Incidental By-catch of Pacific Salmon During Russian Bottom Trawl Surveys in the Bering Sea and Some Remarks on its Ecology

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The data on Pacific salmon by-catch in bottom trawl surveys of the Bering Sea are regarded. During 1974-1991 260 salmonids, mostly chinook and chum salmon, were collected. Chinook and chum salmon vertical distribution were discussed in relation to features of their feeding habits.

INTRODUCTION

It is traditionally considered that the Pacific salmon dwells the upper pelagic layer, mainly during the sea-run phase of its life (Machidori 1966; Birman 1985). However, salmon are by-caught frequently during the groundfish trawl fisheries, particularly the walleye pollock fishery. Since the early 1970s, the Bering Sea has become the chief region of the walleye pollock fishery and has been the major fishery until the early 1990s (Shuntov et al. 1993). Rather comprehensive statistics exist on Pacific salmon by-catch on the eastern Bering Sea shelf and continental slope (Low and Berger 1994). In some years the salmon by-catch reached 120 thousand fish, or about 0,3 thousand tons. In Russian waters such information is missing due to the limited monitoring of groundfish fishery.

To a certain extent, the data from scientific surveys mitigates the information deficit on Pacific salmon by-catch in bottom trawl fisheries. Since 1974, the Pacific Scientific Research Institute of Fisheries and Oceanography (TINRO) has conducted more than 110 scientific and research cruises in the Bering Sea. Data from these cruises are kept in the TINRO-center archive. Until the early 1990s, the bottom trawl survey was one of the main methods of scientific and fisheries information collection. In the 1970s and 1980s such information was collected no less than in 60% of all expeditions. Our report is devoted to analysis of this archival information.

MATERIALS AND METHODS

Examination of the data from bottom trawl surveys made during the 1970s and 1980s shows that information on by-catch species appears to be both scarce and approximate. In addition, in some cases the Pacific salmon were not recorded in catches due to fear of penalties for unsanctioned by-catch. For this reason, information from only those bottom trawl surveys where salmon by-catch data were taken was used for the analysis.

The information file contained data from 21 cruises from 1974 to 1991 which encompassed the entire period: 5 cruises in 1974-1980, 9 - in 1981-1985, 7 - in 1986-1991. To a great degree the data reflected the intensity of research activity in the Bering Sea region, rather than the salmon stock dynamics. In these expeditions 2,880 bottom and 469 near-bottom (in contact with the ground) trawl operations were executed. Salmonid fishes were captured in 133 cases (4.0%). The bottom trawl operations with salmon by-catch were conducted at a depth range of 20-1,100 m, with most above 350 m. Near-bottom trawls were made at depths of 40-360 m, with depth recorded as that of the upper trawl panel position. In some cases trawling was conducted at several tow depths, and it was assumed that salmon were caught at the upper-most depth. The duration of trawl towing varied from 0.5 to 4.25 hours.

During surveys, the whole size spectrum of

trawls were used. Bottom trawls had vertical openings from 3 to 8 m, and horizontal openings from 20 to 30 m. Pelagic trawls had vertical openings in near-bottom operations from 20 to 30 m, and horizontal openings from 35 to 80 m. On the whole, 256 salmon specimens and 4 chars were collected, 97 from near-bottom trawl operations.

RESULTS

Among the salmon by-catch, 113 specimens (44.9%) were identified as chinook, 100 (39.1%) as chum, 6 (2.3%) as pink, and 3 (1.2%) as coho. Thirty-three fish (12.9%) were identified as sockeye, but we considered the identification to be doubtful. Most of the sockeye identifications (31 fish) were specified for the central Anadyr Gulf and were made by the same collector during one cruise. Chum salmon were the principal species found in the by-catch of other vessels operating in the same location at the same time. Besides, sockeye do not occur on the northern Bering Sea shelf even in pelagic layers (Shuntov 1989; Radchenko and Chigirinsky 1995). This is likely related to the sockeye adherence to the thermocline layer in the deep-sea zone (Radchenko 1994). The occurrence of 2 sockeye specimens on the south-eastern slope seems more possible. Furthermore, the same occurrences were considered in Low and Berger (1994). The coho salmon occurrences on the western Bering Sea shelf (south of the Navarin Cape) seem doubtful to us as well. As indicated by salmon body length (up to 78 cm), these specimens should probably be classified as chinook. In addition to the species mentioned above, an unclassified juvenile salmon with body length 17 cm and weight 100 g was also caught in one case. The by-catch of chars were identified to species as Dolly varden (2 specimens), in one case and to genera (*Salvelinus)* in another.

Areas with Pacific salmon by-catch have been localized in the Anadyr Gulf, on the shelf and upper continental slope of the Oljutorsky-Navarinsky region (Fig. 1- 4). Outside of this area, in summer of 1984 seven chum specimens were caught in southern Karaginsky Bay (Fig. 2) and in autumn and winter 2 chinook were caught in the Oljutorsky Bay (Fig. 3, 4). Single salmon catches (chinook in 7 of 9 cases) were found along the 200-meter contour on the whole eastern Bering Sea shelf in winter (Fig. 4).

As a whole, 68 of 71 salmon specimens caught in winter (95.8%) were chinook. Also 32 chinook specimens were caught in an area not further than 100 miles from the Navarin Cape during the fall, and an additional 14 salmon were caught in summer and 2 in the spring. Almost all chum, and both pink salmon were caught in summer and fall - from July to October inclusively. In July, chum were encountered in the Karaginsky Bay and a few were by-caught more generally in the northern Bering Sea (a distance of up to 200 miles from the continental coast). In August, chum occurred mainly in catches in the near-shore zone. In September, chum were chiefly concentrated in the western Anadyr Gulf (opposite the Anadyr River estuary) and in October were found near the Navarin Cape and southwards along the shelf edge. Pink salmon by-catch occurred in July of 1974 in the Navarin region and in September of 1989 in the Shirshov Ridge area.

Chinook by-catch specimens ranged in body length from 21 to 130 cm, with a modal group of 60-80 cm representing 67.6% of the total number (Fig. 5). Chum salmon were mostly represented by large maturing specimens with body lengths ranging from 25 to 78 cm and a modal length of 60 to 65 cm (34%). Fish with a body length above 60 cm comprised more than three-quarters of the chum number. A dependence of the frequency of salmon occurrence by time of day was not evident. Possibly, some part of the salmon stock occupies the near-bottom layers throughout the day.

DISCUSSION

Because of the small vertical opening of a bottom trawl, it is unlikely that salmon are by-caught during the trawl retrieval operation in large numbers. Besides, chinook salmon generally occur in the near-bottom zone (up to 110 m) (Healey 1991).

The number of immature chinook of ocean age 2 or older are likely significantly underestimated during the pelagic trawl surveys. For instance, in autumn 1987 the calculated number of chinook with a body length above 40 cm contributed 9.0%, and above 50 cm 2.3% of the total numbers. Later in the year, chinook salmon begin to leave the Russian exclusive economic zone and the portion of larger sized specimens increases with the oceanward migrations of smaller individuals. In late October - November of 1990 the portion of chinook above 50 cm contributed 17.0% of the total species number, and in November - December of 1988 31.6% of the total. Therefore, part of the chinook stock likely spends winter in near-bottom layers of the northern Bering Sea.

A synthetic curve combining data from the length distribution of chinook salmon in the western and central Bering Sea pelagic zone throughout the year but seasons mainly summer and autumn has only one well-expressed peak. It coincides to the number of chinook specimens spending their second marine year in the pelagic zone (Fig. 5). On the contrary, larger chinook aged 1.2 - 2.2 mainly appear

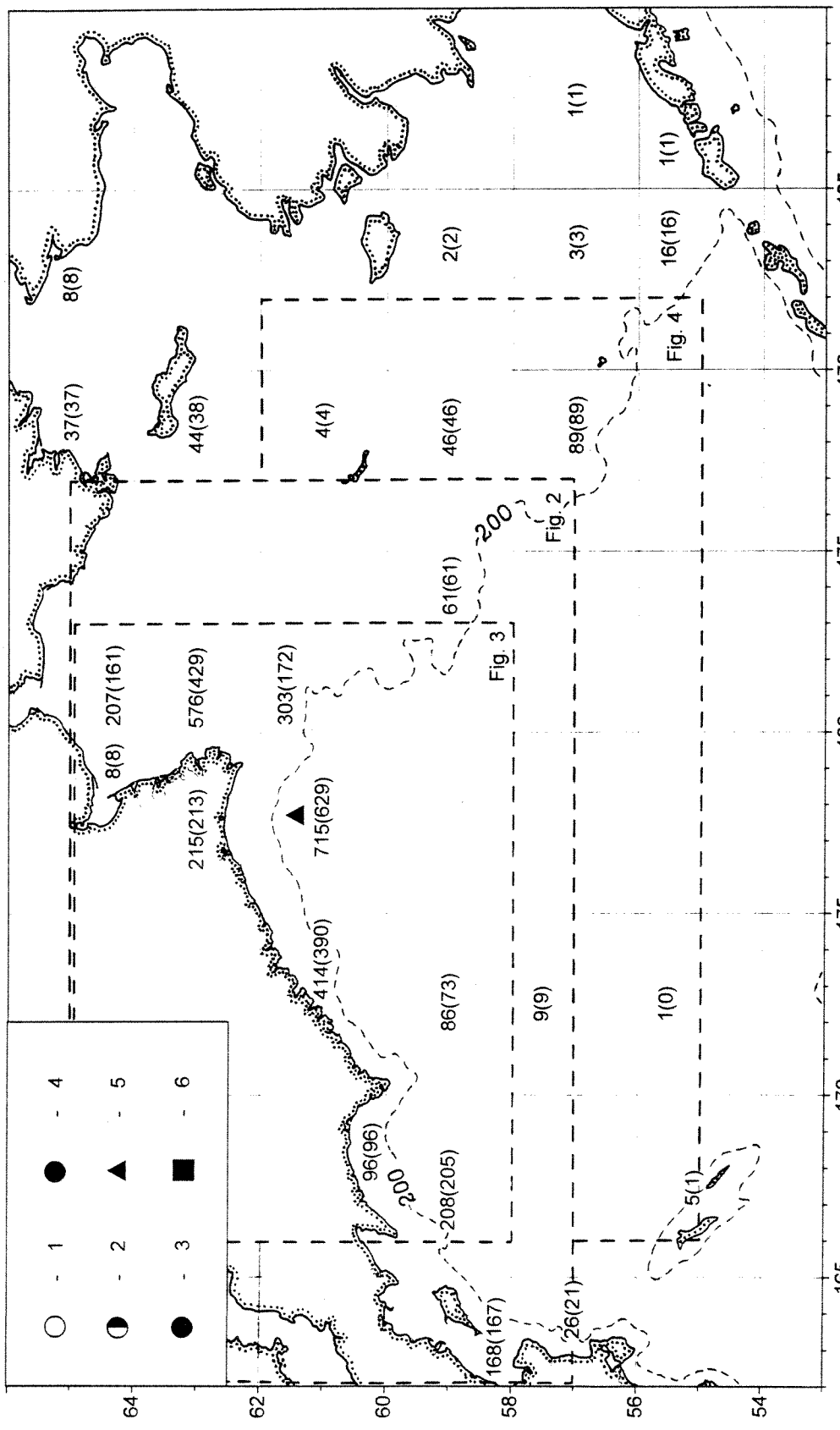


Fig. 1 Distribution of the groundfish survey efforts in the Bering Sea, 1974-1991. Ciphers show the total number of bottom and near-bottom trawl hauls in rectangles 2°N per 5°E and W, in brackets-bottom hauls only. Triangle shows single salmon catch in spring. Position of areas with salmon catches in other seasons are given. The symbols for Fig. 1-4 are following: 1 - first month of season; 2 - second month; 3 - third month; 4 - Chum; 5 - Chinook; 6 - Pink.

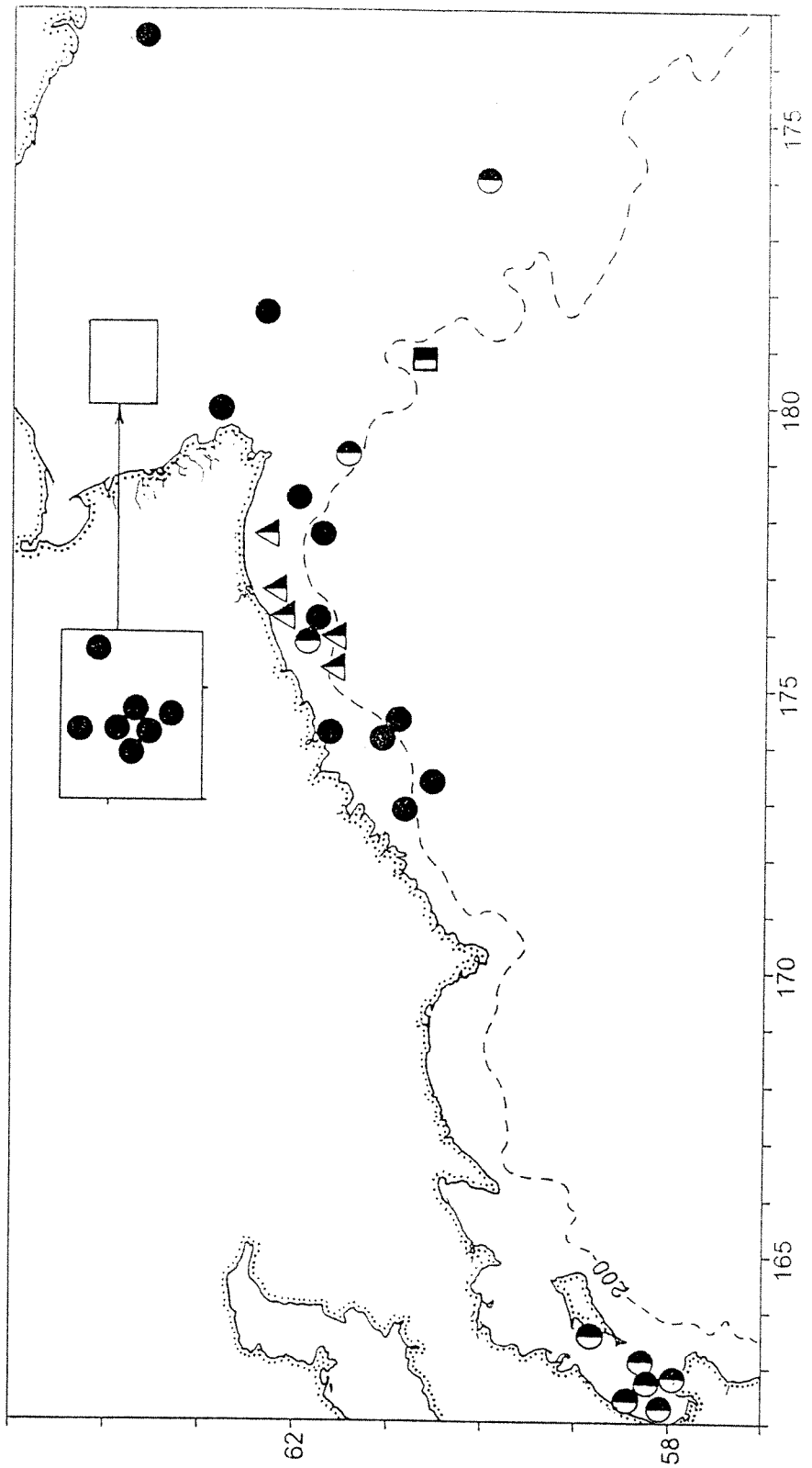


Fig. 2 Pacific salmon catch distribution during the groundfish surveys in the Bering Sea in summer. Legends as on Fig. 1.

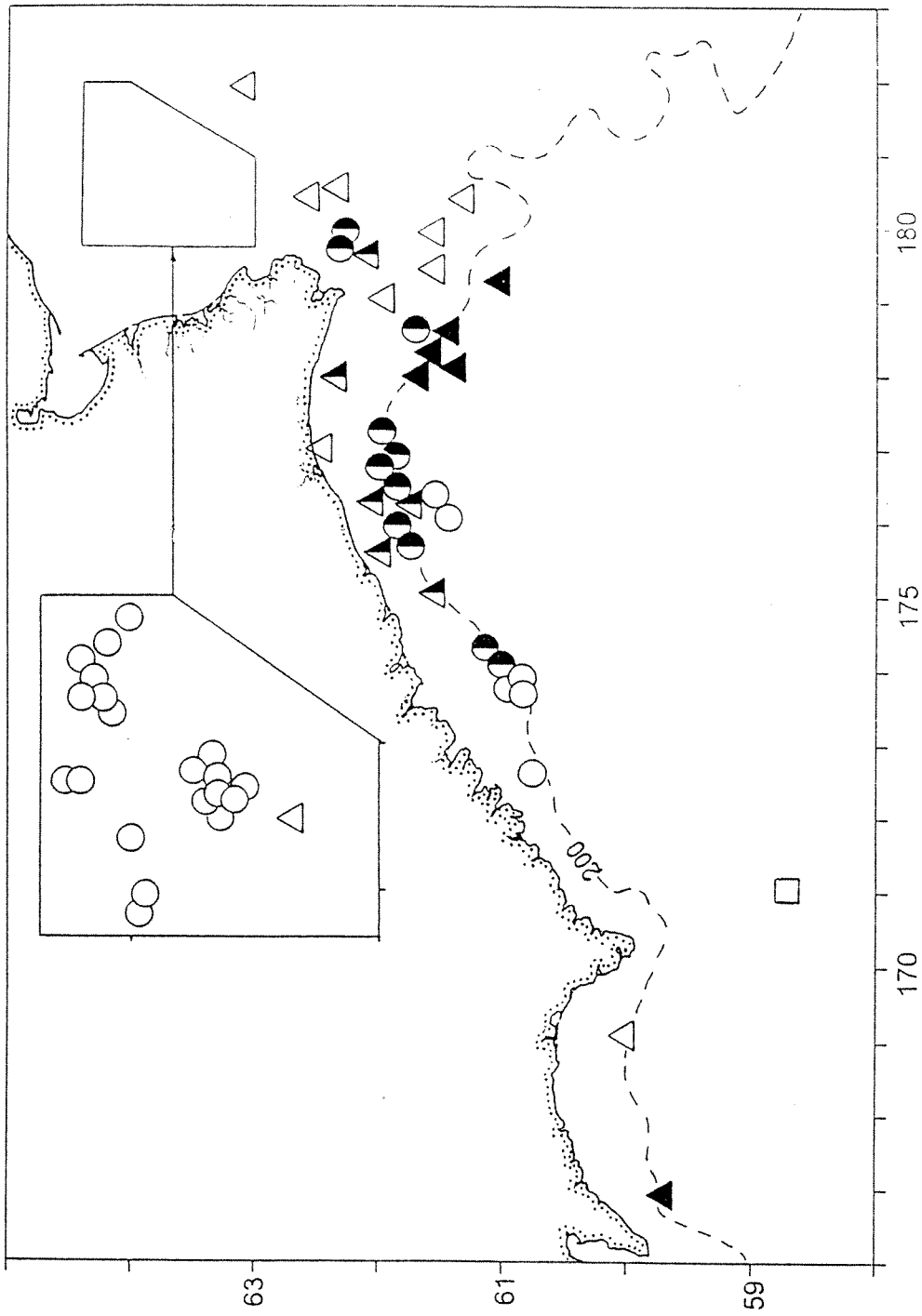


Fig. 3 Pacific salmon catch distribution during the groundfish surveys in the Bering Sea in autumn. Legends as on Fig. 1.

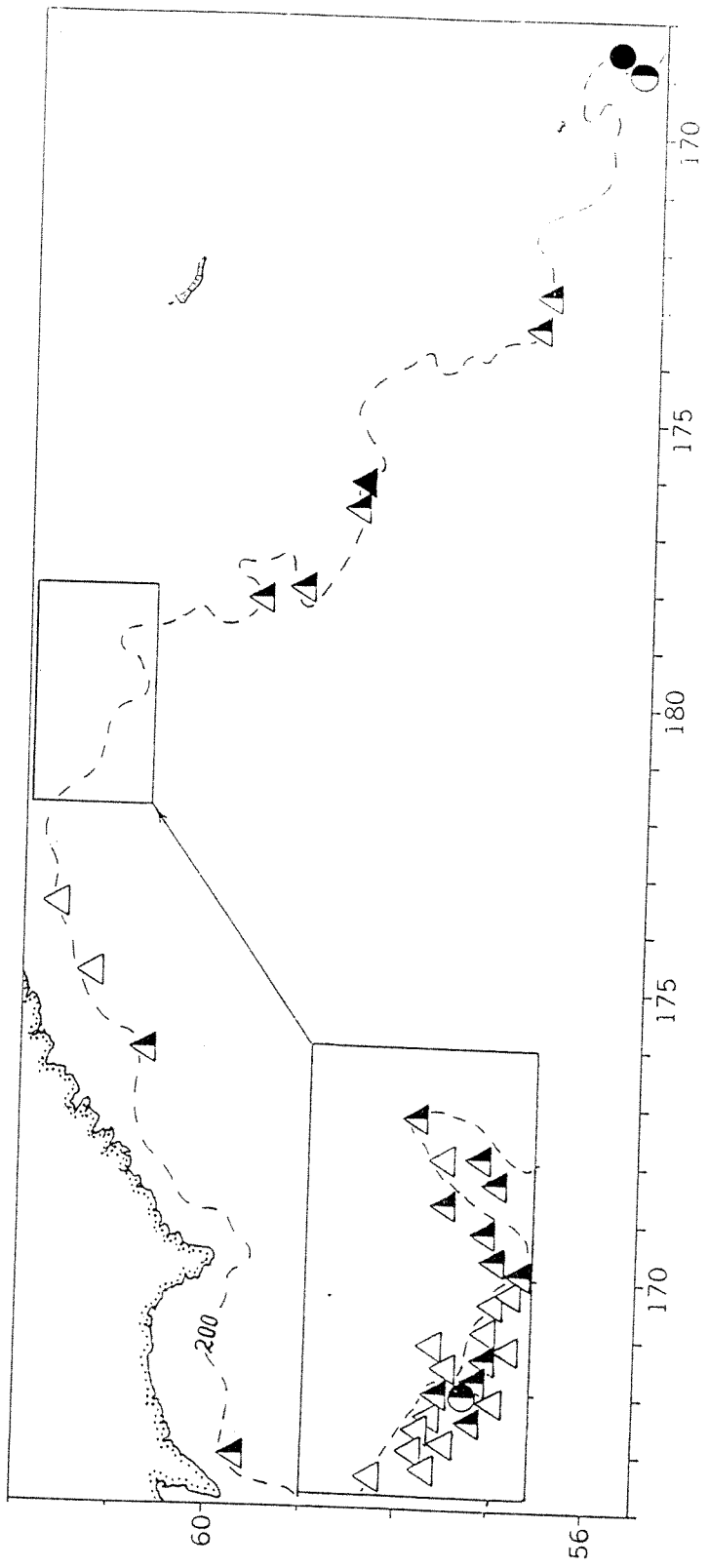
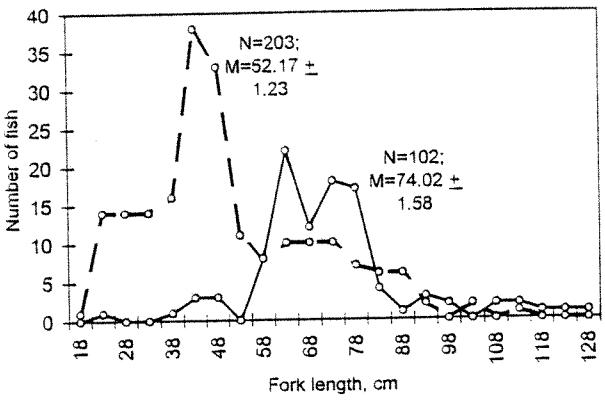


Fig. 4 Pacific salmon catch distribution during the groundfish surveys in the Bering Sea in winter. Legends as on Fig. 1.

Fig. 5 Length distribution of chinook salmon from the bottom (solid line) and pelagic (dotted line) trawl catches, 1974-1993.



in the bottom and near-bottom trawl catches. After their third year at sea, chinook salmon in the Bering Sea usually mature and this is reflected by the decreasing occurrence of larger fish in trawl catches (Fig. 5).

The organisms at near-bottom layers of the outer shelf, in particular adult squid *Berryteuthis magister,* predominate in the chinook diet composition (Radchenko and Chigirinsky, 1995). At the same time, juvenile squid dwell chiefly in pelagic deep-sea regions (Radchenko 1992) and constitute the main part of chinook diet during the second marine year. Also euphausiids are an important component of chinook diet in pelagic deep-sea regions (Chuchukalo et al. 1994). Thus, features of chinook distribution coincide well with the distribution of their primary food organisms.

Large, mostly maturing chum salmon occur in near-bottom layers. It is interesting that during pelagic trawl surveys the largest chum specimens are caught in the near-shore zone. Chum salmon of 0.2 age occur over the outer shelf and continental slope and yearlings in the offshore Bering Sea (Sobolevsky et al. 1994). During May-June in the Gulf of Alaska, chum prefer the 53-65 m layer (Manzer 1964). During the May-June period 80-100% of the chum salmon were maturing. Then, in late June to early July, the percentage of immature chum increased to 50-58.3% and during day-light hours, a portion of the chum stock was found in a layer from 0 to 26 m and another layer (likely maturing specimens) below 53 m (Manzer 1964). It must be noted that the food spectra differ noticeably between immature and maturing chum (Gorbatenko and Chuchukalo 1989).

Chum adherence to deeper sea layers in warm seasons may be connected to the dynamics of salmon maturation in the relatively cold temperatures of near-bottom water. The increase of efficiency of consumed food utilization is known for fish at low positive water temperatures in comparison with higher ones (Smith et al. 1986). It is possible that the change-over between somatic and gonadal growth appears in such conditions for maturing chum. In any case, the metabolic costs are noticeably reduced for salmon in conditions of low oxygen concentrations and temperatures of 3-5EC (Hoar et al. 1979). This is reflected in the lowest values of the maintaining ration in such conditions (Brett et al. 1969) cited after Hoar *et al.*, 1979.

Existing data on the intensity of walleye pollock fishing in the Navarin region in 1980s - 1990s allow us to estimate the value of Pacific salmon by-catch. In 1979 - 1988 the walleye pollock catch varied in the Navarin region from 218 to $855x10^3$ tons, until in 1995 declined to $135x10^3$ tons (Wespestad 1995). The long-term average was $379x10^3$ tons. Average catch per unit effort for large-tonnage vessels was 19.1 tons for 1979 - 1988. Thus, no less than 19.9 thousand trawl operations have been conducted annually for the determination of the mean value of walleye pollock catch. Since the walleye pollock fishery is usually conducted by pelagic trawls in the near-bottom layer, the annual Pacific salmon by-catch can be estimated at approximately 4.1 thousand fish (chinook and chum), or a salmon biomass estimate of roughly $12.2x10^3$ tons based on the mean weight of salmon specimens for the south-eastern Bering Sea shelf (Low and Berger 1994). This value is insignificant in comparison with either natural salmon mortality or commercial catches. The groundfish trawl fisheries in other regions of the western Bering Sea shelf and on other species are characterized by significantly lower fisheries effort.

CONCLUSIONS

The groundfish trawl fisheries in the shelf and continental slope zones of the Bering Sea do not appear to measurably affect the stock conditions of salmon feeding in this region. However, observations of the cases of salmon by-catch suggest some interesting features of chinook and chum salmon ecology. Salmon vertical distribution in the ocean varies among species and among age chum within species as well. These differences are perhaps related to differences in trophic linkages and metabolism and among chum age groups within species as well.

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