14	115	8	8	7	1508

Table 4. The percent occurrence of major prey categories in stomachs of sockeye salmon. Data are grouped by oceanic and geographic features and modified by salmonid catch distribution. Mean length and range calculated from the total number of stomachs examined. Mean index of stomach content weight and range calculated from stomachs containing prey.

Prey Category	South of Subarctic Boundary (Stations 1-2)	Transition Area (Stations 3-10)	Subarctic Current Area (Stations 11-13)	Aleutian Islands (Stations 16-17)	Bering Sea (Stations 18-23)
Fishes	0			10	7
Squids	6			10	18
Copepods	11			10	11
Euphausiids	22			20	13
Amphipods	17			20	9
Pteropods	38			10	27
Appendicularia	0			0	4
Chaetognaths	0			0	0
Gelatinous zooplankton	0			0	7
Other ¹	0			0	0
Unidentified material ²	6			20	4

Sockeye Salmon Biological Data:

Number of stomachs examined	0	0	12	7	23
Number of empty stomachs			4	4	4
Mean length (mm, \pm S.D.)			539.9 \pm 62.8	525.1 \pm 38.2	542.7 \pm 92.9
Range in length (mm)			436-640	452-560	344-770
Mean index of stomach content weight ³ (\pm S.D.)			0.61 \pm 0.52	0.51 \pm 0.12	0.50 \pm 0.63
Range in index of stomach content weight			0.04-1.27	0.40-0.62	0.03-2.60

¹ includes mysids, zoea, polychaetes, shrimp, and isopods

² heavily digested or otherwise unidentifiable material

³ stomach content weight X 100/body weight

Table 5. The percent occurrence of major prey categories in stomachs of chum salmon. Data are grouped by oceanic and geographic features and modified by salmonid catch distribution. Mean length and range calculated from the total number of stomachs examined. Mean index of stomach content weight and range calculated from stomachs containing prey.

Prey Category	South of Subarctic Boundary (Stations 1-2)	Transition Area (Stations 3-10)	Subarctic Current Area (Stations 11-13)	Aleutian Islands (Stations 16-17)	Bering Sea (Stations 18-23)
Fishes		0	1	1	2
Squids		3	5	1	5
Copepods		0	11	1	9
Euphausiids		3	7	1	12
Amphipods		28	17	21	10
Pteropods		1	14	9	13
Appendicularia		0	0	0	19
Chaetognaths		0	15	0	1
Gelatinous zooplankton		8	1	9	11
Other ¹		0	0	0	0
Unidentified material ²		57	29	57	18
Chum Salmon Biological Data:					
Number of stomachs examined	0	48	60	40	119
Number of empty stomachs		3	2	0	0
Mean length (mm, \pm S.D.)		429.9 \pm 49.6	404.9 \pm 45.8	466.0 \pm 69.1	521.0 \pm 73.1
Range in length (mm)		361-638	306-508	370-676	400-688
Mean index of stomach content weight ³ (\pm S.D.)		1.50 \pm 0.82	1.19 \pm 0.74	1.46 \pm 0.84	1.55 \pm 0.79
Range in index of stomach content weight		0.26-3.48	0.09-4.29	0.13-3.92	0.33-4.32

- 1 includes mysids, zoea, polychaetes, shrimp, and isopods
- 2 heavily digested or otherwise unidentifiable material
- 3 stomach content weight X 100/body weight

Table 6. The percent occurrence of major prey categories in stomachs of pink salmon. Data are grouped by oceanic and geographic features and modified by salmonid catch distribution. Mean length and range calculated from the total number of stomachs examined. Mean index of stomach content weight and range calculated from stomachs containing prey.

Prey Category	South of Subarctic Boundary (Stations 1-2)	Transition Area (Stations 3-10)	Subarctic Current Area (Stations 11-13)	Aleutian Islands (Stations 16-17)	Bering Sea (Stations 18-23)
Fishes	0	0	5	11	20
Squids	16	16	14	7	22
Copepods	13	13	18	17	9
Euphausiids	16	16	25	8	16
Amphipods	26	26	10	17	17
Pteropods	24	24	25	21	10
Appendicularia	0	0	0	0	0
Chaetognaths	0	0	2	0	0
Gelatinous zooplankton	0	0	0	0	2
Other ¹	0	0	0	1	0
Unidentified material ²	5	5	1	18	4

Pink Salmon Biological Data:

Number of stomachs examined	0	14	60	40	112
Number of empty stomachs	0	0	2	5	7
Mean length (mm, \pm S.D.)		423.2 \pm 28.8	426.2 \pm 23.6	433.0 \pm 22.6	454.0 \pm 35.6
Range in length (mm)		365-468	380-485	386-482	335-554
Mean index of stomach content weight ³ (\pm S.D.)		1.27 \pm 0.59	1.70 \pm 1.05	0.59 \pm 0.58	1.61 \pm 1.28
Range in index of stomach content weight		0.40-2.30	0.09-4.23	0.08-2.57	0.10-5.72

1 includes mysids, zoea, polychaetes, shrimp, and isopods

2 heavily digested or otherwise unidentifiable material

3 stomach content weight X 100/body weight

Table 7. The percent occurrence of major prey categories in stomachs of coho salmon. Data are grouped by oceanic and geographic features and modified by salmonid catch distribution. Mean length and range calculated from the total number of stomachs examined. Mean index of stomach content weight and range calculated from stomachs containing prey.

Prey Category	South of Subarctic Boundary (Stations 1-2)	Transition Area (Stations 3-10)	Subarctic Current Area (Stations 11-13)	Aleutian Islands (Stations 16-17)	Bering Sea (Stations 18-23)
Fishes		5		0	0
Squids		51		100	0
Copepods		0		0	0
Euphausiids		4		0	100
Amphipods		19		0	0
Pteropods		19		0	0
Appendicularia		0		0	0
Chaetognaths		0		0	0
Gelatinous zooplankton		2		0	0
Other ¹		0		0	0
Unidentified material ²		0		0	0

Coho Salmon Biological Data:

Number of stomachs examined	0	83	0	1	1
Number of empty stomachs		6		0	0
Mean length (mm, \pm S.D.)		533.8 \pm 32.7		654	630
Range in length (mm)		456-607			
Mean index of stomach content weight ³ (\pm S.D.)		1.80 \pm 1.45		0.10	0.50
Range in index of stomach content weight		0.04-5.87			

1 includes mysids, zoea, polychaetes, shrimp, and isopods

2 heavily digested or otherwise unidentifiable material

3 stomach content weight X 100/body weight

Table 8. The percent occurrence of major prey categories in stomachs of chinook salmon. Data are grouped by oceanic and geographic features and modified by salmonid catch distribution. Mean length and range calculated from the total number of stomachs examined. Mean index of stomach content weight and range calculated from stomachs containing prey.

Prey Category	South of Subarctic Boundary (Stations 1-2)	Transition Area (Stations 3-10)	Subarctic Current Area (Stations 11-13)	Aleutian Islands (Stations 16-17)	Bering Sea (Stations 18-23)
Fishes	0	0			32
Squids	50	50			36
Copepods	0	0			3
Euphausiids	0	0			29
Amphipods	25	25			0
Pteropods	0	0			0
Appendicularia	0	0			0
Chaetognaths	0	0			0
Gelatinous zooplankton	0	0			0
Other ¹	0	0			0
Unidentified material ²	25	25			0

Chinook Salmon Biological Data:

Number of stomachs examined	0	2	0	0	22
Number of empty stomachs		0			4
Mean length (mm, \pm S.D.)		661.0 \pm 103.2			523.6 \pm 124.1
Range in length (mm)		588-734			314-786
Mean index of stomach content weight ³ (\pm S.D.)		0.48 \pm 0.57			0.69 \pm 0.90
Range in index of stomach content weight		0.08-0.89			0.05-4.04

1 includes mysids, zoea, polychaetes, shrimp, and isopods
 2 heavily digested or otherwise unidentifiable material
 3 stomach content weight X 100/body weight

Table 9. The percent occurrence of major prey categories in stomachs of steelhead trout. Data are grouped by oceanic and geographic features and modified by salmonid catch distribution. Mean length and range calculated from the total number of stomachs examined. Mean index of stomach content weight and range calculated from stomachs containing prey.

Prey Category	South of Subarctic Boundary (Stations 1-2)	Transition Area (Stations 3-10)	Subarctic Current Area (Stations 11-13)	Aleutian Islands (Stations 16-17)	Bering Sea (Stations 18-23)
Fishes		18			
Squids		32			
Copepods		0			
Euphausiids		3			
Amphipods		31			
Pteropods		5			
Appendicularia		0			
Chaetognaths		0			
Gelatinous zooplankton		0			
Other ¹		8			
Unidentified material ²		3			

Steelhead Trout Biological Data:

Number of stomachs examined	0	14	0	0	0
Number of empty stomachs		0			
Mean length (mm, \pm S.D.)		602.7 \pm 104.8			
Range in length (mm)		520-797			
Mean index of stomach content weight ³ (\pm S.D.)		1.56 \pm 1.75			
Range in index of stomach content weight		0.07-6.30			

1 includes mysids, zoea, polychaetes, shrimp, and isopods

2 heavily digested or otherwise unidentifiable material

3 stomach content weight X 100/body weight

Table 10. The percent occurrence of major prey categories in stomachs of Pacific pomfret. Data are grouped by oceanic and geographic features and modified by salmonid catch distribution. Mean length and range calculated from the total number of stomachs examined. Mean index of stomach content weight and range calculated from stomachs containing prey.

Prey Category	South of Subarctic Boundary (Stations 1-2)	Transition Area (Stations 3-10)	Subarctic Current Area (Stations 11-13)	Aleutian Islands (Stations 16-17)	Bering Sea (Stations 18-23)
Fishes	13	8			
Squids	19	23			
Copepods	0	0			
Euphausiids	10	18			
Amphipods	23	20			
Pteropods	2	9			
Appendicularia	0	0			
Chaetognaths	0	0			
Gelatinous zooplankton	16	12			
Other ¹	2	2			
Unidentified material ²	15	8			

Pacific Pomfret Biological Data:

Number of stomachs examined	48	67	0	0	0
Number of empty stomachs	9	6			
Mean length (mm, \pm S.D.)	425.8 \pm 28.2	403.8 \pm 31.6			
Range in length (mm)	371-501	342-468			
Mean index of stomach content weight ³ (\pm S.D.)	0.42 \pm 0.41	0.98 \pm 0.82			
Range in index of stomach content weight	0.07-1.76	0.08-4.35			

1 includes mysids, zoea, polychaetes, shrimp, and isopods

2 heavily digested or otherwise unidentifiable material

3 stomach content weight X 100/body weight

Table 11. The percent occurrence of major prey categories in stomachs of walleye pollock. Data are grouped by oceanic and geographic features and modified by salmonid catch distribution. Mean length and range calculated from the total number of stomachs examined. Mean index of stomach content weight and range calculated from stomachs containing prey.

Prey Category	South of Subarctic Boundary (Stations 1-2)	Transition Area (Stations 3-10)	Subarctic Current Area (Stations 11-13)	Aleutian Islands (Stations 16-17)	Bering Sea (Stations 18-23)
Fishes			0		0
Squids			0		0
Copepods			0		12
Euphausiids			20		39
Amphipods			30		12
Pteropods			0		0
Appendicularia			0		25
Chaetognaths			0		0
Gelatinous zooplankton			50		0
Other ¹			0		0
Unidentified material ²			0		12

Walleye Pollock Biological Data:

Number of stomachs examined	0	0	0	1	4
Number of empty stomachs				0	1
Mean length (mm, \pm S.D.)				580	543.0 \pm 47.6
Range in length (mm)					500-610
Mean index of stomach content weight ³ (\pm S.D.)			0.28		1.24 \pm 1.36
Range in index of stomach content weight					0.15-2.76

¹ includes mysids, zoea, polychaetes, shrimp, and isopods

² heavily digested or otherwise unidentifiable material

³ stomach content weight X 100/body weight

Table 12. The percent occurrence of major prey categories in stomachs of Atka mackerel. Data are grouped by oceanic and geographic features and modified by salmonid catch distribution. Mean length and range calculated from the total number of stomachs examined. Mean index of stomach content weight and range calculated from stomachs containing prey.

Prey Category	South of Subarctic Boundary (Stations 1-2)	Transition Area (Stations 3-10)	Subarctic Current Area (Stations 11-13)	Aleutian Islands (Stations 16-17)	Bering Sea (Stations 18-23)
Fishes				0	20
Squids				6	20
Copepods				25	20
Euphausiids				13	20
Amphipods				13	0
Pteropods				13	0
Appendicularia				0	0
Chaetognaths				0	0
Gelatinous zooplankton				6	20
Other ¹				0	0
Unidentified material ²				24	0

Atka Mackerel Biological Data:

Number of stomachs examined	0	0	0	5	3
Number of empty stomachs				0	1
Mean length (mm, \pm S.D.)				341.2 \pm 56.4	346.3 \pm 43.7
Range in length (mm)				270-396	305-392
Mean index of stomach content weight ³ (\pm S.D.)				2.46 \pm 0.53	2.05 \pm 2.28
Range in index of stomach content weight				1.64-3.04	0.44-3.67

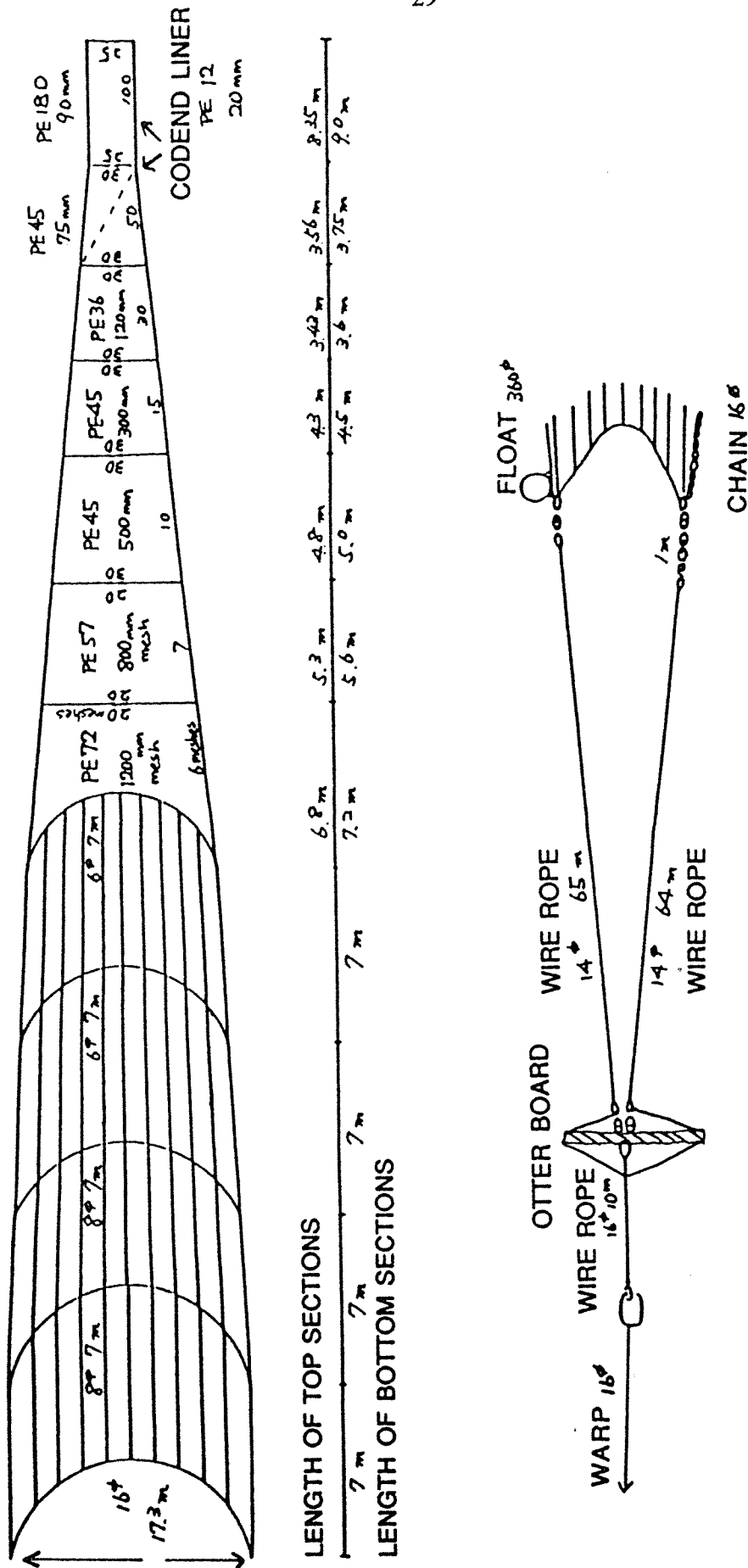
¹ includes mysids, zoea, polychaetes, shrimp, and isopods

² heavily digested or otherwise unidentifiable material

³ stomach content weight X 100/body weight

Table 13. Summary of digestion experiments on chum and pink salmon. Estimated digestion rate matched to chum salmon experimental data is $d=0.20$. Estimated digestion rate matched to pink salmon experimental data is $d=0.15$. Time is the hour of the day. Index is the index of stomach content weight (stomach content weight X 100/body weight). Percent stomach content weight remaining is the estimated percent of the original stomach content weight that remains after each hour.

Time	Chum Salmon				Pink Salmon			
	N	Observed Index (mean \pm S.D.)	Estimated Index	% Stomach Content Weight Remaining	N	Observed Index (mean \pm S.D.)	Estimated Index	% Stomach Content Weight Remaining
2300	28	1.66 \pm 1.23	1.66	100.0	27	1.73 \pm 1.26	1.73	100.0
2400			1.33	80.0			1.47	85.0
0100			1.06	64.0			1.25	72.3
0200	22	0.89 \pm 0.96	0.85	51.2	22	1.08 \pm 0.80	1.06	61.4
0300			0.68	41.0			0.90	52.2
0400			0.54	32.8			0.77	44.4
0500	24	0.36 \pm 0.47	0.44	26.2	22	0.49 \pm 0.52	0.65	37.7
0600			0.35	21.0			0.55	32.1
0700			0.28	16.8			0.47	27.2
0800			0.22	13.4			0.40	23.2
0900			0.18	10.7			0.34	19.7
1000	26	0.14 \pm 0.36	0.14	8.6	26	0.47 \pm 0.97	0.29	16.7
1100			0.11	6.9			0.25	14.2
1200			0.09	5.5			0.21	12.1
1300			0.07	4.4			0.18	10.3
1400			0.06	3.5			0.15	8.7
1500	7	0.06 \pm 0.17	0.05	2.8			0.13	7.4



Appendix Figure 1. Design of the midwater trawl used on board the *Wakatake maru*. Dimensions are described by rope thickness (PE value), which is the number of individual fibers in the rope, (stretched) mesh size (millimeters), diameter of the rope (φ, millimeters), and length of top and bottom sections (meters).

Appendix Table 1. Location (degrees and minutes), sea surface temperature (SST, °C), and catch of salmonids, other fishes, birds, and marine mammals by longline (B), research-mesh gillnet (C), and commercial-mesh gillnet (A) for each station.

Sta	Date	Location	SST	Gear	Sockeye	Chum	Pink	Coho	Chinook	Steelhead	Dolly Varden	Neon Flying Squid	Pacific Pomfret	Atka Mackerel	Lancet Fish	Walleye Pollock	Sibarts	Other Fishes	Other Squids	Sea Birds	Marine Mammals
1	6-12	38.30N-179.30W	16.2	B	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0
				C	0	0	0	0	0	0	2	0	0	0	0	0	2	2	3	0	0
				A	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0
				Total	0	0	0	0	0	0	2	19	0	0	0	5	4	3	0	0	0
2	6-13	39.30N-179.30W	14.1	B	0	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0
				C	0	0	0	0	0	0	2	4	0	0	0	0	0	0	1	0	0
				A	0	0	0	0	0	0	6	3	0	0	0	0	0	0	0	0	0
				Total	0	0	0	0	0	0	8	55	0	0	0	0	0	1	0	0	0
3	6-14	40.30N-179.30W	12.6	B	0	0	0	1	0	0	0	0	72	0	0	0	0	0	0	0	0
				C	0	0	0	2	0	0	12	61	0	0	0	0	0	0	30	8	0
				A	0	0	0	3	0	0	0	198	139	0	0	0	1	0	0	0	0
				Total	0	0	0	6	0	0	210	272	0	0	0	1	0	30	8	8	0
4	6-15	41.30N-179.30W	10.6	B	0	0	0	5	0	0	0	0	33	0	0	0	0	0	0	0	0
				C	0	0	0	0	0	0	0	0	57	0	0	0	0	0	0	0	0
				A	0	0	0	8	0	0	0	0	46	0	0	0	1	0	0	1	0
				Total	0	0	0	13	0	0	0	0	136	0	0	0	1	0	0	1	0
5	6-16	42.30N-179.30W	10.7	B	0	2	0	7	0	3	0	0	42	0	0	0	0	0	0	0	0
				C	0	1	1	10	0	0	0	0	19	0	0	0	0	0	0	0	0
				A	0	1	0	46	1	4	0	0	25	0	0	0	0	0	0	0	0
				Total	0	2	1	63	1	7	0	0	86	0	0	0	0	0	0	0	0
6	6-17	43.30N-179.30W	10.8	B	0	4	0	41	0	0	0	0	103	0	0	0	0	0	0	0	0
				C	0	4	0	18	0	0	0	0	93	0	0	0	2	2	0	0	0
				A	0	3	0	98	0	1	0	0	19	0	1	0	5	0	0	0	0
				Total	0	11	0	157	0	1	0	0	215	0	1	0	7	2	0	0	0
7	6-18	44.30N-179.30W	10.3	B	0	4	0	14	0	5	0	0	4	0	0	0	0	0	0	0	0
				C	0	20	0	25	0	9	0	0	17	0	1	0	0	1	2	2	0
				A	0	2	0	114	0	38	0	0	7	0	0	0	4	0	0	3	0
				Total	0	26	0	153	0	52	0	0	28	0	1	0	4	1	2	5	0
8	6-19	45.30N-179.30W	9.4	B	0	6	1	40	0	4	0	0	0	0	0	0	0	0	0	0	0
				C	0	28	1	93	0	7	0	0	0	0	0	0	0	0	5	0	0
				A	0	9	2	525	1	21	0	0	0	0	0	1	0	3	0	0	0
				Total	0	43	4	658	1	32	0	0	0	0	1	0	3	0	5	0	0

Appendix Table 1. Continued.

Sta	Date	Location	SST	Gear	Chum	Pink	Cobo	Chinook	Steelhead	Dolly Varden	Neon Flying Squid	Pacific Pomfret	Atka Mackerel	Lancet Fish	Walleye Pollock	Sharks	Other Fishes	Other Squids	Sea Birds	Marine Mammals
9	6-20	46.30N-179.30W	7.7	B	23	4	73	1	2	0	0	0	0	0	0	0	0	0	0	0
				C	30	8	29	0	1	0	0	0	0	0	0	0	0	8	0	0
				A	27	7	189	6	17	0	0	0	0	0	0	7	0	0	0	1
				Total	80	19	291	7	20	0	0	0	0	0	0	7	0	8	0	1
10	6-21	47.30N-179.30W	7.1	B	14	9	5	1	1	0	0	0	0	0	0	0	0	0	0	0
				C	31	13	19	2	2	0	0	0	0	0	0	0	0	1	0	0
				A	22	4	65	9	14	0	0	0	0	0	0	0	0	0	0	0
				Total	67	26	89	12	17	0	0	0	0	0	0	0	0	1	0	0
11	6-22	48.30N-179.30W	6.4	B	33	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	6-23	49.30N-179.30W	6.8	B	43	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	6-24	50.30N-179.30W	6.5	B	78	83	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	6-25	50.30N-178.30W	6.6	B	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	6-26	50.30N-177.30W	6.6	B	65	65	1	0	0	0	0	0	0	0	0	0	0	0	0	0
16	6-27	51.30N-179.50W	5.3	B	24	38	1	0	0	0	0	0	3	0	1	0	0	0	0	0
17	6-28	52.30N-179.30W	6.4	B	29	52	0	0	0	0	0	0	2	0	0	0	0	0	0	0
18	6-29	53.30N-179.30W	6.6	B	97	75	1	0	0	0	0	0	0	0	1	0	0	0	0	0
19	6-30	54.30N-179.30W	6.6	B	77	119	0	0	0	0	0	0	1	0	2	0	0	0	0	0
20	7-1	55.30N-179.30W	6.3	B	26	38	0	4	0	0	0	0	1	0	0	0	0	0	0	0
				C	70	514	0	5	0	0	0	0	10	0	0	0	0	6	4	0
				A	24	105	0	11	0	0	0	0	0	0	0	0	0	0	0	28
				Total	56	201	0	20	0	0	0	0	11	0	0	0	0	6	32	0
21	7-2	56.30N-179.30W	7.4	B	37	79	0	1	0	0	0	0	1	0	0	0	0	0	0	0
				C	36	373	0	0	0	0	0	0	1	0	0	0	0	0	0	0
				A	28	177	0	7	0	0	0	0	0	0	0	0	1	1	0	0
				Total	64	250	0	8	0	0	0	0	2	0	0	0	1	1	0	0
22	7-3	57.30N-179.30W	7.1	B	22	12	0	3	0	0	0	0	0	0	0	0	0	0	0	0
				C	12	59	329	0	7	0	0	0	0	1	0	0	0	0	0	0
				A	32	186	1245	0	16	0	0	0	0	0	0	0	1	0	6	0
				Total	44	267	1586	0	26	0	0	0	1	0	0	0	1	0	6	0

Appendix Table 1. Continued.

Sta	Date	Location	SST	Gear	Socketeye	Chum	Pink	Coho	Chinook	Steelhead	Dolly Varden	Neon Flying Squid	Pacific Mackerel	Alta Mackerel	Lancea Fish	Walleye Pollock	Sharks	Other Fishes	Other Squids	Sea Birds	Marine Mammals
23	7-4	58.30N-179.30W	7.6	B	0	51	26	0	14	0	0	0	0	0	0	1	0	0	0	0	0
				C	38	98	324	0	35	0	0	0	0	1	0	1	0	0	0	2	0
				A	16	445	1245	0	20	0	0	0	0	0	0	0	0	1	0	5	0
				Total	54	594	1595	0	69	0	0	0	0	1	0	2	0	1	0	7	0
24	7-5	57.30N-178.30W	7.6	B	4	45	80	0	2	0	1	0	0	0	0	0	0	0	0	0	0
				C	21	36	517	0	8	0	0	0	0	8	0	0	0	0	0	2	0
				A	25	189	1982	0	18	0	0	0	0	0	0	0	0	0	0	13	0
				Total	50	270	2579	0	28	0	1	0	0	8	0	0	0	0	0	15	0
25	7-6	57.30N-177.30W	7.7	B	3	55	41	0	2	0	0	0	0	0	0	0	0	0	0	0	0
				C	11	36	328	0	5	0	0	0	0	4	0	0	0	0	0	10	0
				A	20	183	1195	0	2	0	0	0	0	0	0	0	0	0	0	11	0
				Total	34	274	1564	0	9	0	0	0	0	4	0	0	0	0	0	21	0
26	7-7	56.30N-177.30W	8.4	B	5	65	41	0	1	0	0	0	0	0	0	0	0	0	0	0	0
				C	13	21	209	0	1	0	0	0	0	27	0	0	0	0	0	3	0
				A	33	103	338	0	2	0	0	0	0	0	0	0	0	0	0	24	0
				Total	51	189	588	0	4	0	0	0	0	27	0	0	0	0	0	27	0
27	7-8	56.30N-178.30W	8.5	B	0	33	53	0	3	0	0	0	0	0	0	0	0	0	0	0	0
				C	24	75	330	0	18	0	0	0	0	3	0	0	0	0	0	2	0
				A	42	210	972	1	19	0	0	0	0	0	0	0	0	0	0	9	0
				Total	66	318	1355	1	40	0	0	0	0	3	0	0	0	0	0	11	0
28	7-9	56.30N-179.30E	7.4	B	6	48	57	0	1	0	0	0	0	0	0	0	0	0	0	0	0
29	7-10	56.30N-178.30E	7.6	B	4	57	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	7-11	56.30N-177.30E	7.5	B	13	71	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	7-12	56.30N-176.30E	6.7	B	9	21	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Subtotal		B	99	1037	1114	189	33	15	1	0	321	8	0	5	0	0	0	0	0
				C	185	545	2947	196	81	19	0	16	251	55	1	1	4	5	56	33	0
				A	222	1662	10214	1049	112	95	1	204	239	0	2	0	24	5	1	100	1
		Total			506	3244	14275	1434	226	129	2	220	811	63	3	6	28	10	57	133	1

Appendix Table 2. Numbers of fish sampled and items measured aboard Japanese salmon research vessels. A: Fork length, body weight, sex, gonad weight, and scale collection. B: Fork length, sex, gonad weight, and scale collection. C: Fork length, sex, and scale collection.

Species	Gillnet				Longline	
	Research-Mesh		Commercial-Mesh			
Sockeye ¹	1-30	A	1-60	A	1-30	A
	31-100	B	61-100	B	31-100	B
Chum ¹	1-30	A	1-30	A	1-30	A
	31-100	B	31-60	B	31-100	B
Pink ²	1-30	A	1-30	A	1-30	A
	31-100	B			31-100	B
Coho ³	1-30	A	1-60	A	1-30	A
	31-100	B	61-100	B	31-100	B
Chinook ³	1-30	A	1-60	A	1-30	A
	31-100	B	61-100	B	31-100	B
Steelhead ³	1-30	A	1-60	A	1-30	A
	31-100	B	61-100	B	31-100	B

¹ One scale sampled from each fish

² One scale sampled from fish caught by commercial-mesh gillnet

³ One scale sampled from both sides of the fish

Appendix Table 3. Location (degrees, minutes, and decimal-minutes) and fish catch by midwater trawl. Begin tows time is local time (JST plus 3 hours). Tow duration is one hour unless otherwise noted. Net depth is the distance between the surface of the water and the bottom of the net. Net height is the vertical size of the net opening. Dash indicates the net depth or net height is unknown because of malfunctioning net recorder.

Sta	Date	Set Location	Haul Location	Begin Towing Time	Distance (naut. mi.)	Net Depth (meters)	Net Height (meters)	CATCH													
								Sockeye	Chum	Pink	Coho	Chinook	Suelhead	Alta Mackerel	Walleye Pollock	Cyclopteridae	Leptocephalus	Leuroglossus sp.			
1	6-12	38.33.0N-179.24.5W	38.33.6N-179.19.8W	17:35	3.8	30	16	0	0	0	0	0	0	0	0	0	0	0	0		
2	6-13	39.32.8N-179.29.6W	39.33.3N-179.35.4W	16:57	4.2	20	14	0	0	0	0	0	0	0	0	0	0	0	0		
3	6-14	40.32.8N-179.28.4W	40.32.7N-179.33.9W	16:57	4.1	24	11	0	0	0	0	0	0	0	0	0	0	0	0		
4	6-15	41.31.1N-179.29.3W	41.28.3N-179.32.9W	16:45	4	28	17	0	0	0	0	0	0	0	0	0	0	0	0		
5	6-16	42.32.5N-179.30.3W	42.32.4N-179.36.9W	16:44	4.8	-	-	0	0	0	0	0	0	0	0	0	0	0	0		
6	6-17	43.32.2N-179.28.9W	43.31.9N-179.35.7W	16:52	5.5	-	16	0	0	0	0	0	0	0	0	0	0	0	0		
7	6-18	44.27.8N-179.33.3W	44.28.1N-179.29.8W	17:39	2.5	-	16	0	0	0	0	0	0	0	0	0	0	0	0		
8	6-19	45.22.9N-179.31.0W	45.28.2N-179.23.6W	17:36	4.6	-	16	0	0	0	0	0	0	0	0	0	0	0	0		
9	6-20	46.33.0N-179.28.2W	46.33.2N-179.37.8W	17:22	6.5	16	16	0	0	0	0	0	0	0	0	0	0	0	0		
10	6-21	47.32.1N-179.28.9W	47.32.3N-179.34.6W	17:42	3.9	65	16	0	0	0	0	0	0	0	0	0	0	0	0		
11	6-22	48.29.6N-179.33.6W	48.28.3N-179.37.4W	17:16	4.2	26	16	0	0	0	0	0	0	0	0	0	0	0	0		
12	6-23	49.30.5N-179.33.6W	49.31.4N-179.27.4W	17:22	4.1	32	16	0	2	0	0	0	0	0	0	0	0	0	0		
13	6-24	50.33.6N-179.27.4W	50.30.6N-179.30.7W	17:47	4.1	32	16	0	0	0	0	0	0	0	0	0	0	0	0		
14	6-25	50.30.1N-178.23.0W	50.30.5N-178.31.0W	17:57	4.1	20	16	0	1	0	0	0	0	0	0	0	0	0	0		
15	6-26	50.29.8N-177.37.3W	50.29.0N-177.31.7W	5:12	3.9	20	16	0	0	0	0	0	0	0	0	0	0	0	0		
16	6-27	51.39.2N-179.47.8W	51.35.8N-179.47.9W	18:05	3.9	20	16	0	0	0	0	0	0	0	0	0	0	0	0		
17	6-28	52.32.9N-179.33.6W	52.30.1N-179.26.9W	18:14	5	25	16	0	0	0	0	0	0	0	0	0	0	0	0		
18	6-29	53.26.3N-179.29.8W	53.30.0N-179.29.8W	18:18	3.7	25	17	0	0	0	0	0	0	0	0	0	0	0	0		
19	6-30	54.26.7N-179.29.1W	54.30.6N-179.26.9W	18:15	4.1	20	16	0	3	2	0	0	0	0	0	0	0	0	0		
20	7-1	55.30.0N-179.24.0W	55.34.4N-179.23.9W	18:41	4.4	20	16	0	5	3	0	0	0	0	0	0	0	0	0		
20*	7-2	55.28.4N-179.29.2W	55.31.5N-179.30.9W	0:12	12	23	16	0	3	5	0	2	0	0	0	0	0	0	0		
21	7-2	56.31.2N-179.27.9W	56.31.3N-179.35.5W	18:40	4.3	20	16	0	2	0	0	0	0	0	0	0	0	0	0		
22	7-3	57.31.8N-179.28.0W	57.34.0N-179.34.4W	18:42	4.2	-	-	0	1	0	0	0	0	0	0	0	0	0	0		
23	7-4	58.32.0N-179.28.5W	58.34.3N-179.35.8W	18:55	4.4	20	16	0	0	0	0	0	0	0	0	0	0	0	0		
24	7-5	57.31.8N-178.27.1W	57.34.0N-178.34.1W	18:40	4.4	20	16	0	0	0	0	0	0	0	0	0	0	0	0		
25	7-6	57.32.0N-177.26.6W	57.34.2N-177.33.3W	18:40	4.3	20	16	0	0	0	0	0	0	0	0	0	0	0	0		
26	7-7	56.31.7N-177.28.6W	56.32.0N-177.36.2W	18:25	4.3	-	-	0	0	0	0	0	0	0	0	0	0	0	0		
27	7-8	56.29.9N-179.27.4E	56.32.0N-178.37.1W	18:25	4.3	20	16	0	0	0	0	0	0	0	0	0	0	0	0		
28	7-9	56.29.3N-178.37.2E	56.30.0N-179.29.3E	18:38	4.4	20	16	1	1	7	0	0	0	0	0	0	0	0	0		
29	7-10	56.29.3N-178.37.2E	56.29.8N-178.29.4E	18:40	4.4	20	16	0	11	0	0	0	0	0	0	0	0	0	0		
29**	7-10	56.30.7N-178.29.3E	56.33.2N-177.38.1E	23:35	28.4	20	16	0	2	0	0	0	0	0	0	0	0	0	0		
30	7-11	56.30.2N-177.38.7E	56.30.8N-177.30.9E	18:30	4.4	20	16	0	0	0	0	0	0	0	0	0	0	0	0		
31	7-12	56.29.5N-176.28.5E	56.31.1N-176.21.2E	5:20	4.4	20	16	0	1	0	0	0	0	0	0	0	0	0	0		
Total								1	32	22	0	4	0	0	1	1	3	3	0	0	2

* tow duration was 4 hours and 18 minutes
 ** tow duration was 6 hours and 25 minutes

Appendix Table 4. Location, sea surface temperature (SST, °C), and catch of squid caught by jigging. At each station, five people fished for squid for 30 minutes unless otherwise noted.

Sta.	Date	Location	SST	Neon flying squid ¹		Boreal club-hook squid ²		Boreopacific gonate squid ³	
				Number	Total Wet weight (g)	Number	Total Wet weight (g)	Number	Total Wet weight (g)
1	6/12	38° 30' N 179° 30' W	15.8	1	150	0		0	
2	6/13	39° 30' N 179° 30' W	14.0	1	2400	0		0	
3	6/14	40° 30' N 179° 30' W	12.7	3	6700	1	250	1	250
4	6/15	41° 30' N 179° 30' W	9.9	0		0		3	920
5 ⁴	6/16	42° 30' N 179° 30' W	10.7	0		1	900	0	
6	6/17	43° 30' N 179° 30' W	11.2	0		4	3000	0	
7	6/18	44° 30' N 179° 30' W	10.2	0		1	280	2	850
8	6/19	45° 30' N 179° 30' W	9.6	0		0		0	
9 ⁵	6/20	46° 30' N 179° 30' W	7.0	0		0		0	
10	6/21	47° 30' N 179° 30' W	7.0	0		0		0	
11 ⁶	6/22	48° 30' N 179° 30' W	6.4	0		0		0	
12	6/23	49° 30' N 179° 30' W	6.2	0		0		0	
13 ⁵	6/24	50° 30' N 179° 30' W	6.7	0		0		0	
14	6/25	50° 30' N 178° 30' W	6.7	0		0		0	
15	6/26	50° 30' N 177° 30' W	6.5	0		0		0	
16	6/27	51° 35' N 179° 50' W	4.7	0		0		0	
17	6/28	52° 30' N 179° 30' W	6.4	0		0		0	
18	6/29	53° 30' N 179° 30' W	6.4	0		0		0	
19	6/30	54° 30' N 179° 30' W	6.3	0		0		0	
20	7/1	55° 30' N 179° 30' W	6.3	0		0		0	
21	7/2	56° 30' N 179° 30' W	7.3	0		0		0	
22	7/3	57° 30' N 179° 30' W	6.8	0		0		0	
23	7/4	58° 30' N 179° 30' W	7.2	0		0		0	
Total				5	9,250	7	4,430	6	2,020

1 *Ommastrephes bartramii*

2 *Onychoteuthis borealijaponica*

3 *Gonatopsis borealis*

4 fishing time was 40 minutes

5 fishing time was 45 minutes

6 fishing time was 20 minutes