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DISTRIBUTIONAL OVERLAP OF SALMONIDS AND FLYING SQUID (*Ommastrephes bartrami*) IN THE WESTERN AND CENTRAL NORTH PACIFIC OCEAN, AS INDICATED BY ANALYSIS OF JAPANESE SALMON RESEARCH VESSEL CATCHES AND INCIDENTAL CATCHES, 1972-85

by

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DISTRIBUTIONAL OVERLAP OF SALMONIDS AND FLYING SQUID (Ommastrephes bartrami) IN THE WESTERN AND CENTRAL NORTH PACIFIC OCEAN, AS INDICATED BY ANALYSIS OF JAPANESE SALMON RESEARCH VESSEL CATCHES AND INCIDENTAL CATCHES, 1972-85

ABSTRACT

Several studies have addressed the overlap of salmonid and flying squid (Ommastrephes bartrami) distributions, and the potential for incidental catches of salmonids by the Japanese squid driftnet fishery. However, these past studies have not had available much squid catch data with which to describe the empirical relationships between salmonid and squid abundance and their co-occurrence in gillnet catches. This study examines salmonid catch data (1972-85) and flying squid incidental catch data (1982-85) from gillnet sampling by Japanese salmon research vessels. Maps depicting mean annual catch-per-unit-effort (CPUE) of each salmonid species and of squid indicate that squid range north of the authorized squid fishery area farther north than salmonids range south within it. Chum, pink, and coho salmon were encountered within the squid fishery area in June or July, and all salmonid species except sockeye were encountered in the 2°-latitude sector immediately north of the squid fishery area. Analysis of the relationships between salmonid and squid CPUE and sea surface temperature suggested that co-occurrence of salmonids and squid would happen mostly in the temperature range 10°-15°C. Co-occurrence of salmonids and squid was infrequent within the squid fishery area, but markedly increased just north of the northern boundary. This study confirmed earlier conclusions that incidental salmonid catches within the squid fishery area would in general be infrequent and low, but that frequency, magnitude, and species diversity of salmonid incidental catches would markedly increase in waters just north of the area or in waters within the area in cold years.

INTRODUCTION

The recent development of the Japanese high seas drift gillnet fishery for flying squid raised the concern amongst North American fishing interests that substantial incidental catches of North American salmonids may occur in the fishery (Burgner et al. 1982, Burgner and Meyer 1983, Dahlberg and Sigler 1987, Japan Fisheries Agency 1982, Walker and Burgner 1985). In 1979, gear conflicts in the squid fishery off the Japan coast prompted the Japan Fisheries Agency (JFA) to reserve the nearshore waters for the squid jigging fleet and to move the drift gillnet fleet offshore, east of 170°E and north of 20°N. In consideration of salmonid and squid distributions, a movable northern boundary was established in 1981 based on the monthly location of the 15°C isotherm. The fishing season begins in June, when the northern boundary is at 40°N. The boundary shifts north each month in 2°-latitude increments through September (46°N), and then shifts south again in 2°-latitude monthly increments through December. This was intended to prohibit the squid driftnet fishery from operating in waters cooler than 15°C - areas favored by salmonids (Japan Fisheries Agency 1982).

Several analyses have been done to infer the degree of distributional overlap of flying squid and salmonids, with respect to surface temperature and with respect to the operational area of the squid driftnet fishery (Burgner et al. 1982, Burgner and Meyer 1983, Takagi 1983, Walker and Burgner 1985, Dahlberg and Sigler 1987). In general, these studies have indicated that there is some overlap of salmonid and flying squid distributions, and that temperatures less than 15°C can be found in the northern sectors of the squid fishery area. However, the overall conclusion from these studies is that incidental catches of salmonids made within the authorized squid fishery area would probably be very low.

Burgner et al. (1982) examined salmon distributions and sea surface temperatures relative to the squid driftnet fishery area, and proposed that an overlap in the distribution of squid and salmon may exist. The large variability in the 15°C isotherm relative to the northern boundary of the squid fishery area suggested that salmon may occur in cooler waters at the northern extreme of the area. High catch-per-unit-effort (CPUE) of flying squid may occur at surface temperatures below 15 C (Bernard 1981, Dahlberg and Sigler 1987, Japan Fisheries Agency 1982, 1987). Accordingly, fishing effort has been high near the northern boundary of the squid fishery area (see Fig. 3 in Japan Fisheries Agency 1982), where salmon by-catch is possible.

Burgner and Meyer (1983) made further analysis of salmon distribution with respect to surface temperatures, and suggested that low densities of chum, pink and coho salmon may occur along the northern border of the squid fishery zone in June and that all five salmon species could be encountered in July and September. Walker and Burgner (1985) analyzed steelhead catch data in a similar fashion, and concluded that steelhead (Salmo spp., including the Asian anadromous trout) may occur in low numbers near the northern border of the squid fishery area during July in years with temperatures cooler than average, while moderate incidental catches could be expected in September.

The previous studies cited did not directly address overlap of squid and salmonid distributions, because the investigators did not analyze actual squid catch data in concert with salmonid catch data. In recent years Japan has provided through the International North Pacific Fisheries Commission (INPFC) data on incidental catches of flying squid (and other squid and non-salmonid fish species) in salmon research vessel operations employing gillnet gear. Sufficient data have been accumulated to permit an analysis that more directly addresses the distributional overlap and co-occurrence of salmonids and flying squid. In this paper we use these recent data to describe the overlap of squid and salmonid distributions, to describe the relationships between squid and salmonid catches and sea surface temperature, and to examine the co-occurrence of salmonids and flying squid in gillnet catches inside and adjacent to the Japanese squid driftnet fishery area.

DATA SOURCES AND METHODS

Two sets of data from Japanese salmon research vessel operations were used in this study. Gillnet effort and salmonid catch data have been routinely provided through INPFC, and recently the 1972-85 data were corrected and provided to the United States on computer tape by JFA. Beginning with 1982, JFA has provided in INPFC documents data on incidental catches (in numbers) of fish and squid in the salmon research vessel gillnet operations. We coded the 1982-85 flying squid incidental catches and merged the data onto the salmonid catch and effort data file. Because the incidental catch data provided catches by combined gillnet mesh-size (i.e., including variable mesh "C" gear, commercial mesh "A" gear, and special mesh "F" gear), the salmonid catch and effort data used were also for all mesh sizes (coded "Z" gear records on the data tape). We selected data for the study area south of 48°N, 150°E-145°W and for the period May through August.

Graphical descriptions of the spatial distributions of flying squid and salmonids within the study area were prepared by calculating the unweighted mean annual CPUE, in numbers per tan of gillnet, stratified by 2°-latitude by 5°-longitude INPFC statistical areas and by month, and by plotting these CPUE values (represented by intervals) on maps. The relationships between abundance of each salmonid species and abundance of squid, and between squid and salmonid abundance and sea surface temperature, were examined by graphical analysis of CPUE. Since the CPUE values are based on data representing both variable mesh and commercial mesh gear, and since the composition of the types of gillnet in a set varied within and between years, the CPUEs are not completely standardized. However, the amount of variable mesh gillnet is in the great majority of operations less than one-third of the total gillnet string, so the variation in catchability is not expected to be large. We are confident that the calculated CPUEs reflect major spatial trends in abundance.

Because steelhead catches south of 48°N in May-August 1972-80 were very low relative to those after 1980 (Table 1), we suspected that the earlier steelhead catches were not completely recorded. Therefore, calculation of steelhead CPUE is based on 1981-85 data only.

In order to examine the relationship between salmonid and squid abundance and sea surface temperature, we prepared plots of CPUEs as a function of temperature for individual gillnet operations made in the area south of 48°N, 170°E-145°W. The region east of 170°E was chosen because it includes areas within and immediately north of the squid fishery zone.

RESULTS AND DISCUSSION

General Distribution of Salmonids and Flying Squid

The number of gillnet operations analyzed in this paper, stratified by INPFC statistical area and month, is shown in Fig. 1a-b for 1972-85 and in Fig. 2a-b for 1982-85 (the latter being years when squid incidental catch data were available). The sampling was designed to emphasize the area of salmonid distribution, so it is not surprising that the great majority of operations were conducted north of the squid driftnet fishery area. In June 1972-85, only 10 operations were conducted within the squid fishery area out of 1,318 operations in the entire study area 150E°-145°W and south of 48°N. In July and August, these counts were 52 out of 1,148 and 10 out of 72, respectively. In the period 1982-85, the counts of operations within the squid fishery area were only 3 out of 232, 31 out of 202, and 2 out of 5 in June, July, and August, respectively. Effort within the squid fishery area was heavily concentrated in the northwest corner, although some sampling in July and August was conducted by one research vessel along a north-south transect near 155°W.

The spatial distributions of sockeye, chum, pink, coho, and chinook salmon, steelhead trout, and flying squid are shown by INPFC statistical area and by month in Figs. 3a-b, 3c-d, 3e-f, 3g-h, 3i-j, 3k-l, and 3m-n, respectively. These figures also show the boundary of the squid driftnet fishery area in June-August.

The spring/summer northward migration of sockeye salmon in the central and western North Pacific is clearly depicted in Fig. 3a-b. In May, sockeye occurred in areas north of 40°N and were most abundant north of 46°N. By June there was a marked northward shift of the overall range, and by August only small catches were made in the study area. There were no catches of sockeye in 1972-85 within the squid driftnet fishery area, or even within the 2°-latitude sector immediately north of the June, July and August northern boundaries.

The seasonal northward shift in the distribution of chum salmon is less pronounced than is that of sockeye, but it is still evident in Fig. 3c-d. Chum tend to range farther south than do sockeye, being encountered in the northwest corner of the squid fishery area in July and along the 2°-latitude sector north of the fishery's northern boundary in June-August.

Pink salmon are in greatest abundance in the study area in the far western sectors (Fig. 3e-f). They occurred southward to about the northern edge of the squid fishery area, at least in the central North Pacific, and were encountered inside the northwest corner of the fishery area in July.

Coho salmon tend to have a more southerly distribution than do sockeye or chum salmon. They were generally in low abundance in gillnet catches across the study area in May, but in June their abundance increased markedly, especially in the region south of the central Aleutian Islands (Fig. 3g-h). They occurred within the squid fishery area in June and July, and were in moderate abundance in the 2°-latitude sector just north of the northern boundary in June-August.

Chinook salmon were encountered south of 42°N in June only in waters west of 170°E (Fig. 3i). In July, low abundance of chinook was observed just north of the northern boundary of the squid area, and limited sampling in August showed occurrence of chinook near, but not within, the northwest corner of the fishery area (Fig. 3j).

Steelhead trout (including the North American Salmo gairdneri and the Kamchatkan anadromous trout S. mykiss) were not encountered within the squid fishery area in any month June-August 1981-85, but were caught near the northern border of the fishery area in all three months (Fig. 3k-l).

In general, the results of this analysis support Burgner and Meyer's (1983) conclusion, based on analysis of catches as a function of temperature, that some salmonids might be caught incidentally by the squid fishery operating in June and July. They concluded that coho might be particularly susceptible to incidental capture in June. Figure 3g attests that indeed coho are distributed farther south than are the other salmonid species and are present in the fishery area in June. Burgner and Meyer also concluded that in July all species might be encountered within the squid fishery zone. Walker and Burgner (1985) concluded, also from analysis of catch and temperature data, that steelhead would not likely be encountered in the squid fishery area in June or August, but some extension of their range south of 42°N might occur in July. The present analysis shows that chum, pink and coho salmon definitely occur within the squid fishery area in July, and that the ranges of chinook salmon and steelhead extend at least as far south as the 2°-latitude sector just north of the squid fishery area.

Figure 3m-n, in comparison with the distribution maps for salmonids, shows that the range of flying squid extends north of the squid fishery area farther than the range of any salmonid species extends south into it. Low squid abundance was observed northward to the sector 42°-44°N in June. In July, when CPUE was generally higher throughout the study area, moderate-to-high abundances were observed in the sector 42°-44°N and low abundances were encountered as far north as 44°-46°N and, in waters west of 170°E, as far north as 46°-48°N.

Salmonid and Squid Catches as a Function of Temperature

Figure 4a-n presents a series of plots of CPUE of each salmonid species and of flying squid as a function of temperature, in each month May-August, 1972-85 (1981-85 for steelhead and 1982-85 for squid). In addition, we compiled Appendix Tables 1-4 which provide information on frequency of capture and CPUE of flying squid by 1°C temperature interval in the area southeast of 48°N, 170°E, in each month May to August, respectively, 1982-85. These tables are intended to supplement the series of similar tables prepared by Burgner and Meyer (1983) for Pacific salmons and by Walker and Burgner (1985) for steelhead. To elucidate the ranges of temperature in which salmonids and squid might co-occur, Table 2 was prepared to show the maximum temperatures at which salmonids were caught and the minimum temperatures at which flying squid were caught.

In May and June sockeye salmon catches were few and very low above about 8°C (Fig. 4a, Table 2). Low catches of sockeye were made in waters with temperatures up to about 11°C in July, and, due to the northward movement of immature sockeye and the coastward migration of maturing fish, the species was essentially absent in the catches made in August representing temperatures from about 8°C to 23°C (Fig. 4b). In May and June, chum catches of no more than about 1 fish/tan were made in waters with temperatures more than 8°C and 9°C, respectively, and no catch was made over 13.5°C (Fig. 4c). In July, chum were caught in moderate abundance in warmer waters, as CPUEs up to about 3.5 fish/tan were made in waters over 10°C and small catches occurred up to about 15°C (Fig. 4d, Table 2). Limited data in August show chum CPUE to have been essentially zero over 14°C. In May, June and July, pink salmon CPUE was low (under about 0.3 fish/tan) in waters over about 11°C, although in July they were encountered up to 15.0°C (Fig. 4e-f, Table 2). The apparent absence of pink salmon in August is due to the summertime emigration of the entire population from the south-central North Pacific, rather than due to temperature effects. Coho abundance was highest in waters 8°-9°C and dropped off to nearly zero in waters over 12°C in May and June. As was the case for chum, coho were encountered more abundantly in warmer waters in July (Fig. 4h, Table 2). By August, much of the coho population had migrated out of the study area, but moderate catches were made in waters below 12°C. In May and June, chinook catches were very low over 9°C and 10°C, respectively (Fig. 4i), while in July and August slightly higher catches were made in waters up to 13°C (Fig. 4j, Table 2). Steelhead CPUE abruptly declined in May and June over about 9°C, while in July moderate-to-high abundances were encountered in waters up to about 11°C and trace catches were made up to 13.0°C (Fig. 4k-l, Table 2). CPUE of steelhead in August was essentially zero over 12°C.

Figure 4m-n and Appendix Tables 1-4 suggest that flying squid were not available for capture in waters below 9°C. Generally low-to-moderate catches were made in the 9°-12°C temperature range, although the largest individual catches in June and July were made in this interval. In July, when sampling occurred in several temperature intervals above 15°C, squid were, on the average, caught more frequently and in higher abundance above 15°C than below (Appendix Table 3).

Co-occurrence of Salmonids and Flying Squid in Gillnet Catches

Table 3 shows the frequency of occurrence of salmonids and squid, and of salmonids and squid together, in gillnet sets in various sectors of the study area. In May, salmonids were caught in nearly all of the sets made between 40°N and 48°N, both east and west of 170°E, while squid were encountered in only two out of 109 sets northeast of 40°N, 170°E. In June, salmonids were caught in nearly all sets north of 40°N while squid were caught in less than 10% of the sets north of 40°N. Salmonids were also caught in all but two of the sets in which squid were caught north of 40°N. Squid were more frequently encountered in sets north of the squid fishery boundary in July, having been caught in 21% of the sets northeast of 42°N, 170°E and in 13% of the sets northwest of 42°N, 170°E. Salmonids co-occurred with squid in nearly all of these operations in the northwest sector, but in about half of the operations in the northeast sector. Salmonids were encountered in only about 10% (3 out of 31) of the July sets made southeast of 42°N, 170°E (i.e., in the squid fishery area). In the limited sampling in August east of 170°E, only salmonids were caught north of 44°N and only squid were caught south.

We attempted to visualize empirical relationships between abundance of each salmonid species and flying squid by plotting CPUE of salmonids and squid in individual gillnet sets in which squid occurred, in the area southeast of 48°N, 170°E, and in all months May-August combined (Fig. 5a-f). These plots also provide the maximum CPUE of the salmonid species in all sets made in the area. Sockeye were not caught in any set in which squid were caught (Fig. 5a), which follows from the fact that the temperature ranges of these species overlap very little (Table 2). Other species of salmonids co-occurred with squid, but mostly in sets that yielded low catches of both species (usually about 1 squid/tan or less, and usually much less than the maximum CPUEs for salmonids).

While these results reflect the general inverse relationship between abundance of salmonids and squid, catch variability of both salmonids and squid is large, and there is some likelihood that large catches of both salmonids and squid could occur in individual operations. We did not include the 1986 incidental catch data in this analysis because the corresponding 1986 salmonid catch and effort data were not available on computer medium. However, in a set at 41°N, 180° on 17 June 1986, 200 coho salmon and 489 squid were caught in 124 tans of gillnet (Japan Fisheries Agency 1987). These CPUE values would constitute an extreme outlier in Fig. 5d.

SUMMARY AND CONCLUSIONS

1. Analysis of flying squid incidental catch data from gillnet sampling by Japanese salmon research vessels permitted more inference about the extent of overlap of salmonid and flying squid distributions than has been possible in the past.

2. The distributions of flying squid and salmonids overlap considerably, mainly in waters north of the authorized Japanese squid driftnet fishery area (Fig. 3a-n). Sockeye salmon were encountered neither in the squid fishery area nor in the 2°-latitude sector

north of it. Chum, pink, and especially coho salmon were encountered within the area, and chinook salmon and steelhead were encountered just north of the boundary. Squid were distributed farther north of the fishery area boundary than salmonids were distributed southward into it.

3. The temperature ranges of salmonids and squid overlapped variously depending on species, but in general salmonid catches declined to low levels above about 10°C, and squid catches were generally low below about 12°C (Fig. 4a-n, Table 2). However, some of the largest individual squid catches occurred in waters around 12°C.

4. Squid were encountered in gillnet catches north of the squid fishery area more frequently than salmonids (all species combined) were caught within it (Table 3). Salmonids were caught in only four out of 36 gillnet sets within the squid fishery area in June-August, 1982-85.

5. In general, when salmonids co-occurred with flying squid in gillnet catches they were in low abundance (Fig. 5a-f). The highest CPUEs of each salmonid species in sets in which squid were also caught were considerably lower than the maximum CPUEs obtained in the entire study area south of 48°N. Catch variability is high, however, so large salmonid incidental catches could co-occur with squid catches in some individual sets.

6. We conclude that the northern boundary of the Japanese squid driftnet fishery area is effective in limiting salmonid incidental catches to fairly low levels, although some salmonid catch would occur in the area. Salmonid catches would be expected to increase in cold years when water with temperature less than 15°C extends well into the fishery area. Squid are frequently encountered in moderate-to-high abundance just north of the fishery area, so the present regulation probably serves to limit salmonid incidental catch at the expense of some quality fishing ground for squid. The frequency, magnitude, and species diversity of salmonid incidental catch would markedly increase just north of the fishery area boundary, so fishing north of the boundary would have much more potential for significant by-catch of salmon and steelhead.

ACKNOWLEDGMENTS

We wish to thank the Japanese National Section of INPFC, and particularly the Japan Fisheries Agency, for providing the voluminous 1972-85 salmonid catch and effort data from research vessel operations on computer-readable medium, and for providing incidental squid and non-salmonid fish catch data from 1982-86 research vessel gillnet operations. This study was funded by the National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Research Contract Nos. 85-ABC-00006 and 50-ABNF-7-00002.

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Table 1. Total catch and catch-per-effort of steelhead during gillnet operations by Japanese salmon research vessels, south of 48°N in May-August, 1972-85.

Year	Total catch (numbers)	Total effort (tans)	Catch per tan
1972	0	100,000	0.0
1973	22	126,774	.0002
1974	0	99,565	0.0
1975	4	82,650	.0001
1976	24	93,761	.0003
1977	15	44,485	.0003
1978	182	29,830	.0061
1979	107	21,615	.0050
1980	102	23,000	.0044
1981	412	22,638	.0182
1982	511	26,115	.0196
1983	336	21,271	.0158
1984	654	23,534	.0278
1985	557	13,262	.0420

Table 2. Maximum sea surface temperatures (°C) at which salmonids were caught (1972-85) and minimum temperatures at which flying squid were caught (1982-85), in Japanese salmon research vessel gillnet operations south of 48°N, 170°E-145°W.

Month	Sockeye	Chum	Pink	Coho	Chinook	Steelhead	Squid
May	8.5	11.3	11.3	11.3	10.2	10.9	9.8
June	9.6	13.5	11.8	14.2	11.1	11.8	10.6
July	11.6	15.3	15.0	15.0	13.8	13.0	9.6
August	11.8	13.2	12.3	13.2	12.4	12.4	10.1

Table 3. Frequency of capture of salmonids (all species combined) and of flying squid in Japanese salmon research vessel gillnet operations in the area south of 48°N, 150°E-145°W, divided into four sectors by 170°E and by the northern boundary of the squid driftnet fishery area, in May-August 1982-85. Data are numbers of gillnet sets and, in parentheses, percentage of total number of sets in each month/sector.

Month/ sector	Sets in which salmonids were present		Sets in which squid were present		Sets in which salmonids and squid were present		Total number of sets
May[1]							
NW	108	(99)	0	(0)	0	(0)	109
SW	--		--		--		0
NE	108	(99)	2	(2)	2	(2)	109
SE	--		--		--		0
June							
NW	122	(98)	7	(6)	6	(5)	124
SW	0	(0)	18	(78)	0	(0)	23
NE	81	(99)	7	(9)	6	(7)	82
SE	1	(33)	3	(100)	1	(33)	3
July							
NW	55	(98)	7	(13)	6	(11)	56
SW	0	(0)	2	(100)	0	(0)	2
NE	106	(91)	24	(21)	13	(11)	117
SE	3	(10)	29	(94)	2	(6)	31
August							
NW	--		--		--		0
SW	--		--		--		0
NE	3	(100)	0	(0)	0	(0)	3
SE	0	(0)	2	(100)	0	(0)	2

[1] The squid driftnet fishery does not operate in May, so the northern and southern sectors were defined by 40°N, as in June.

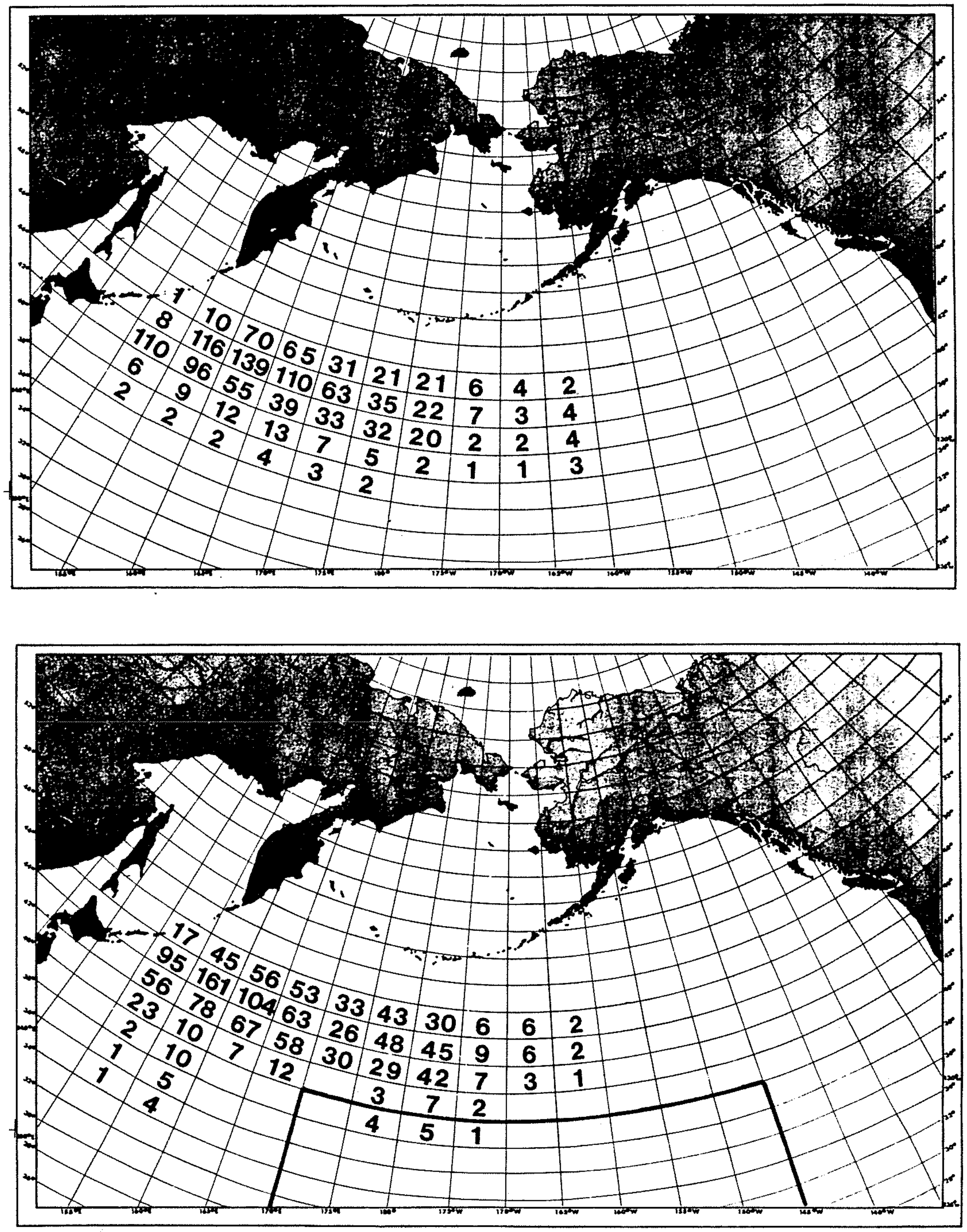


Fig. 1a. Numbers of gillnet operations by Japanese salmon research vessels in the area south of 48°N, 150°E-145°W, in May (upper panel) and June (lower panel), 1972-85. The bold line shows the boundary of the Japanese squid driftnet fishery area in June.

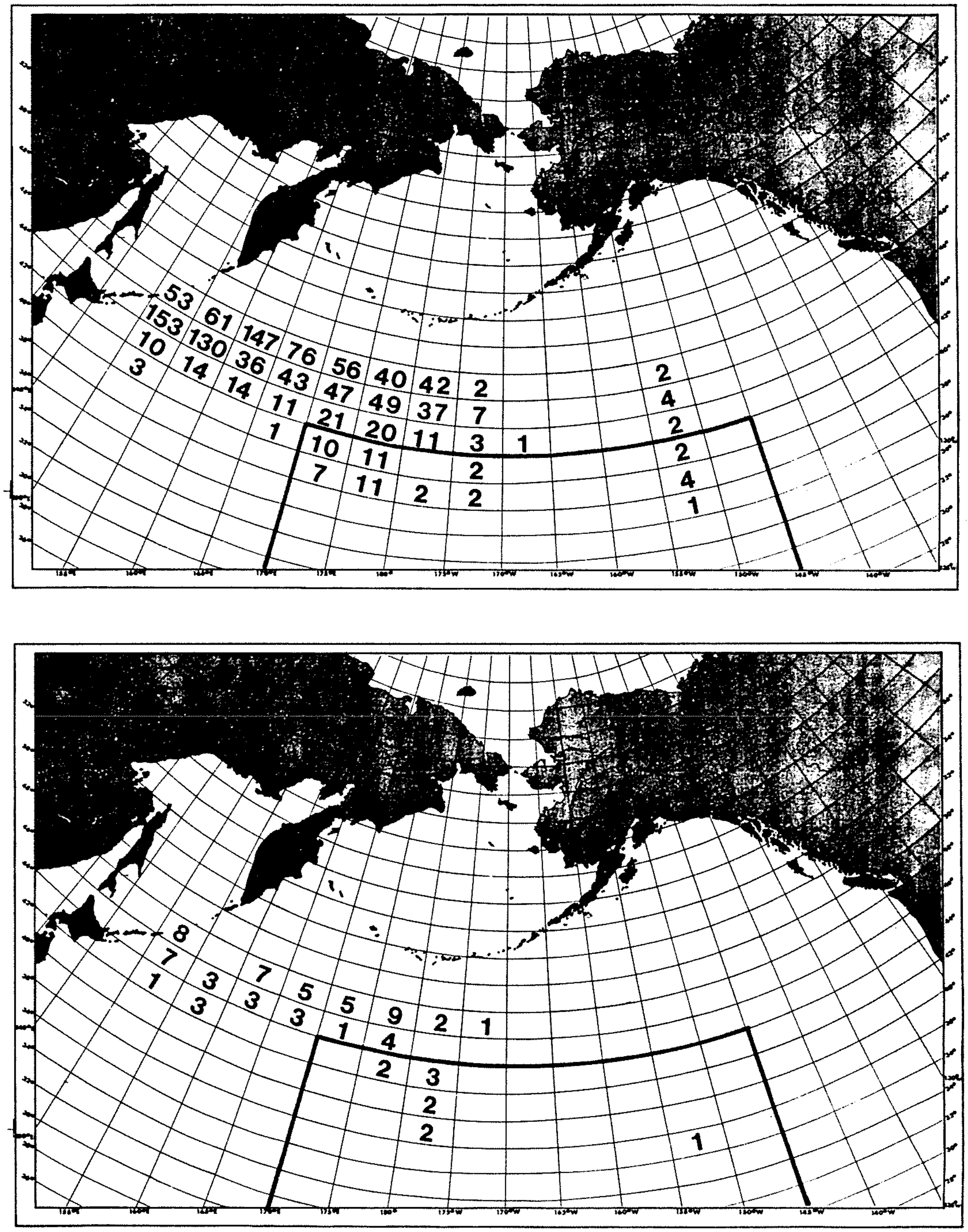


Fig. 1b. Numbers of gillnet operations by Japanese salmon research vessels in the area south of 48°N, 150°E-145°W, in July (upper panel) and August (lower panel), 1972-85. The bold line shows the boundary of the Japanese squid driftnet fishery area.

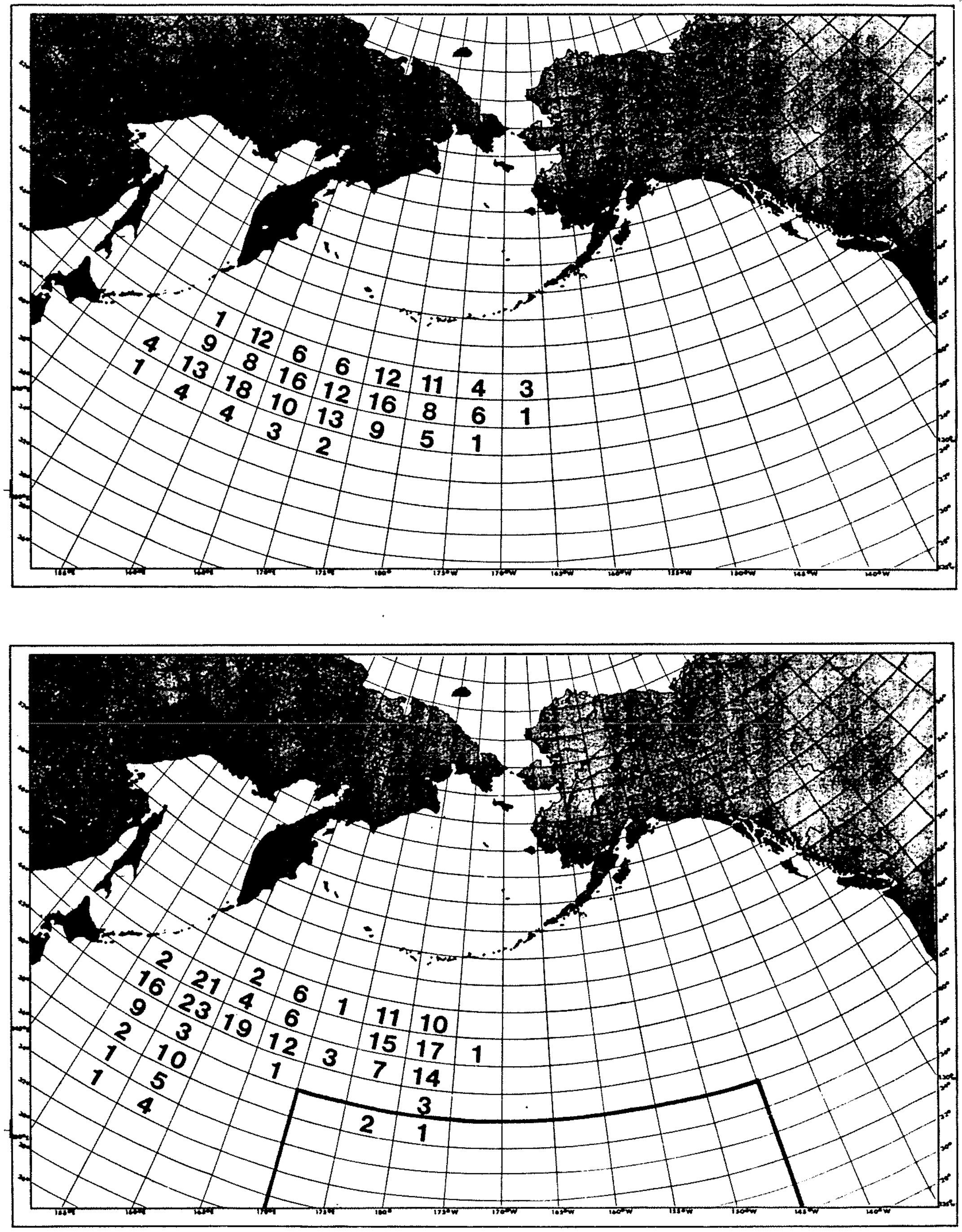


Fig. 2a. Numbers of gillnet operations by Japanese salmon research vessels in the area south of 48°N, 150°E-145°W, in May (upper panel) and June (lower panel), 1982-85. The bold line shows the boundary of the Japanese squid driftnet fishery area in June.

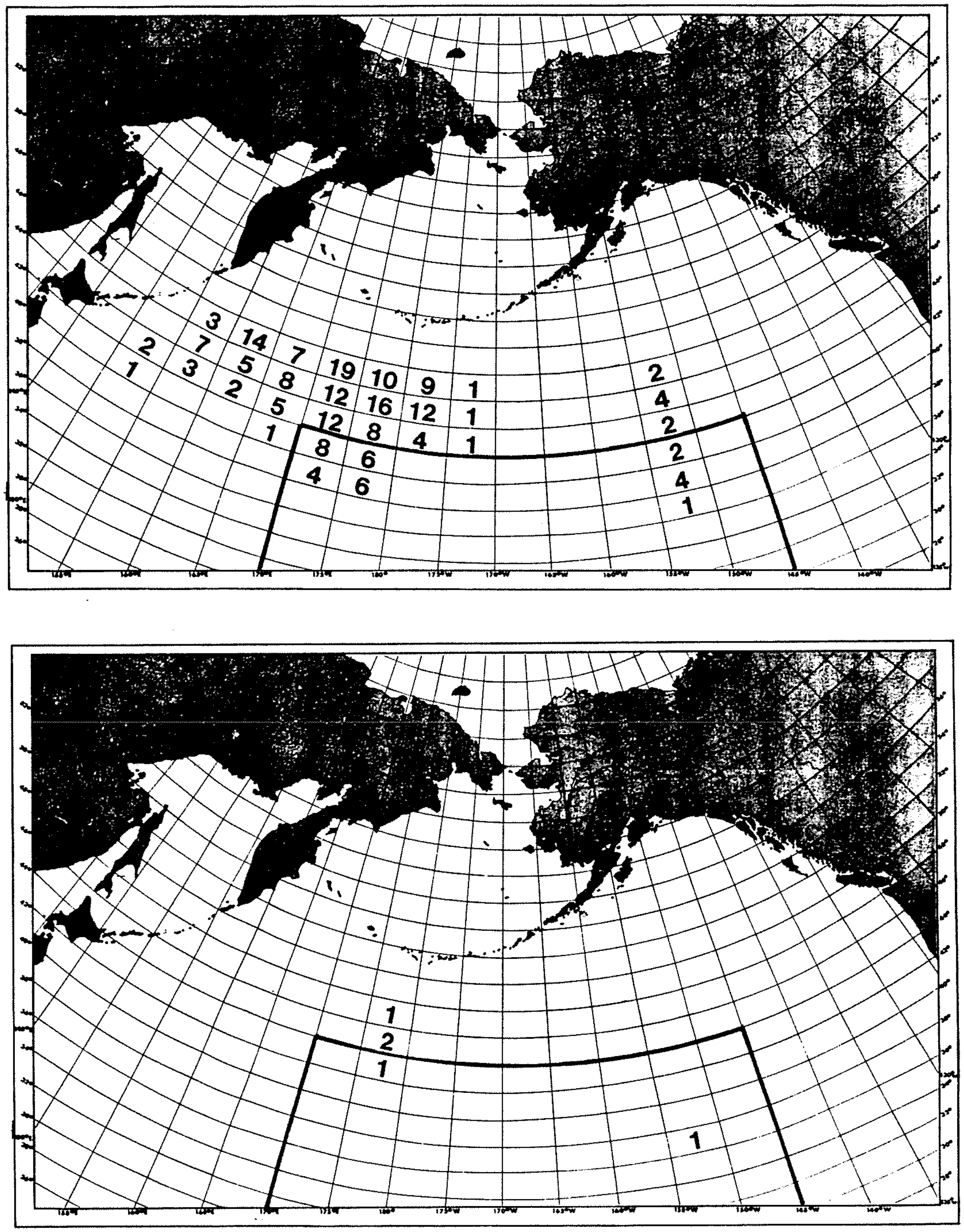


Fig. 2b. Numbers of gillnet operations by Japanese salmon research vessels in the area south of 48°N, 150°E-145°W, in July (upper panel) and August (lower panel), 1982-85. The bold line shows the boundary of the Japanese squid driftnet fishery area.

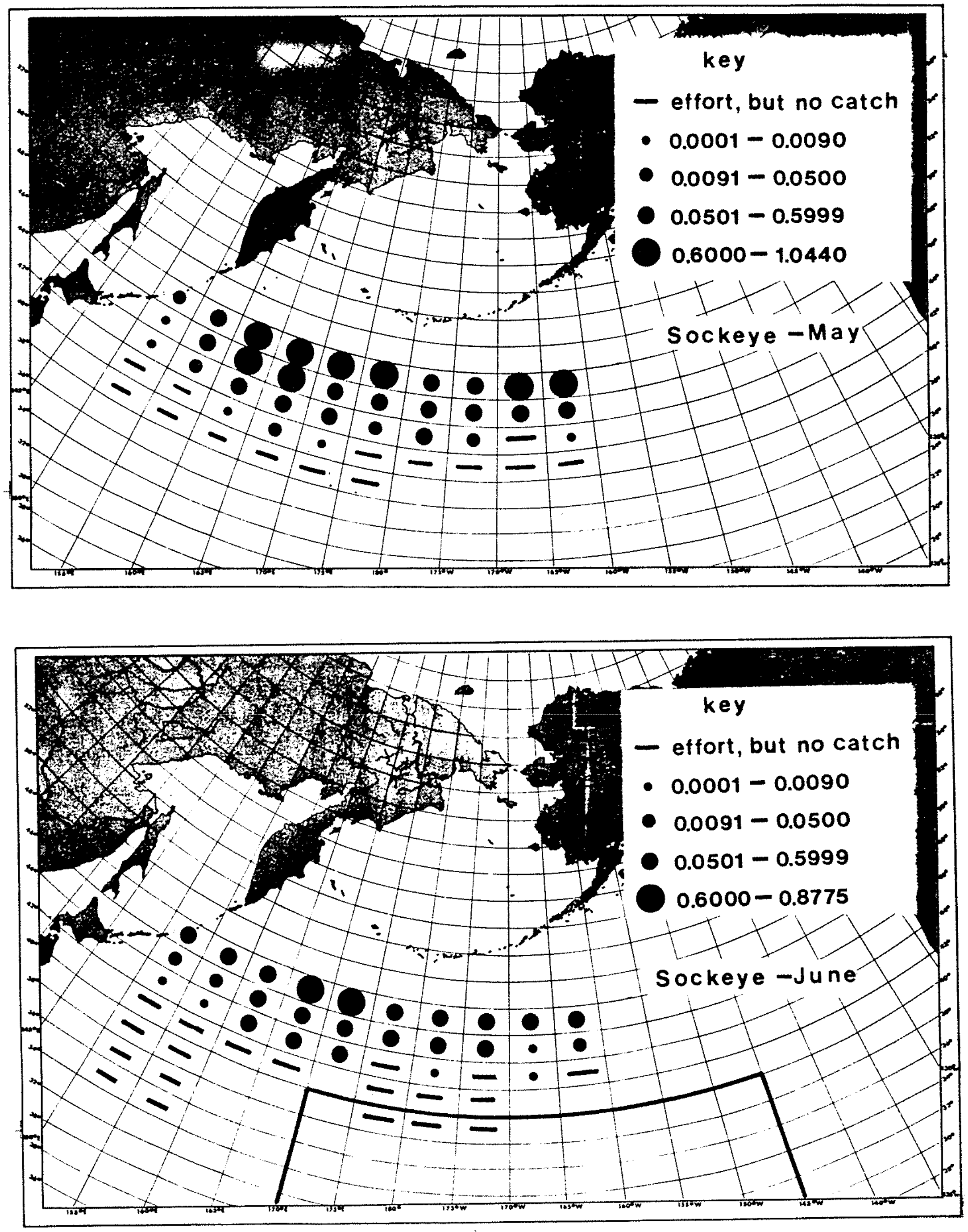
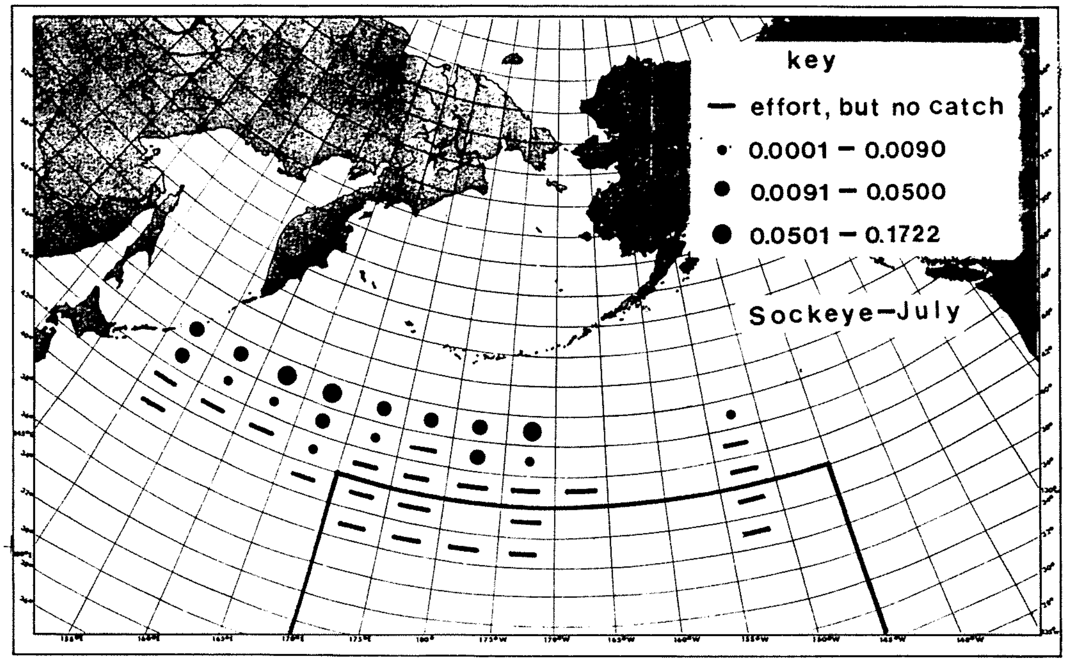


Fig. 3a. Average sockeye salmon CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during May (above) and June (below), 1972-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no sockeye were caught. The heavy outline indicates the squid driftnet fishery zone during June.



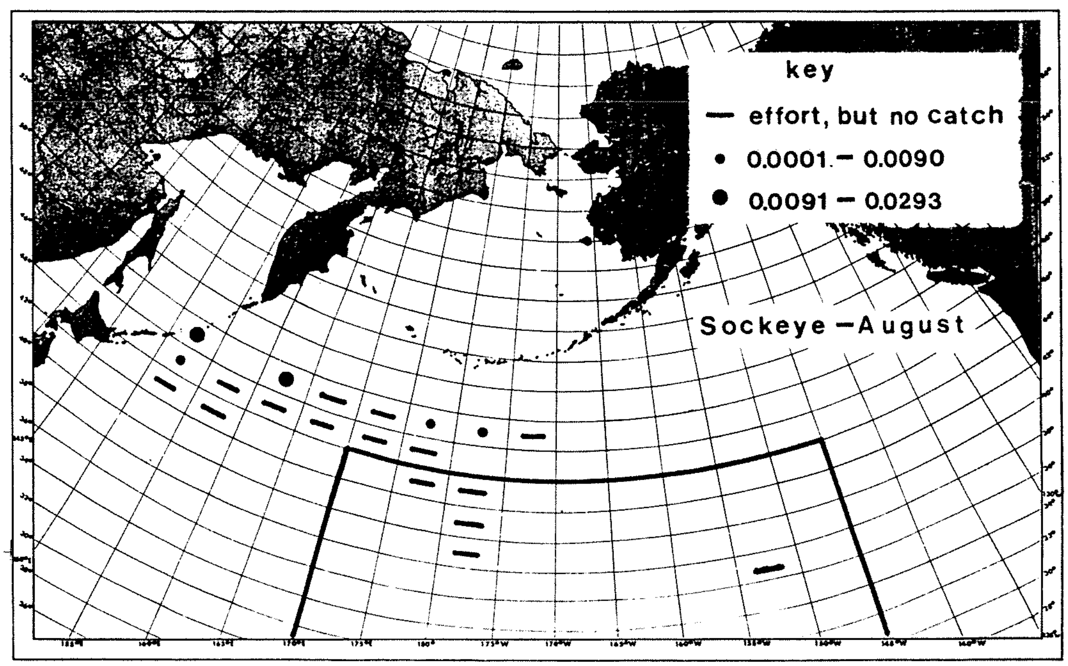
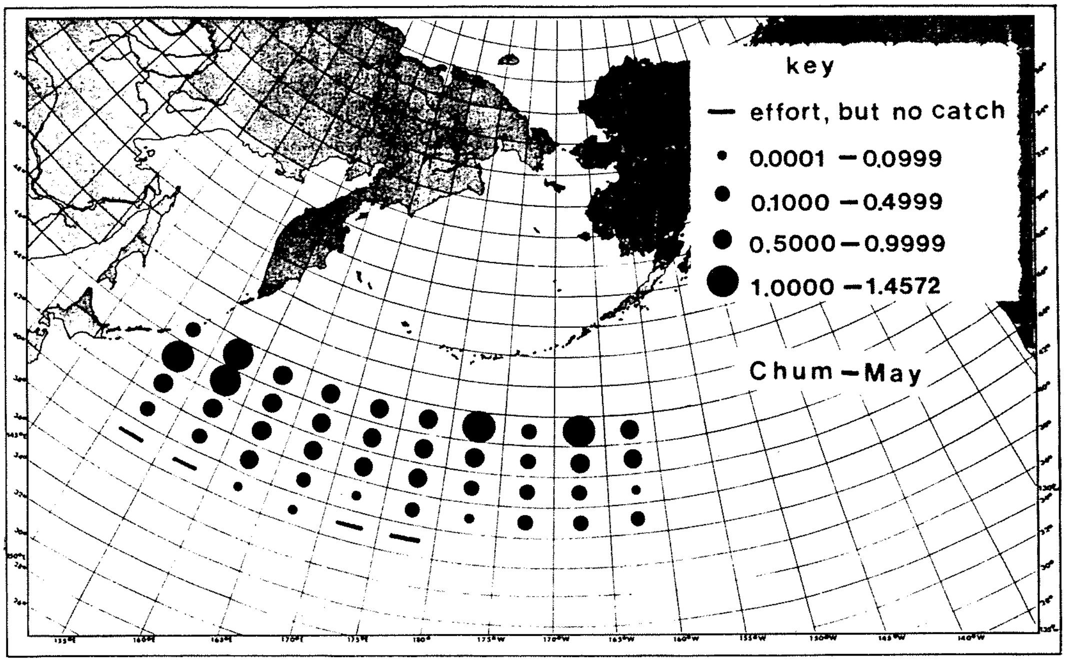


Fig. 3b. Average sockeye salmon CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during July (above) and August (below), 1972-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no sockeye were caught. The heavy outline indicates the squid driftnet fishery zone.



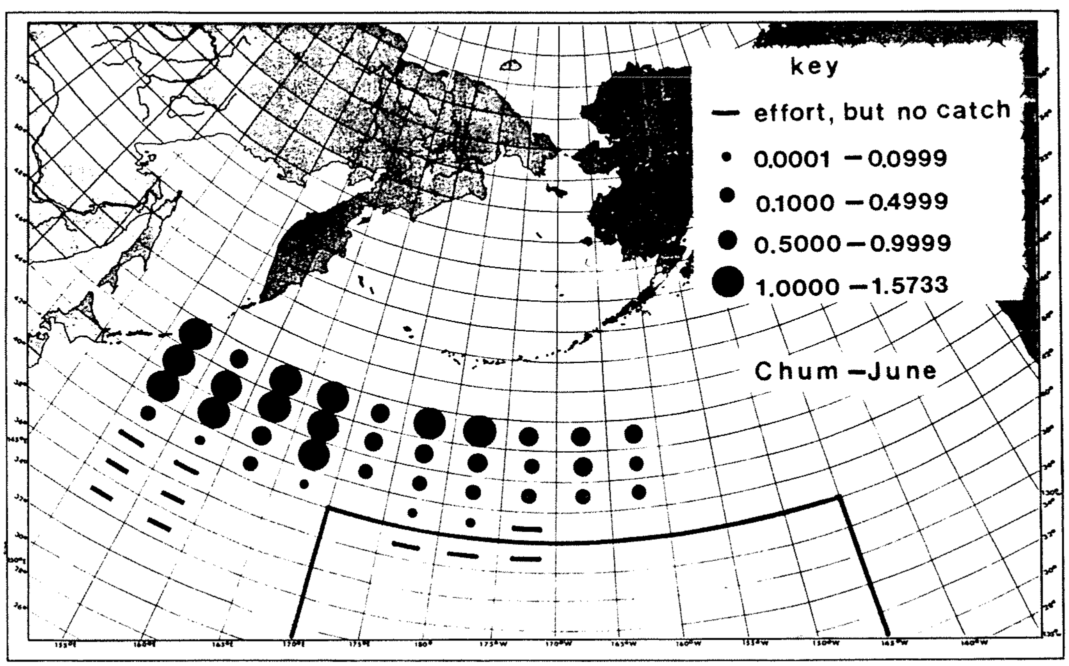
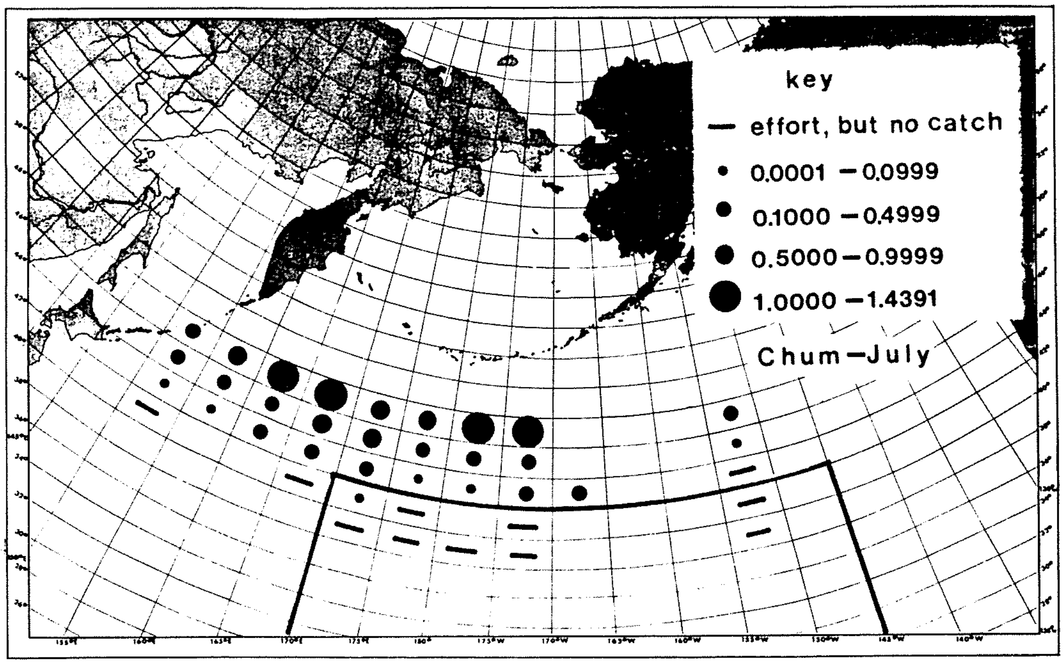


Fig. 3c. Average chum salmon CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during May (above) and June (below), 1972-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no chum were caught. The heavy outline indicates the squid driftnet fishery zone during June.



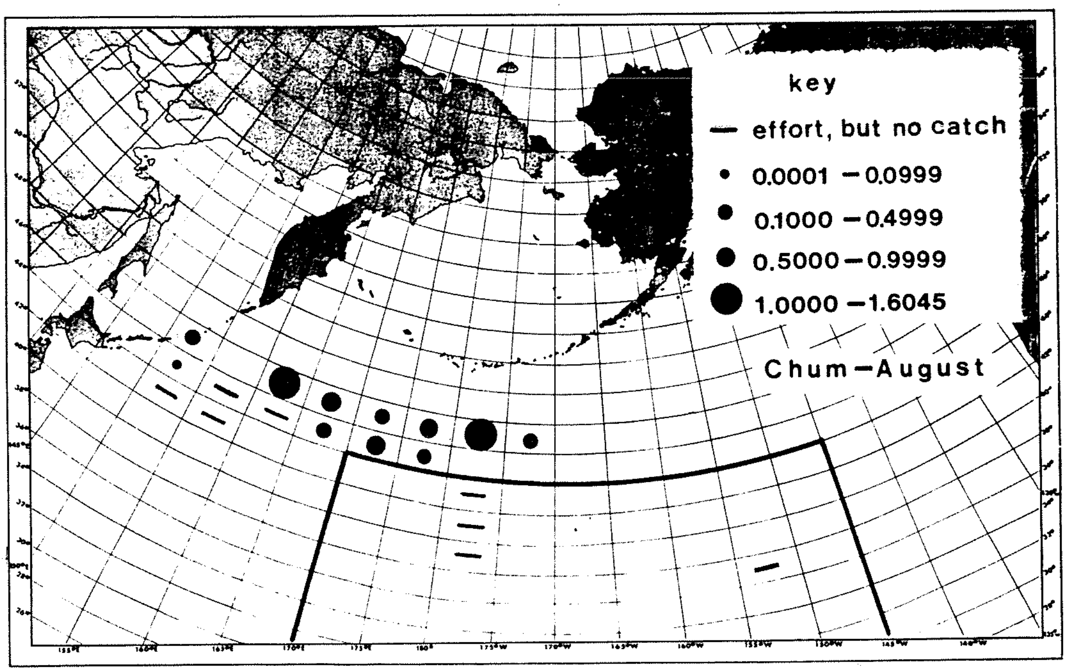
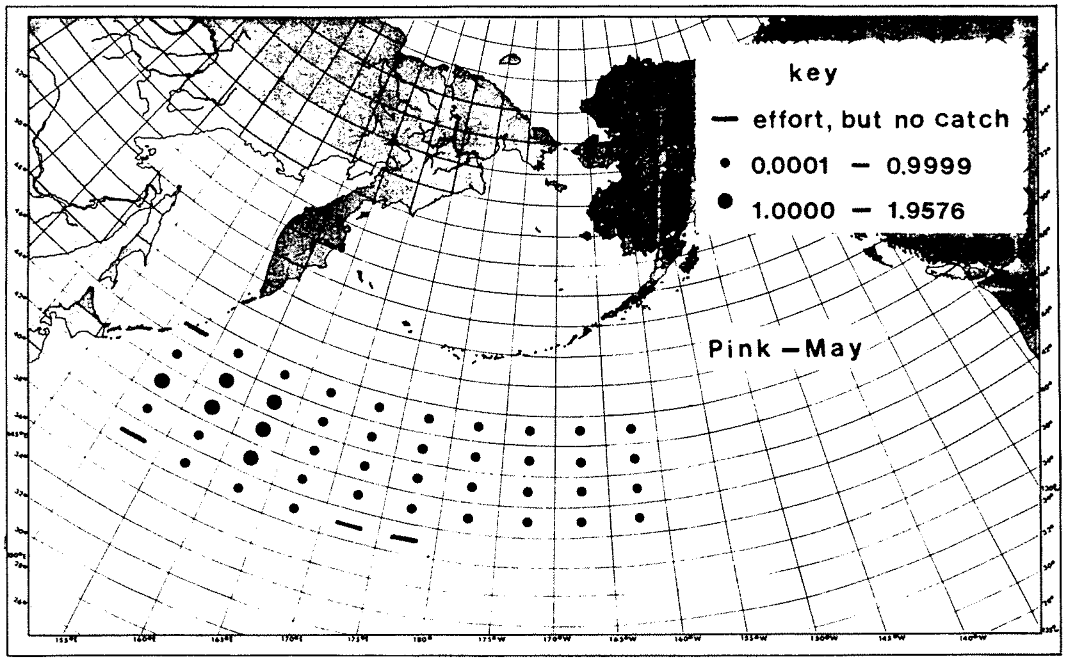


Fig. 3d. Average chum salmon CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during July (above) and August (below), 1972-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no chum were caught. The heavy outline indicates the squid driftnet fishery zone.



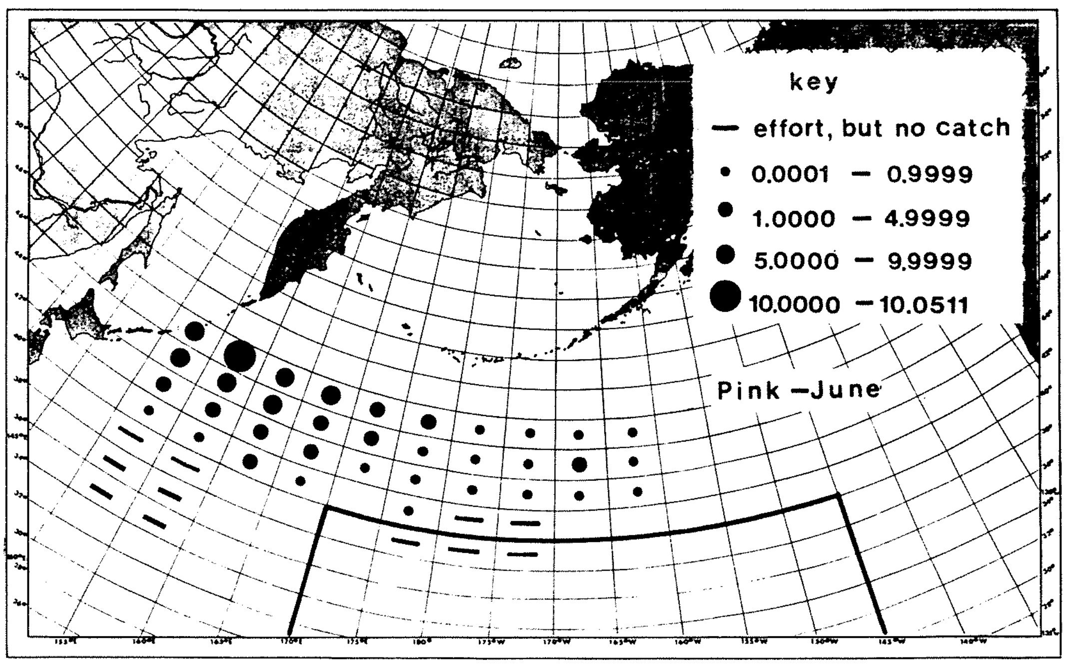
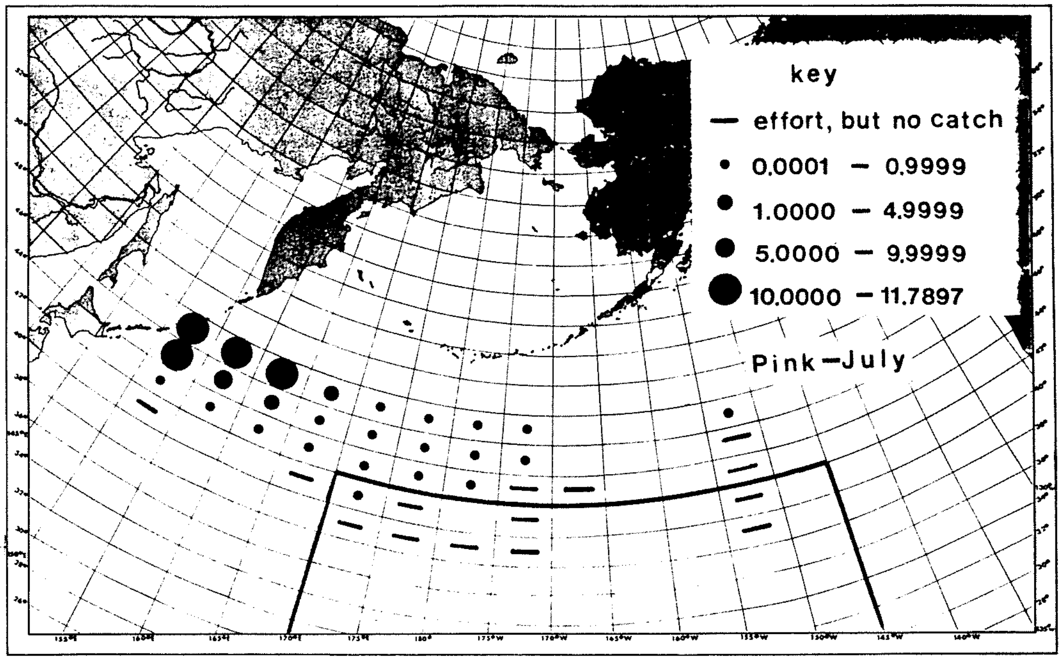


Fig. 3e. Average pink salmon CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during May (above) and June (below), 1972-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no pink were caught. The heavy outline indicates the squid driftnet fishery zone during June.



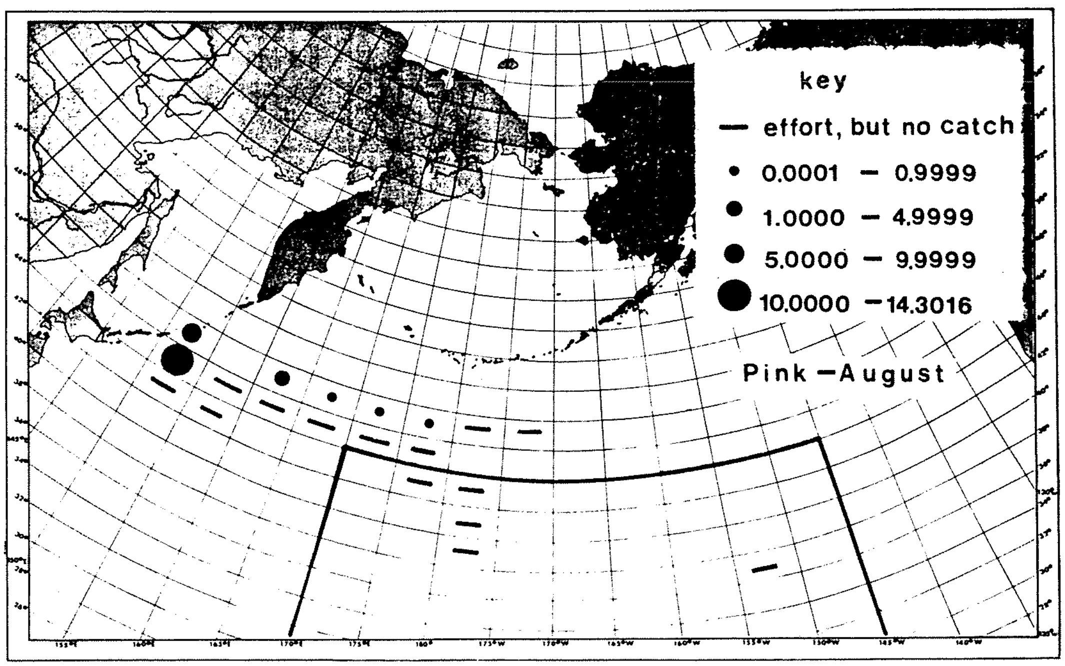
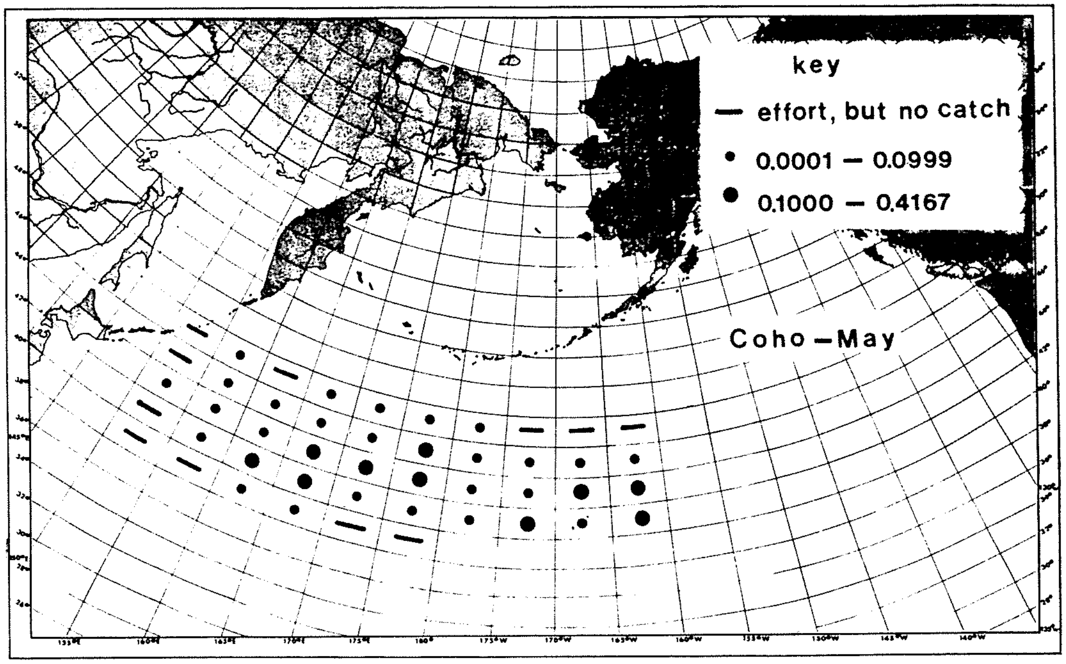


Fig. 3f. Average pink salmon CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during July (above) and August (below), 1972-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no pink were caught. The heavy outline indicates the squid driftnet fishery zone.



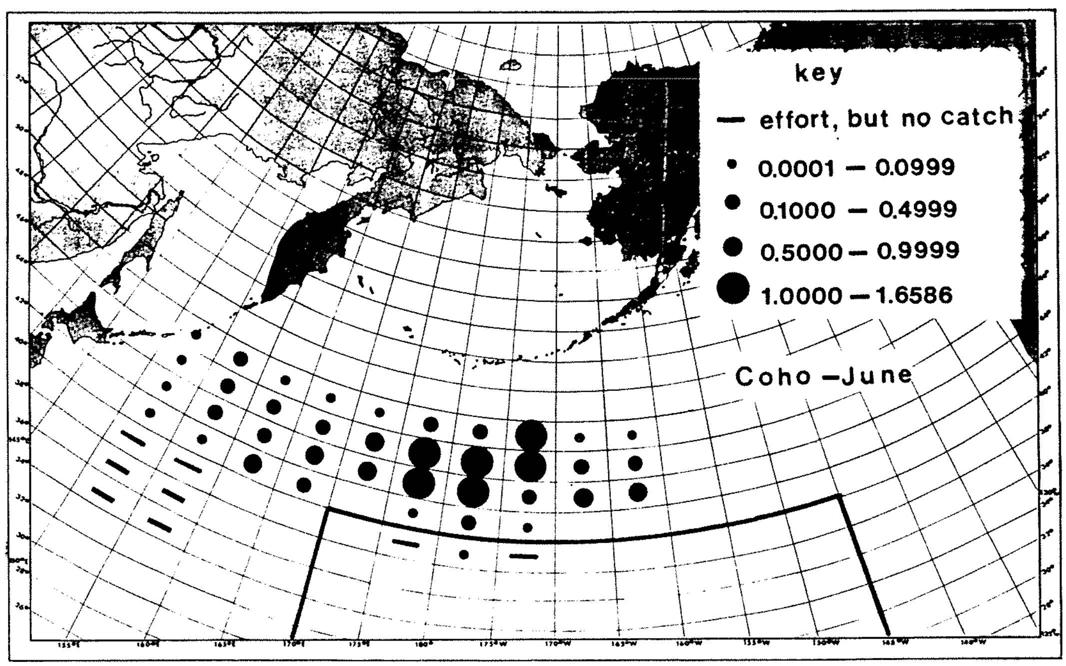
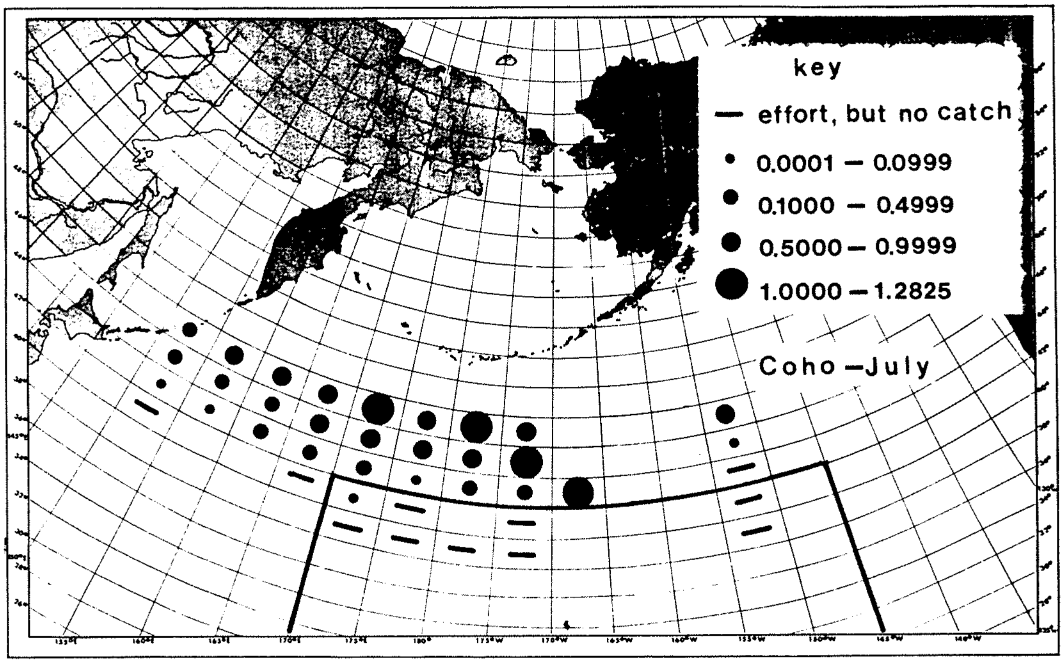


Fig. 3g. Average coho salmon CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during May (above) and June (below), 1972-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no coho were caught. The heavy outline indicates the squid driftnet fishery zone during June.



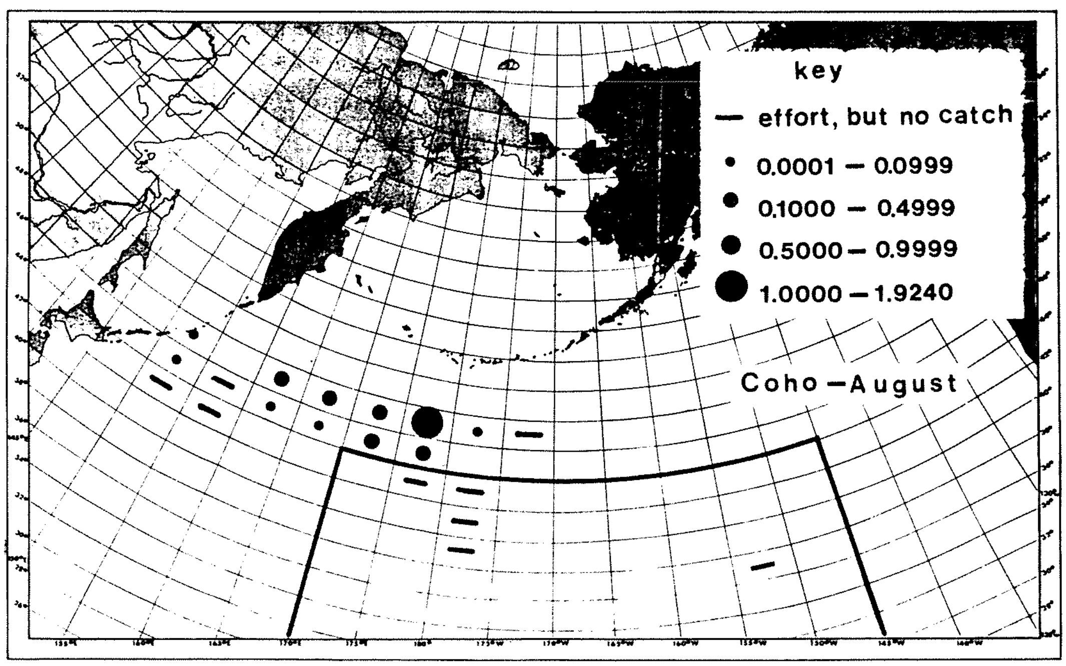
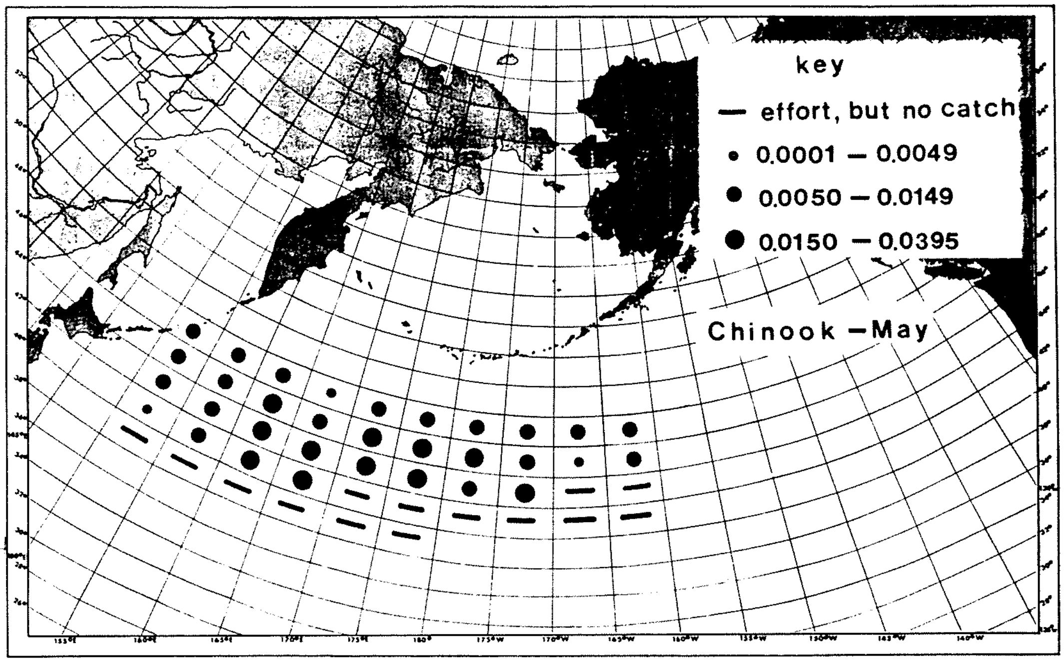


Fig. 3h. Average coho salmon CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during July (above) and August (below), 1972-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no coho were caught. The heavy outline indicates the squid driftnet fishery zone.



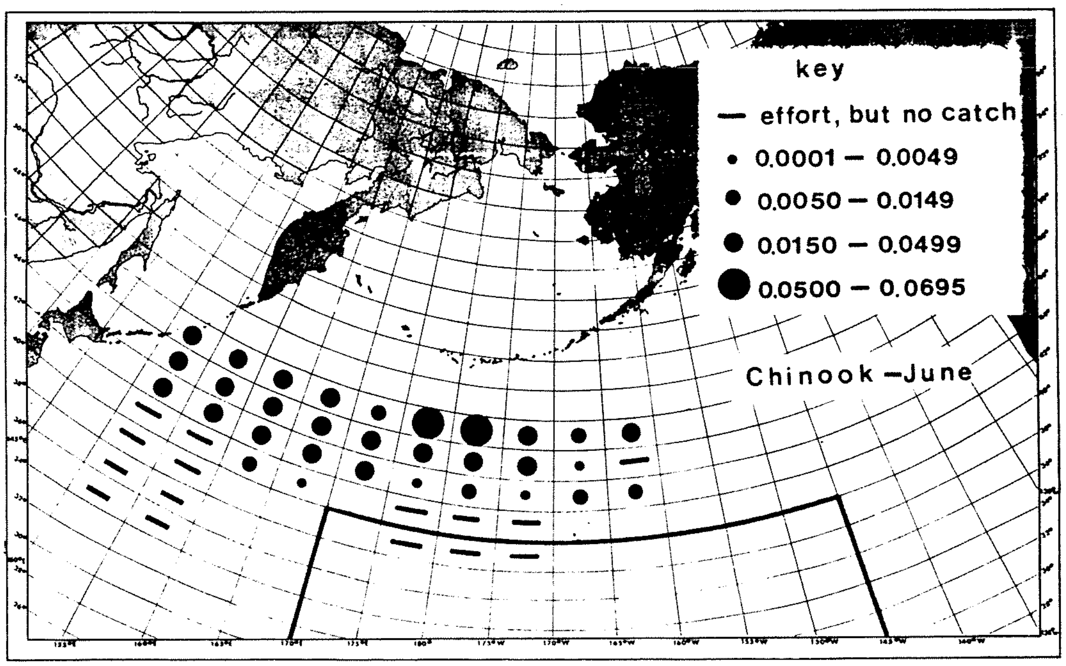
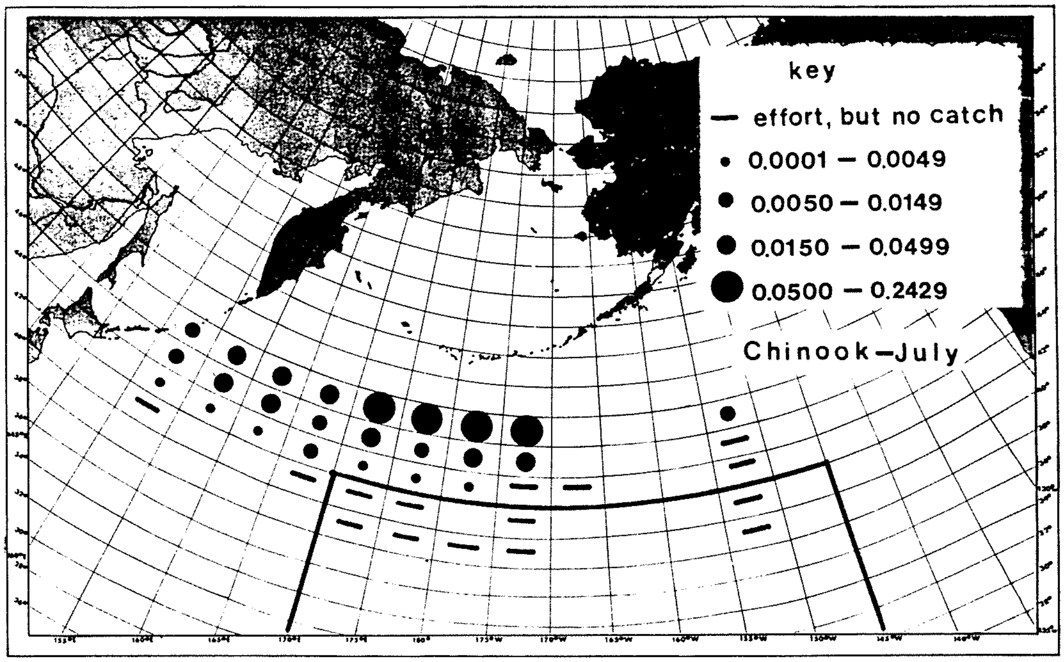


Fig. 3i. Average chinook salmon CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during May (above) and June (below), 1972-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no chinook were caught. The heavy outline indicates the squid driftnet fishery zone during June.



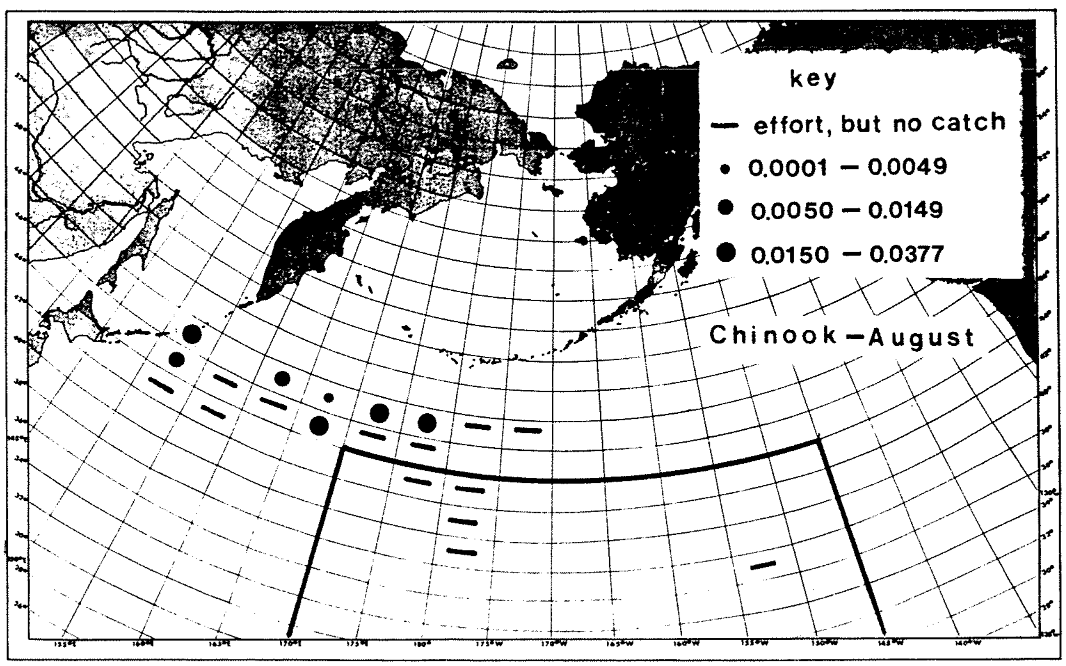
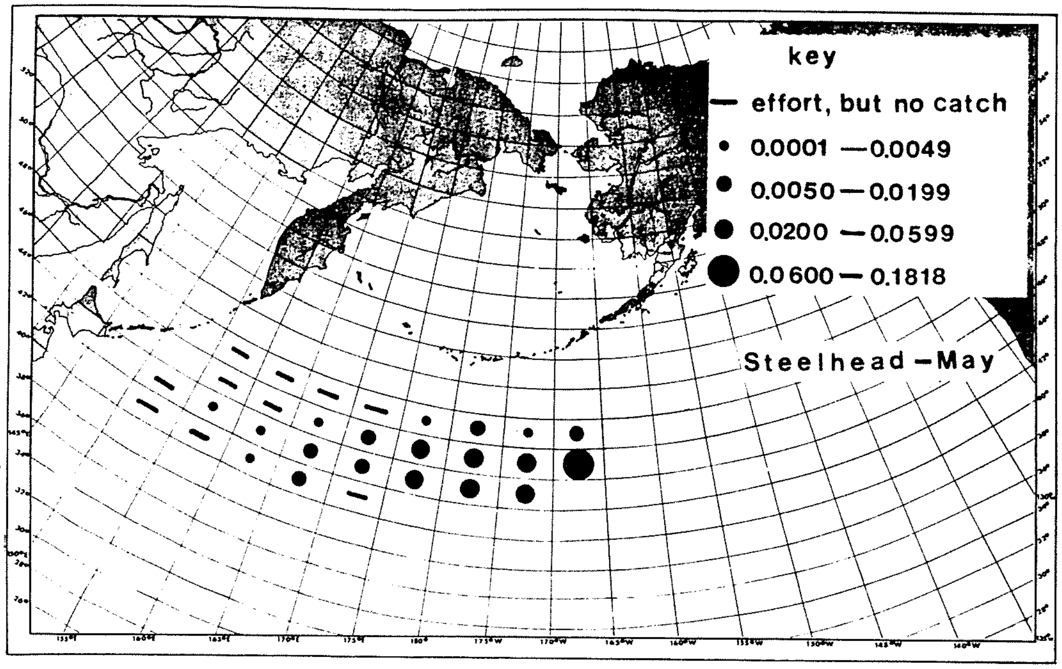


Fig. 3j. Average chinook salmon CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during July (above) and August (below), 1972-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no chinook were caught. The heavy outline indicates the squid driftnet fishery zone.



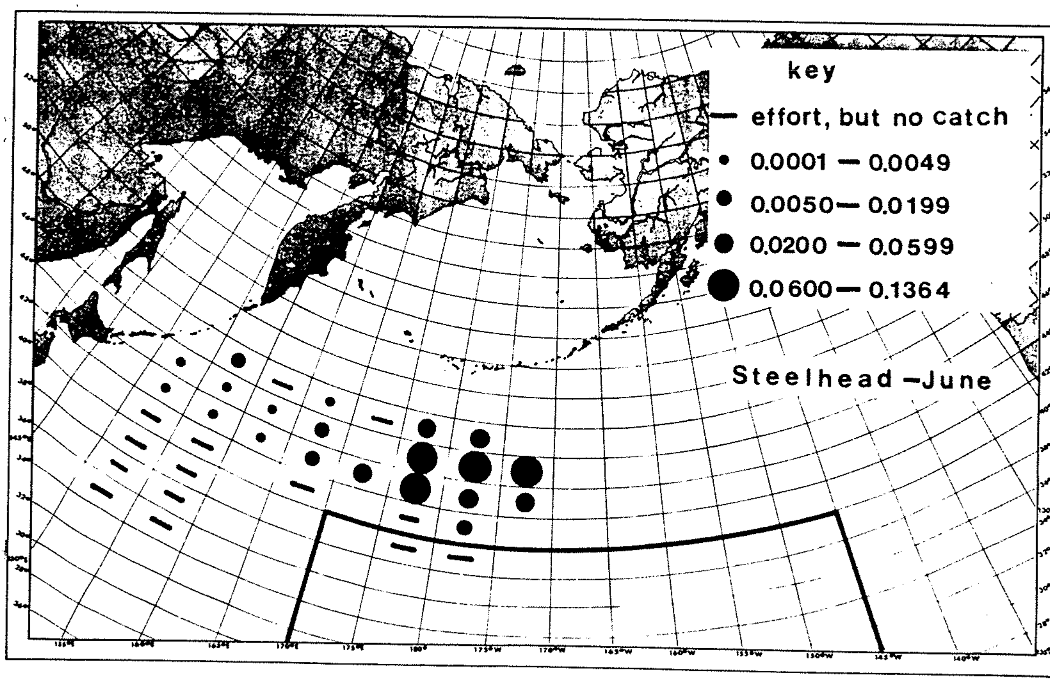
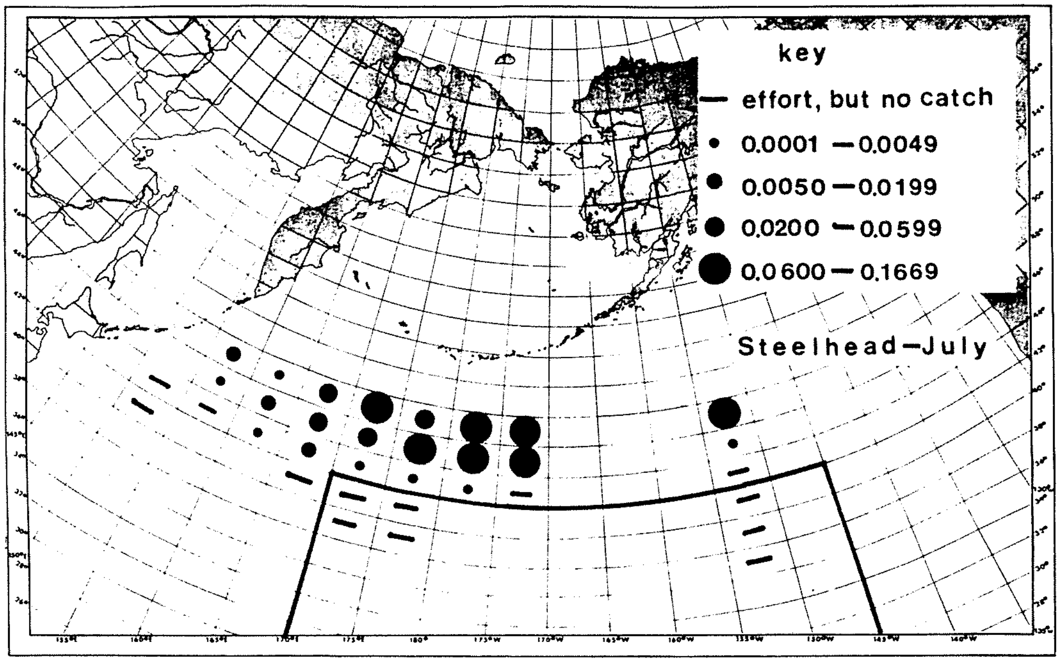


Fig. 3k. Average steelhead CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during May (above) and June (below), 1981-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no steelhead were caught. The heavy outline indicates the squid driftnet fishery zone during June.



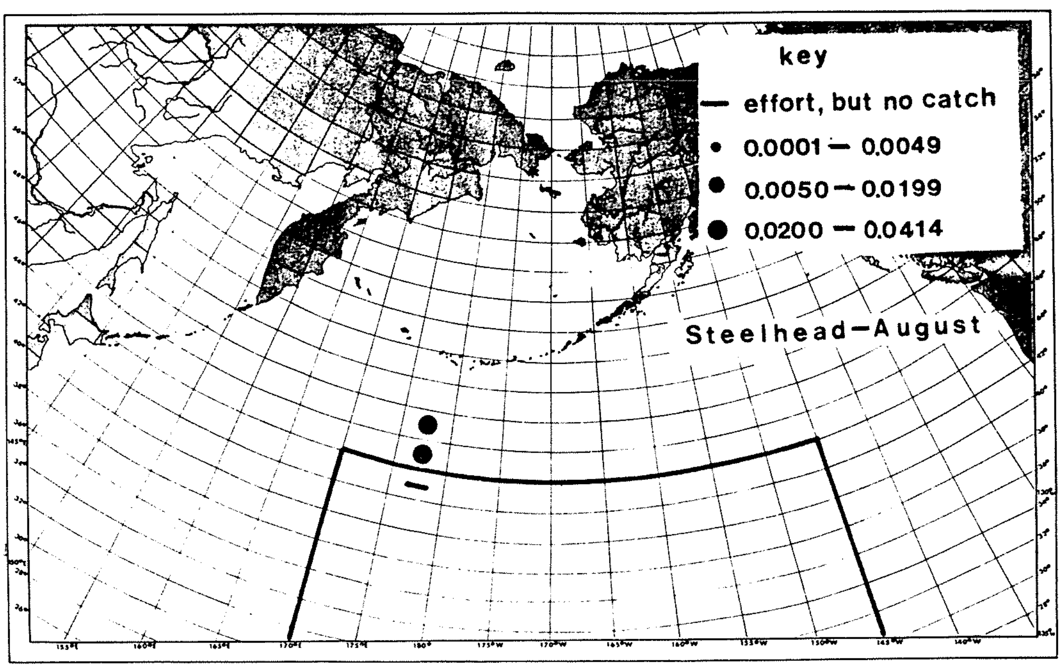
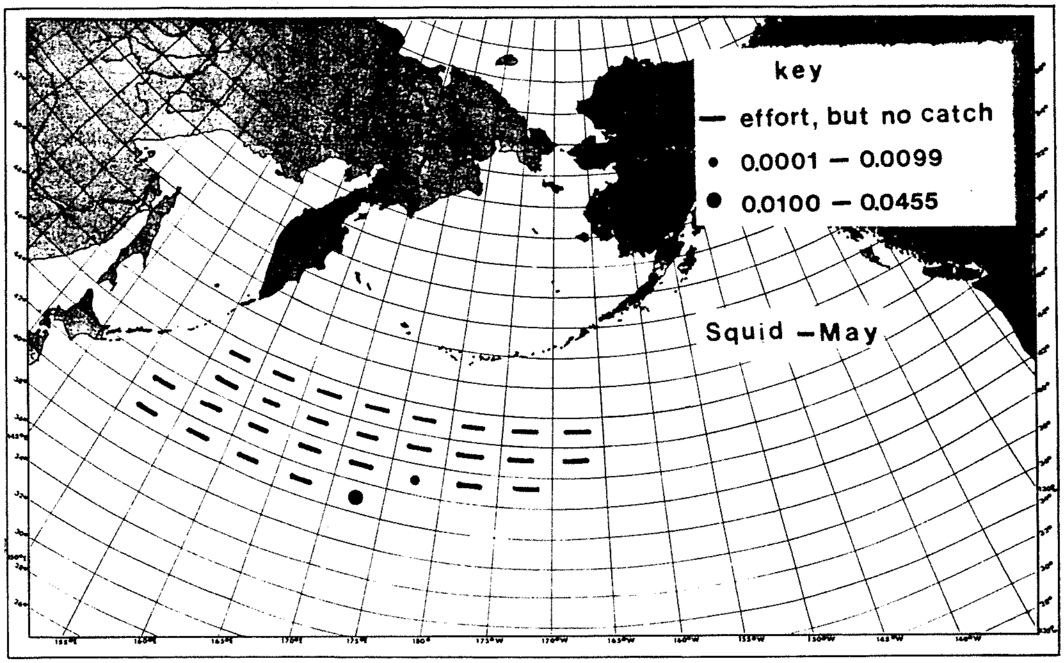


Fig. 31. Average steelhead CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during July (above) and August (below), 1981-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no steelhead were caught. The heavy outline indicates the squid driftnet fishery zone.



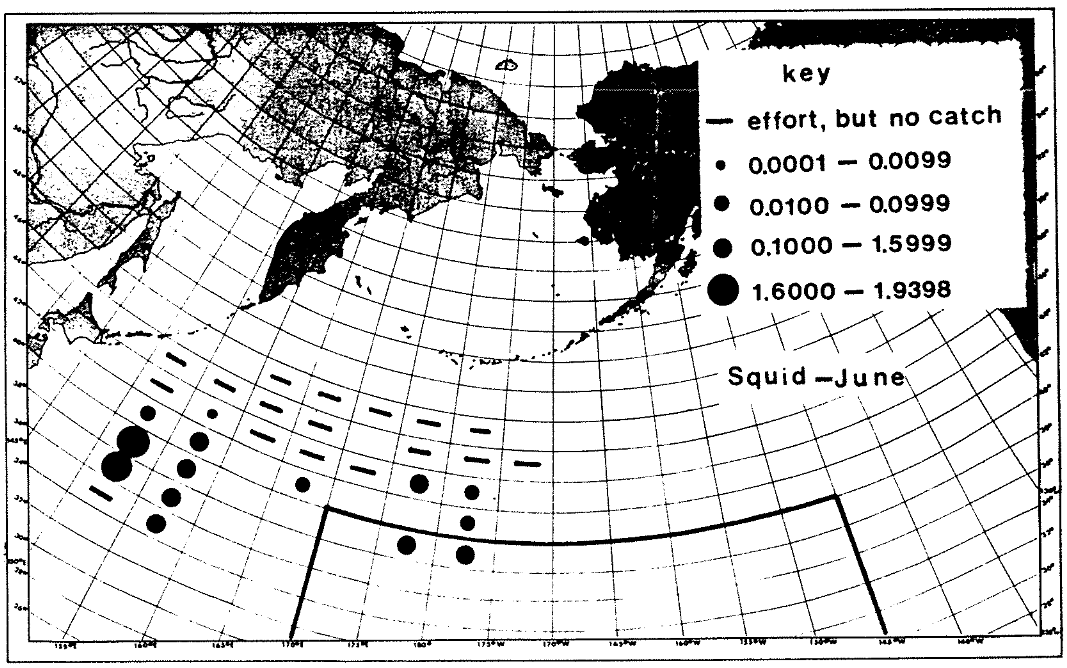
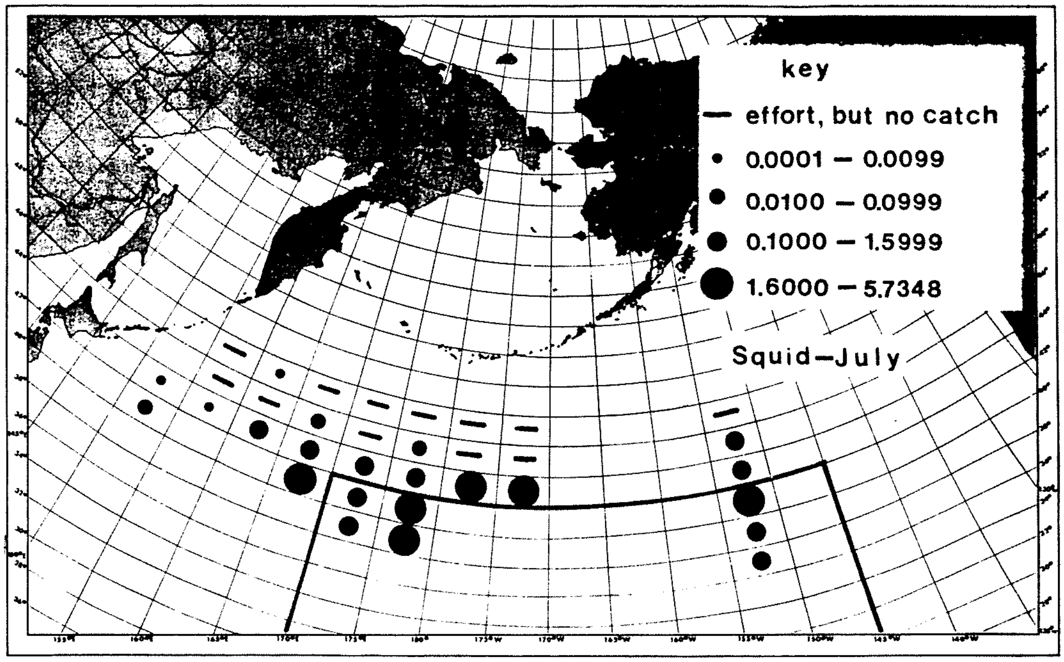


Fig. 3m. Average squid CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during May (above) and June (below), 1982-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no squid were caught. The heavy outline indicates the squid driftnet fishery zone during June.



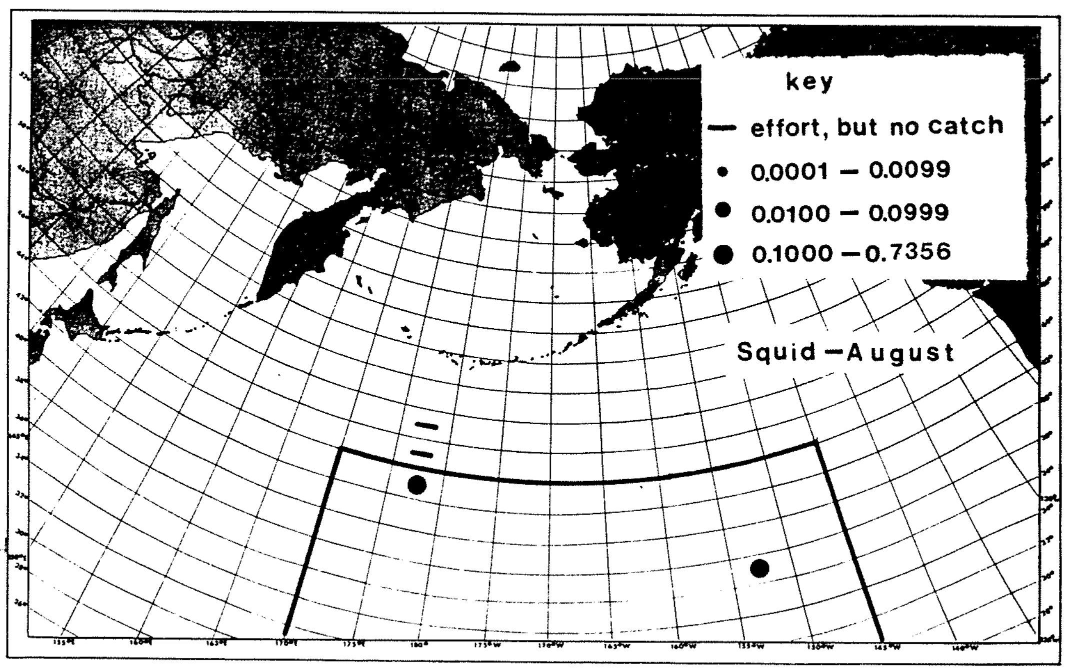
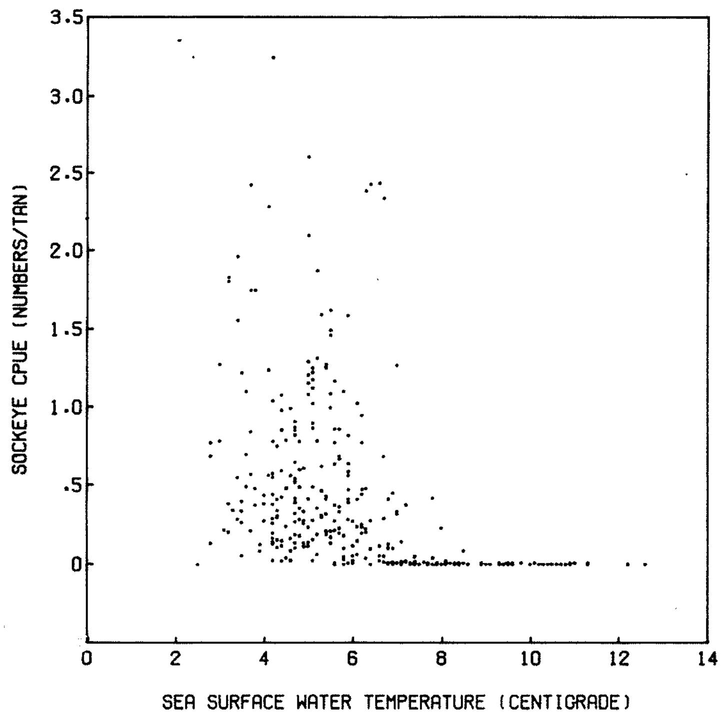


Fig. 3n. Average squid CPUE by 2x5° areas where research vessel operations took place between 150°E and 145°W and south of 48°N during July (above) and August (below), 1982-85. The key defines the range for CPUE by dot size; dash indicates areas where sampling occurred but no squid were caught. The heavy outline indicates the squid driftnet fishery zone.



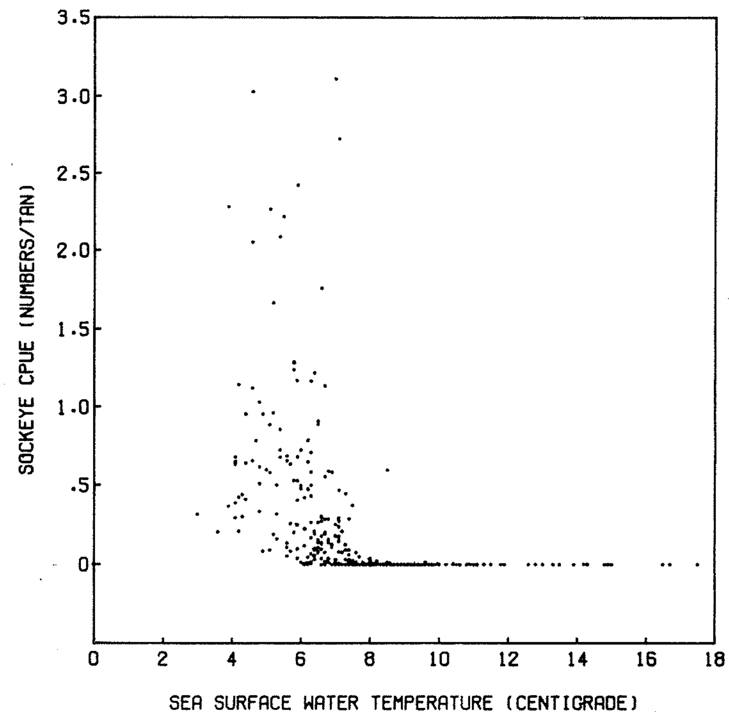


Fig. 4a. Plots of average sockeye CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during May (left) and June (right), 1972-85.

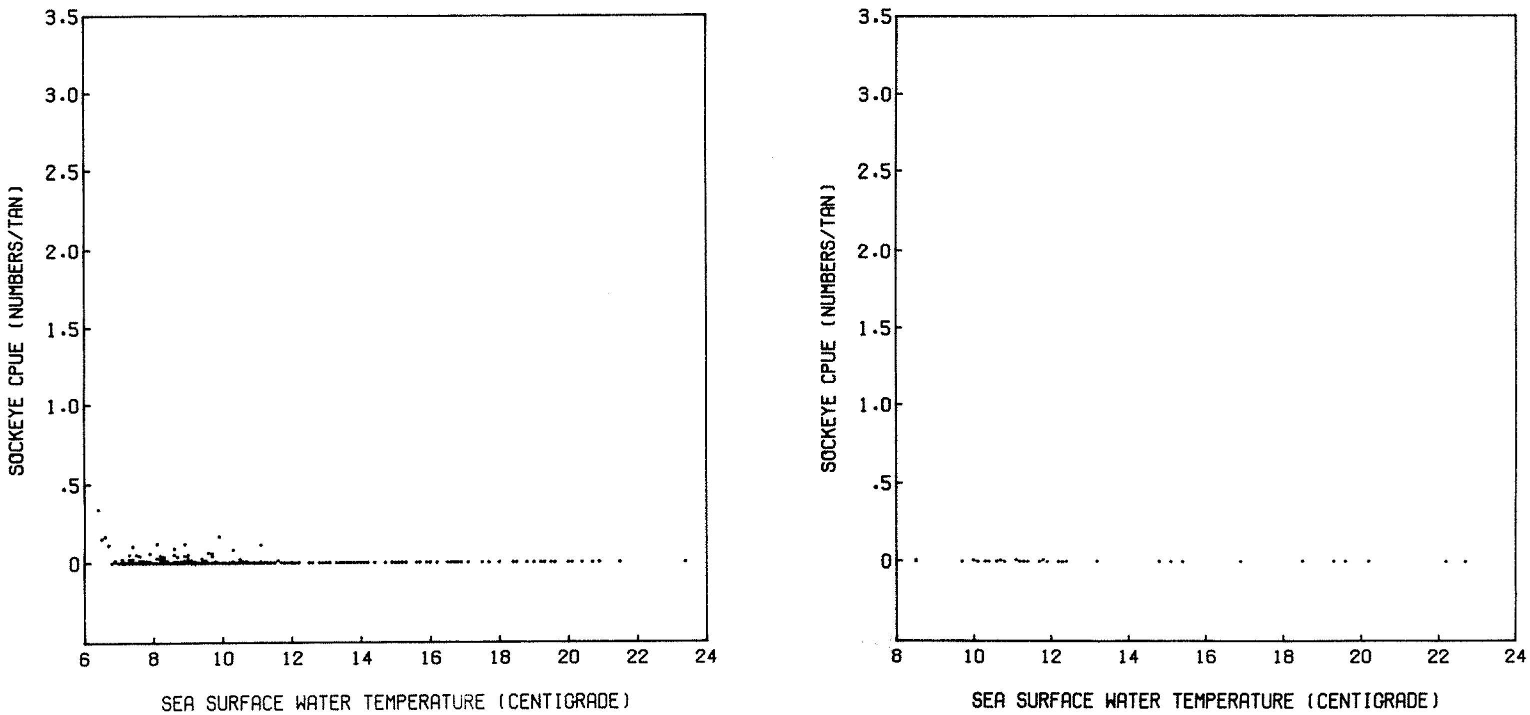


Fig. 4b. Plots of average sockeye CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during July (left) and August (right), 1972-85.

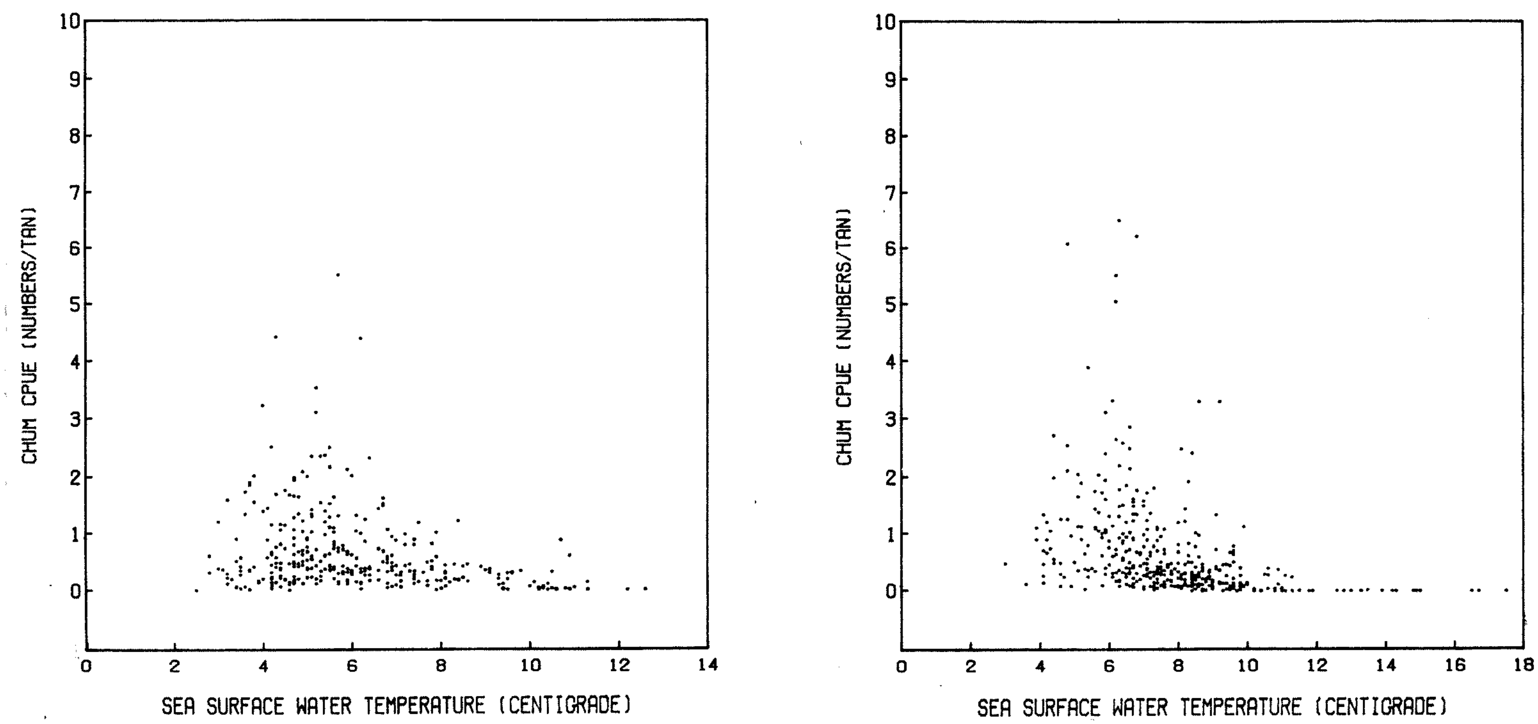


Fig. 4c. Plots of average chum CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during May (left) and June (right), 1972-85.

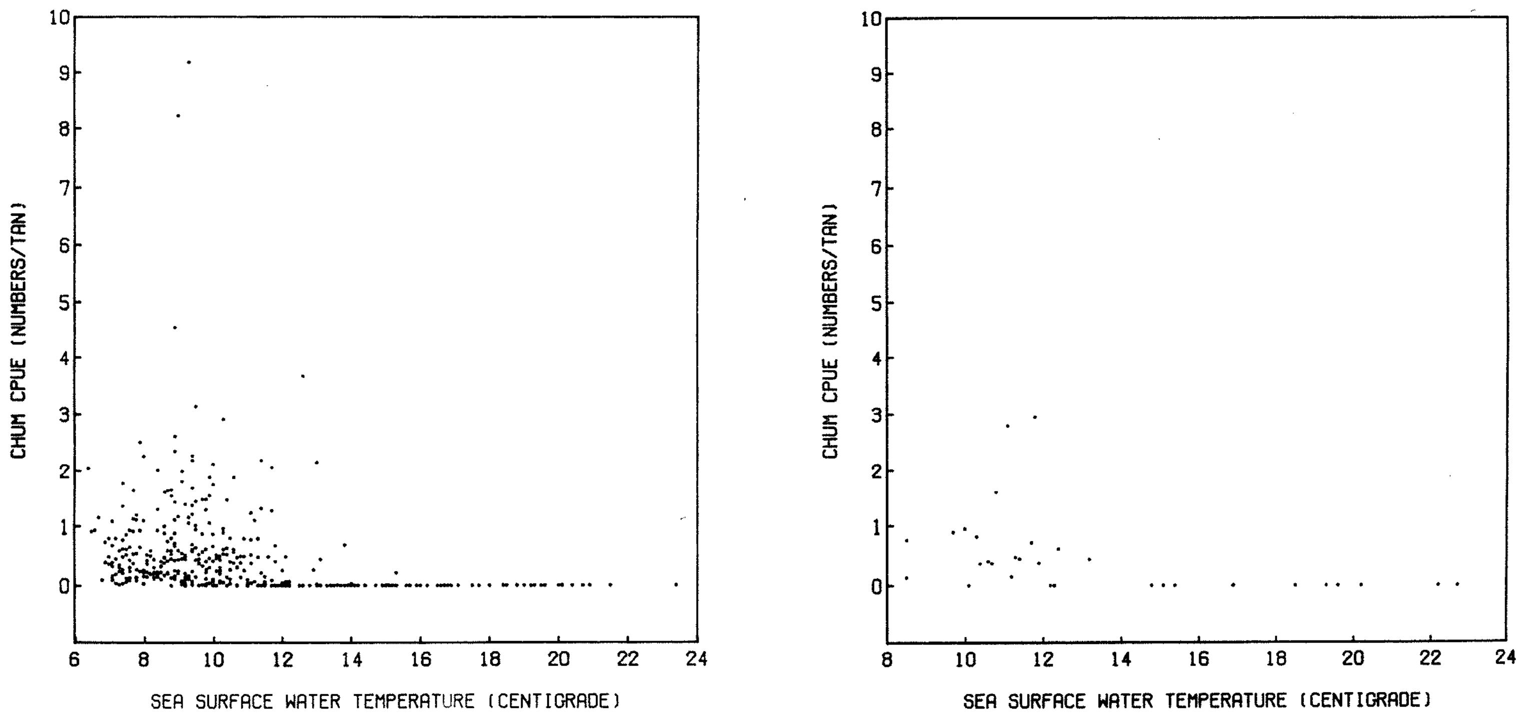


Fig. 4d. Plots of average chum CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during July (left) and August (right), 1972-85.

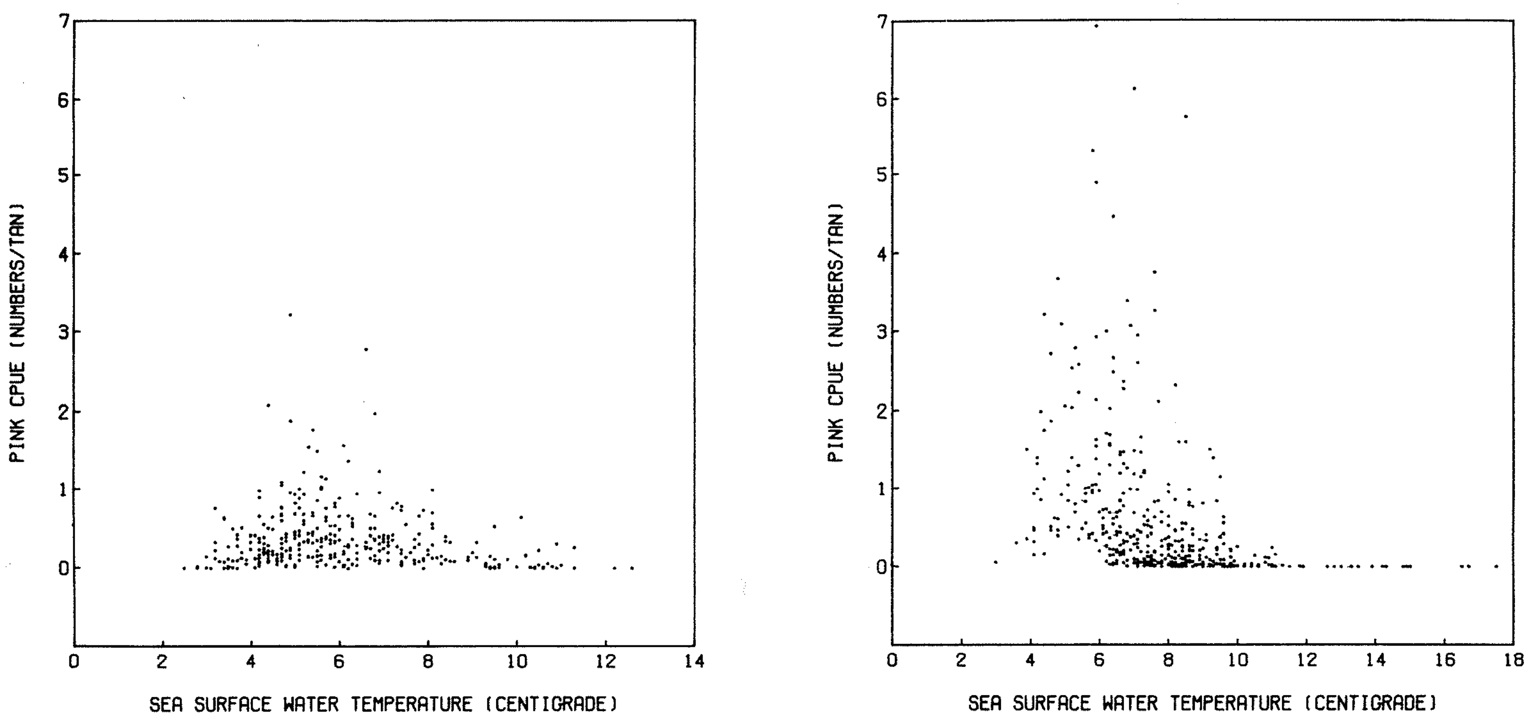


Fig. 4e. Plots of average pink CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during May (left) and June (right), 1972-85.

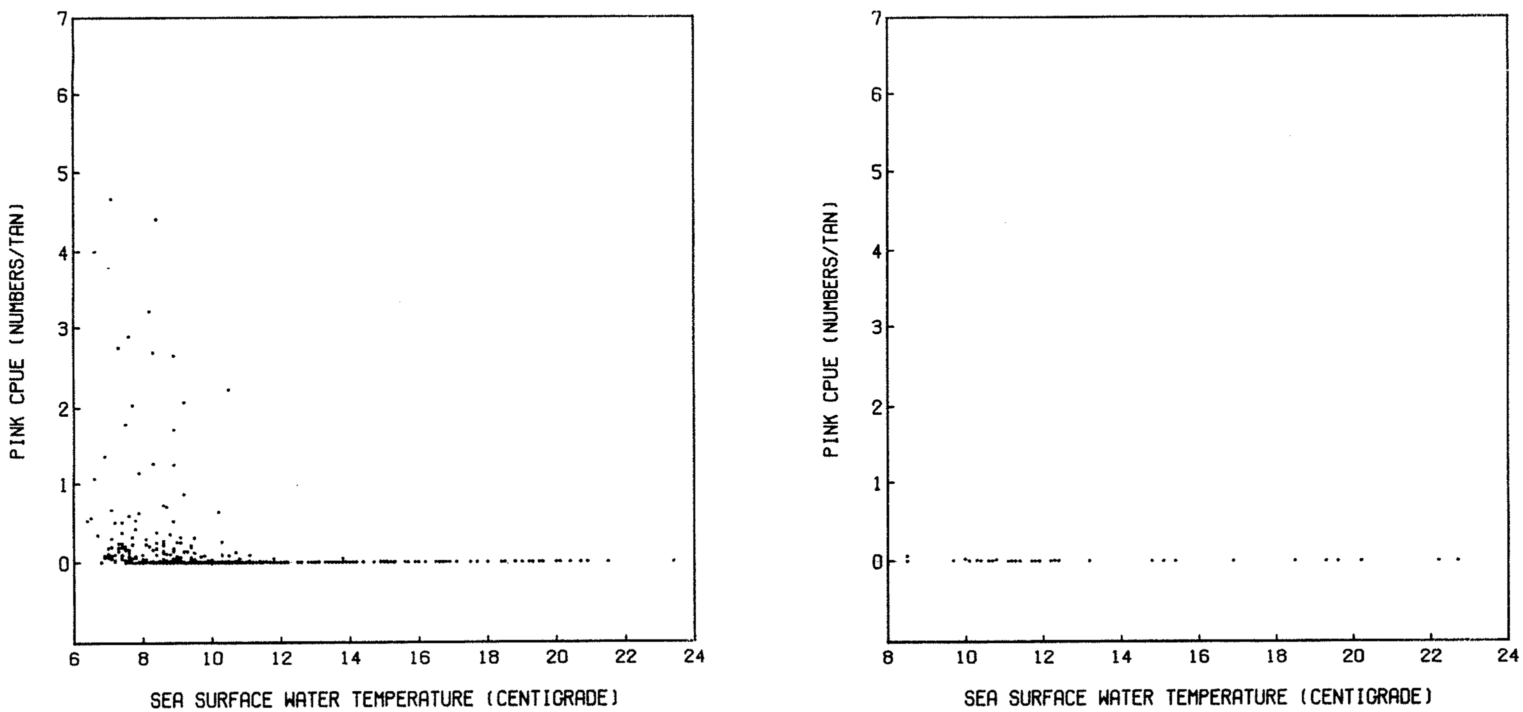


Fig. 4f. Plots of average pink CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during July (left) and August (right), 1972-85.

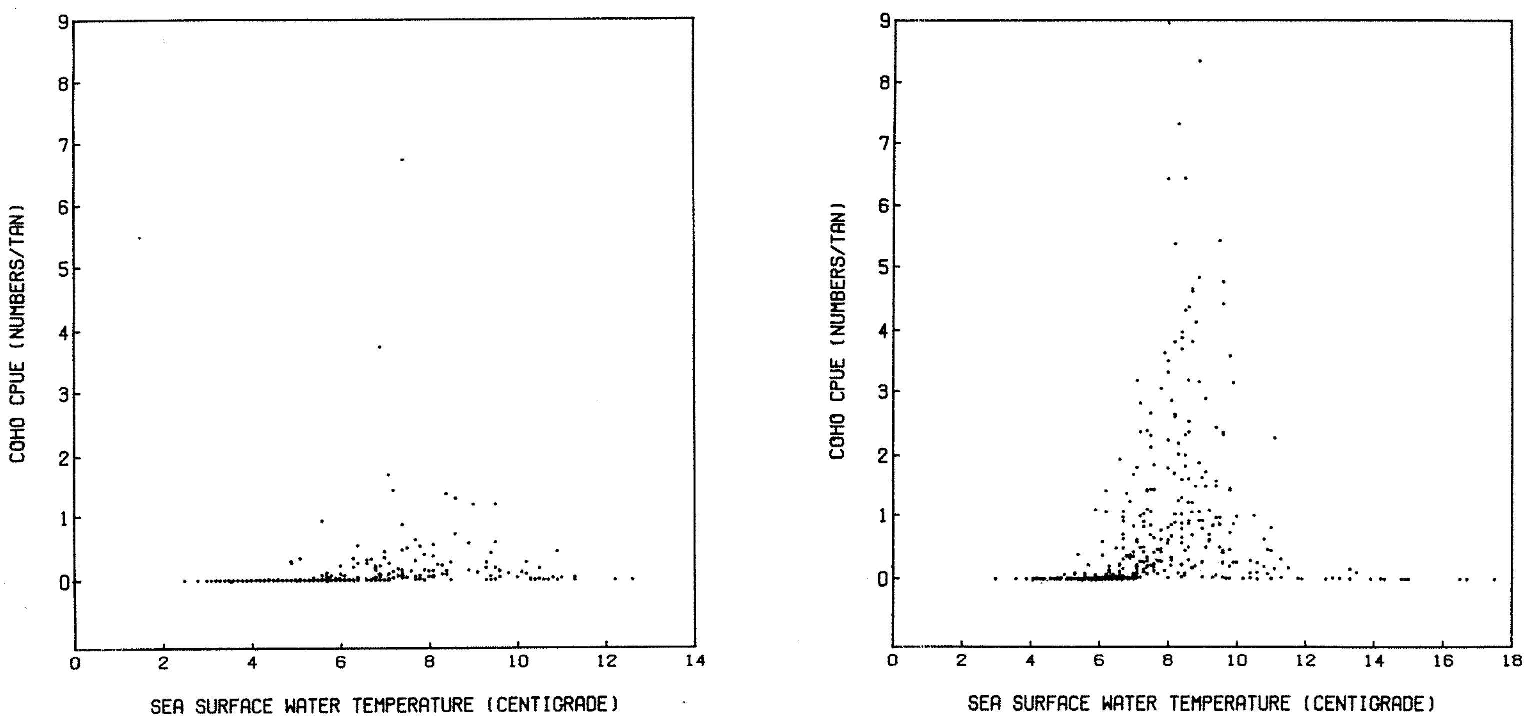


Fig. 4g. Plots of average coho CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during May (left) and June (right), 1972-85.

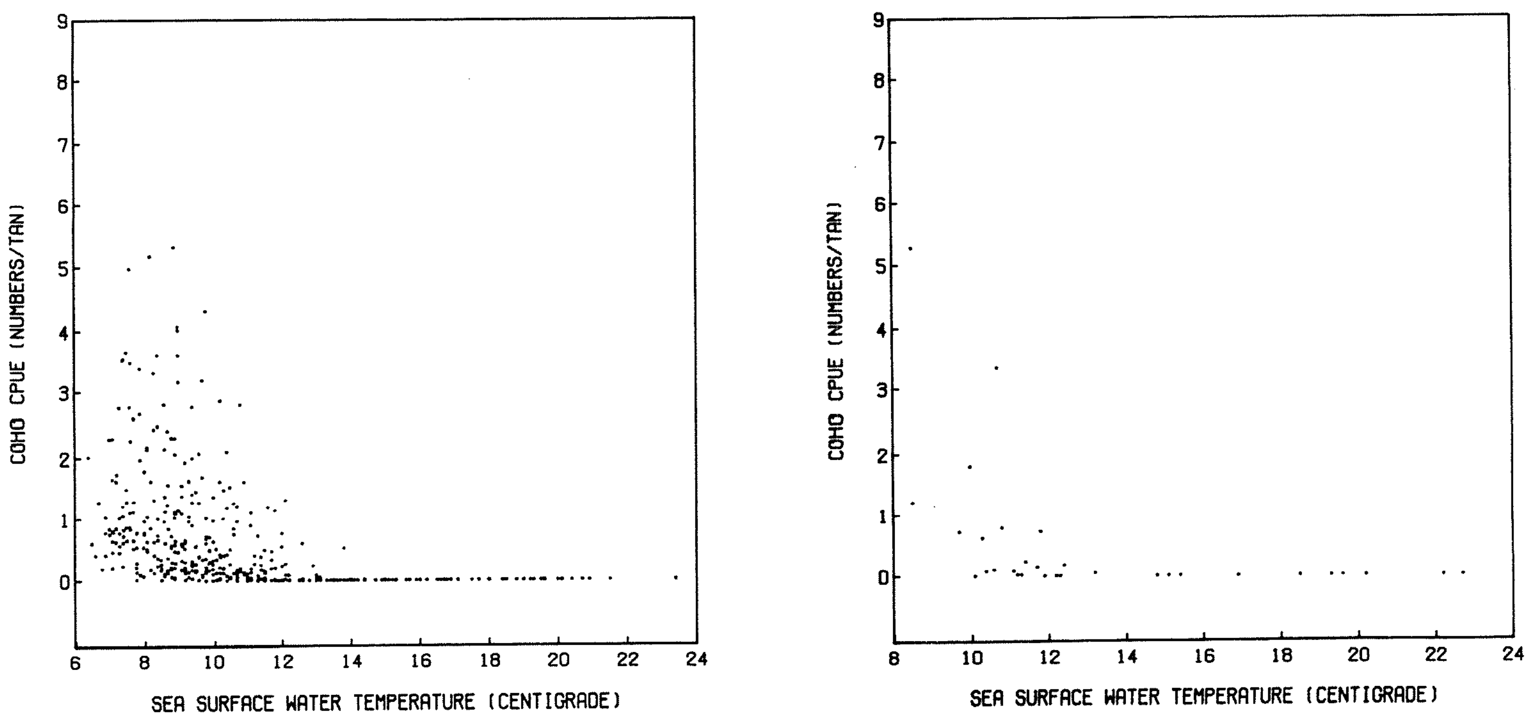
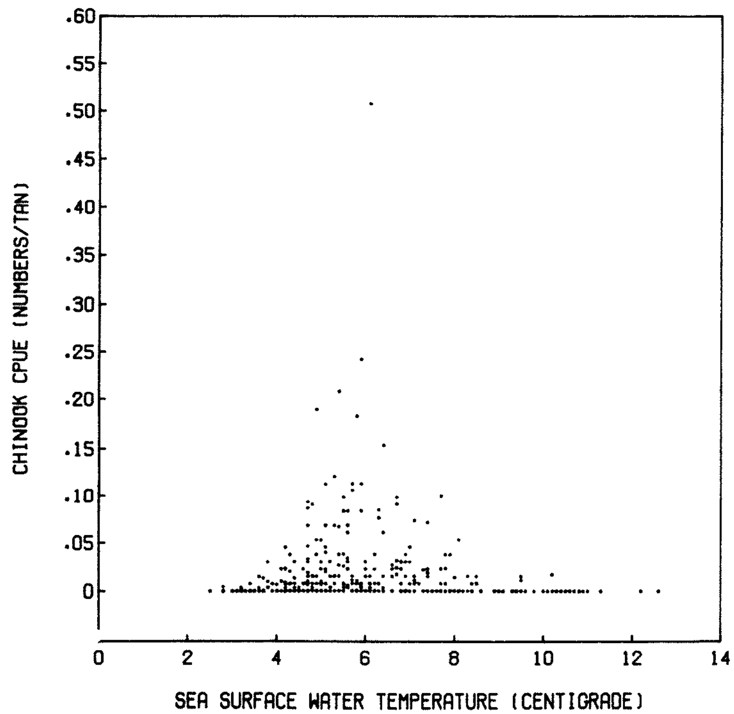


Fig. 4h. Plots of average coho CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during July (left) and August (right), 1972-85.



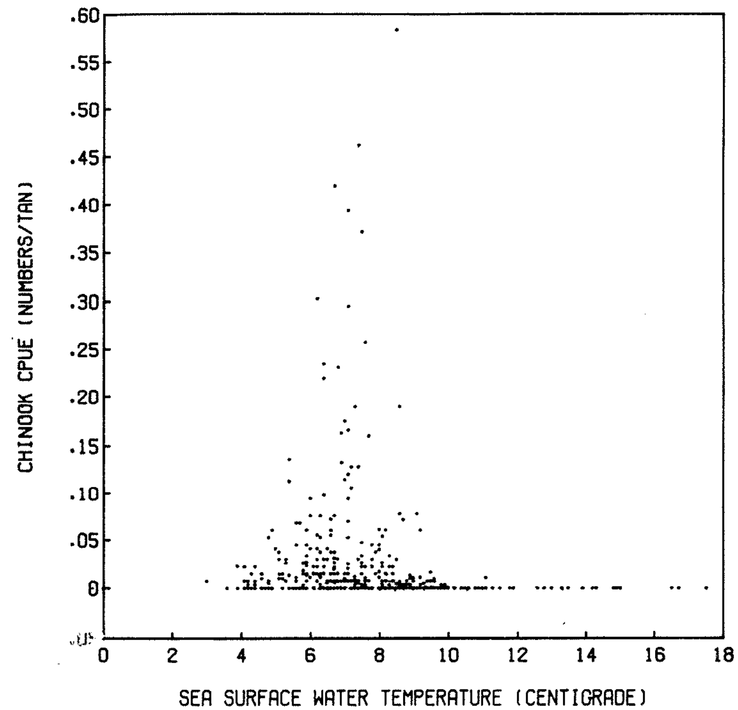


Fig. 4i. Plots of average chinook CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during May (left) and June (right), 1972-85.

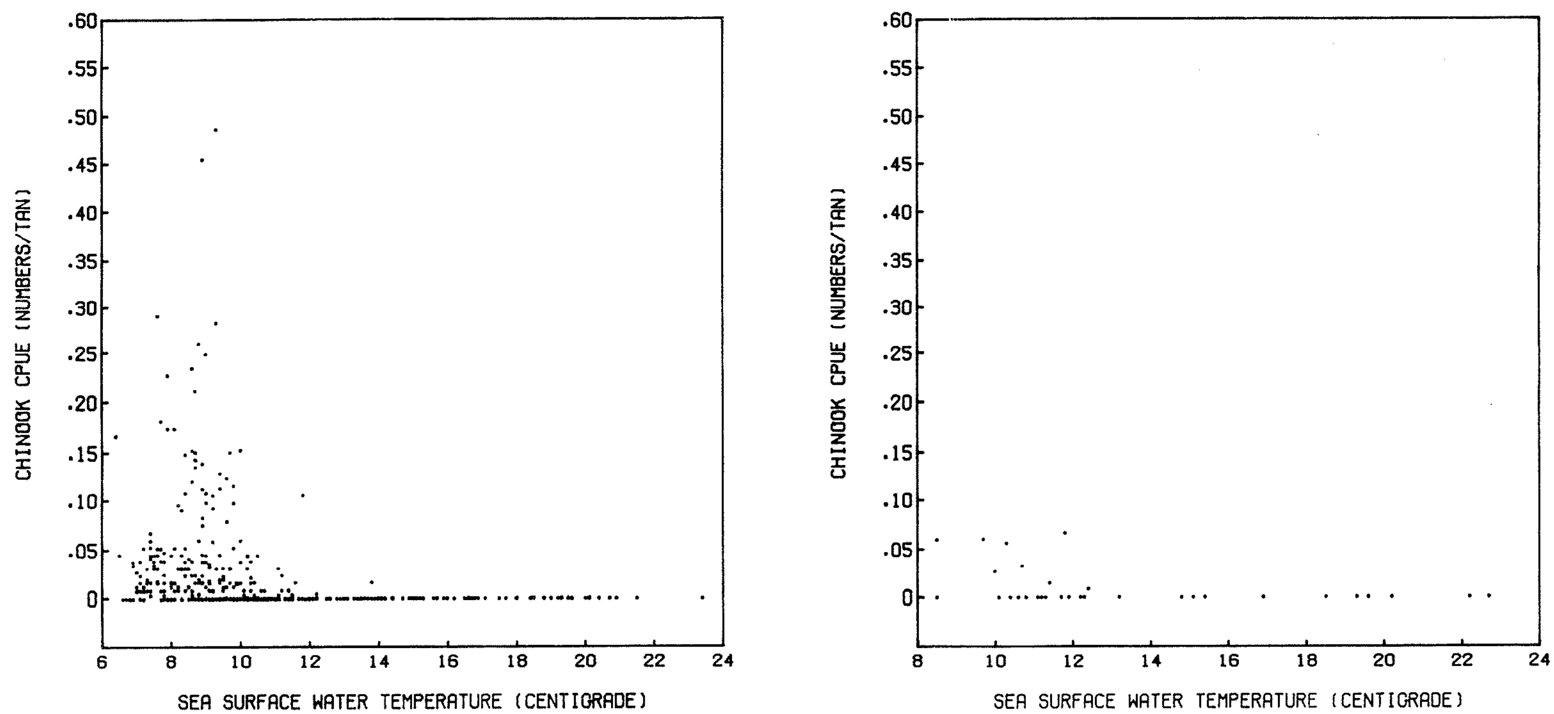


Fig. 4j. Plots of average chinook CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during July (left) and August (right), 1972-85.

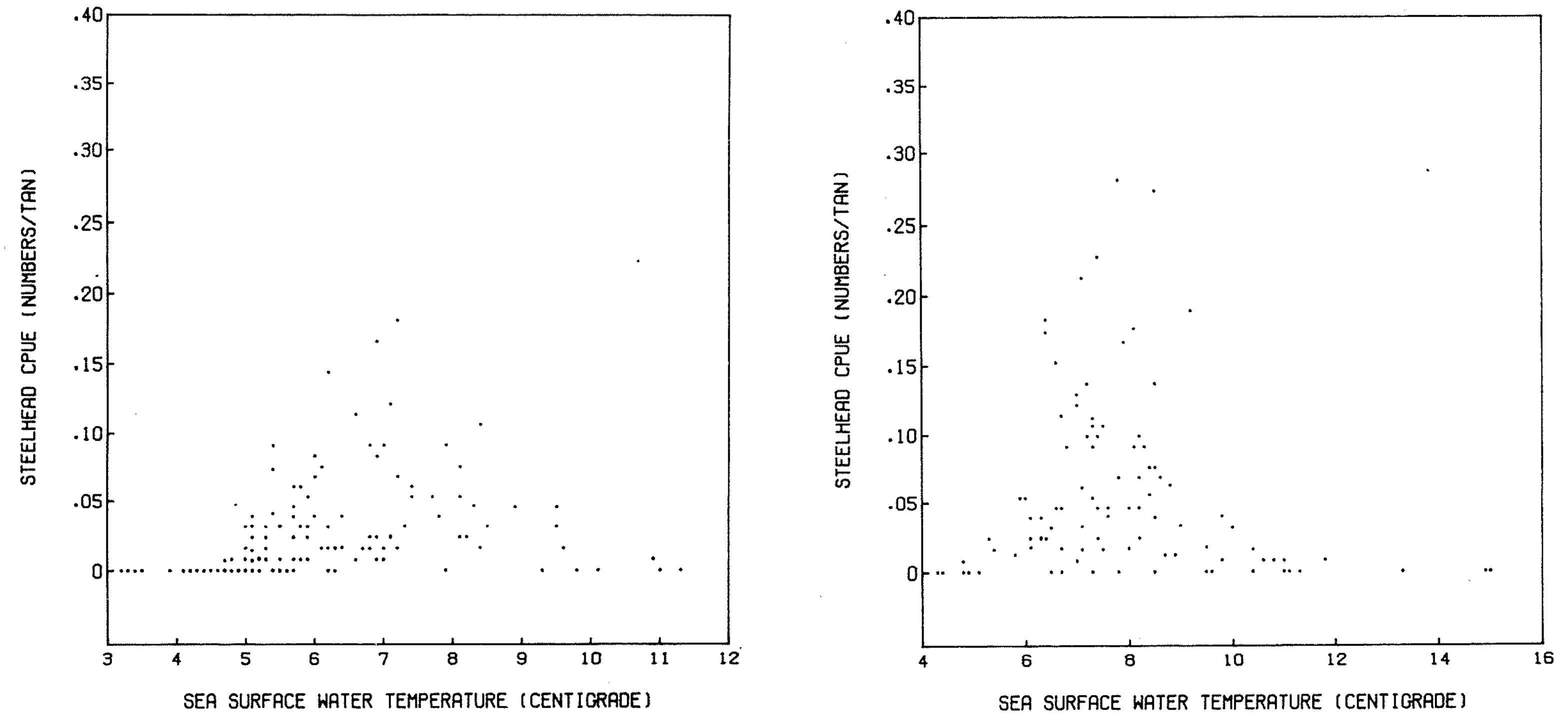


Fig. 4k. Plots of average steelhead CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during May (left) and June (right), 1981-85.

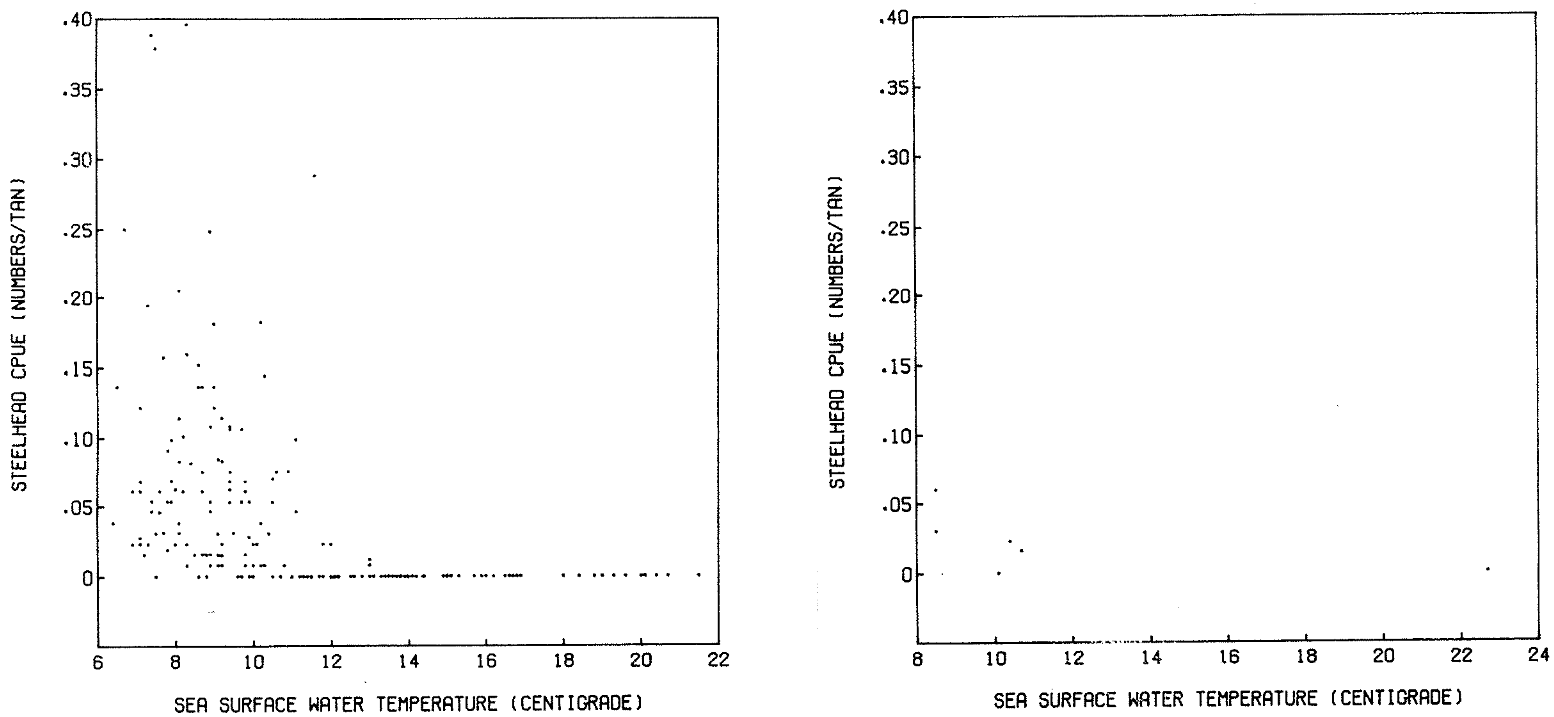


Fig. 41. Plots of average steelhead CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during July (left) and August (right), 1981-85.

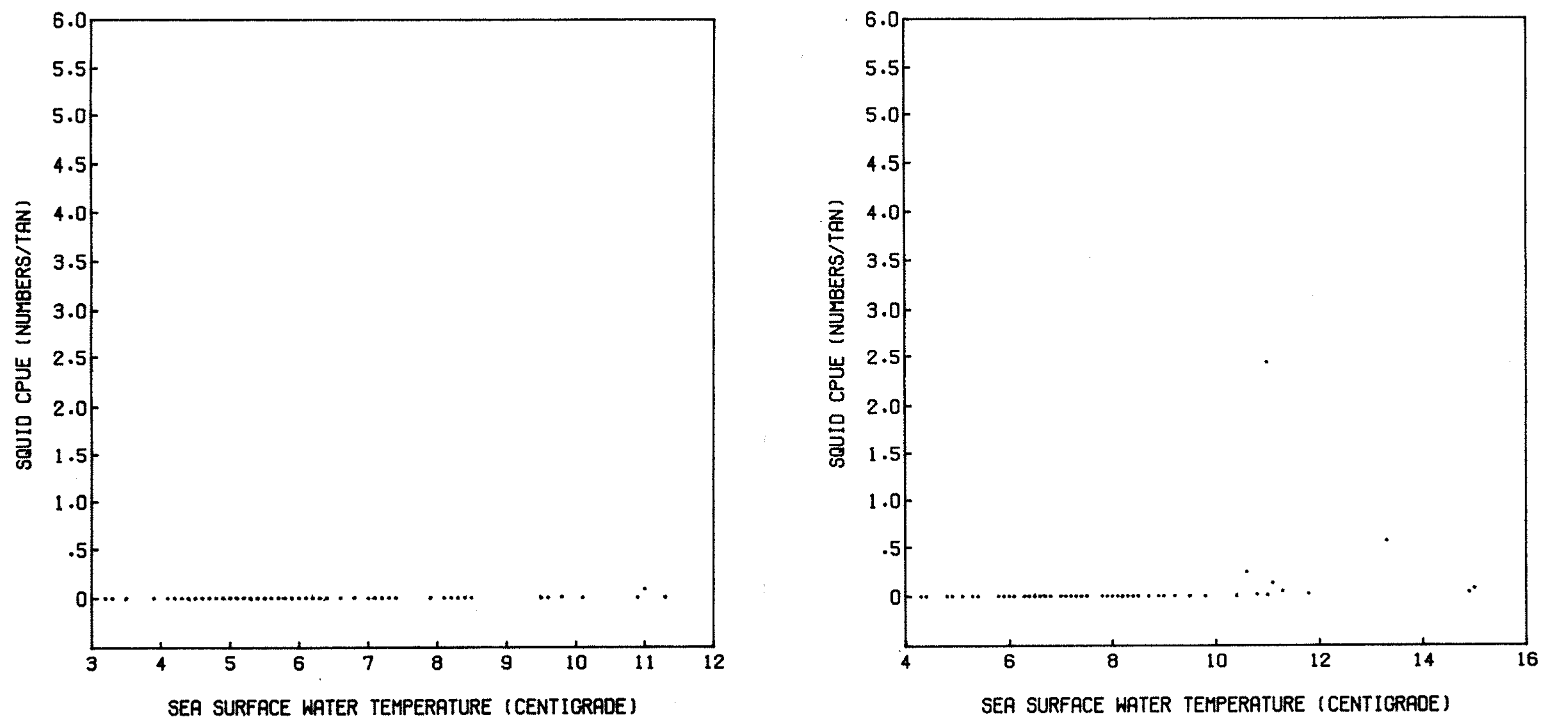


Fig. 4m. Plots of average squid CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during May (left) and June (right), 1982-85.

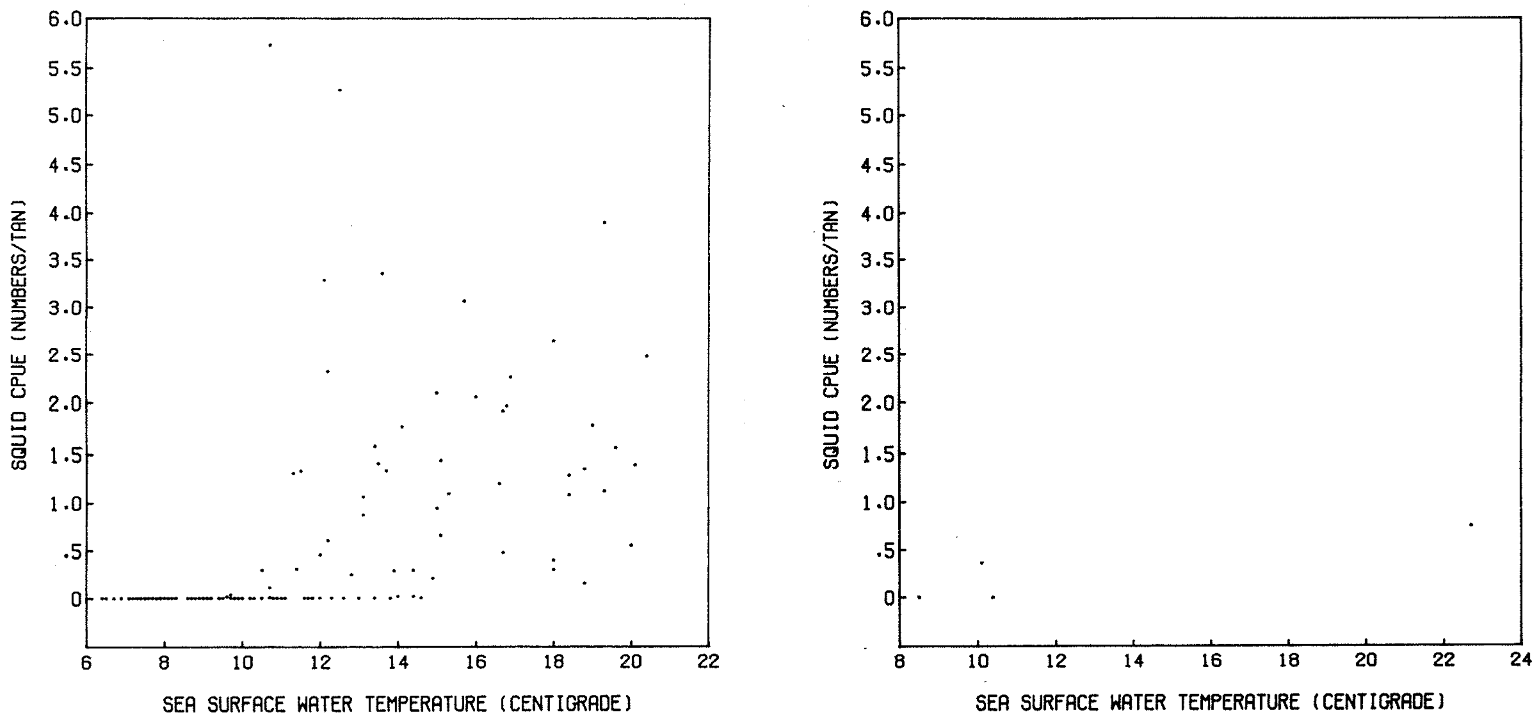


Fig. 4n. Plots of average squid CPUE as a function of surface water temperature, based on Japanese salmon research vessel operations conducted between 170°E and 145°W and south of 48°N during July (left) and August (right), 1982-85.

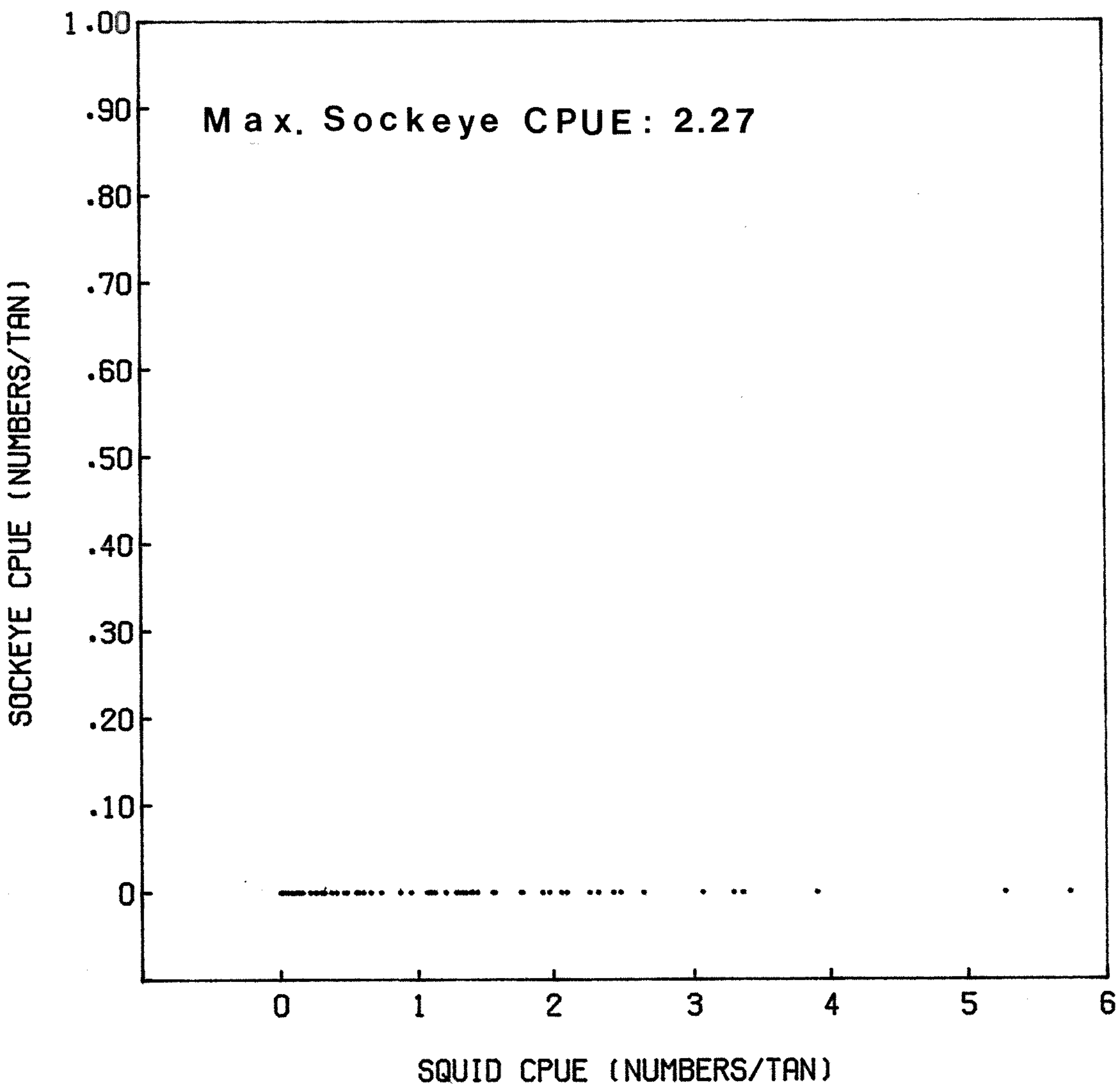


Fig. 5a. Plot showing correlation between sockeye CPUE and squid CPUE for research stations in which squid occurred between 170°E and 145°W and south of 48°N during May, June, July and August, 1982-85.

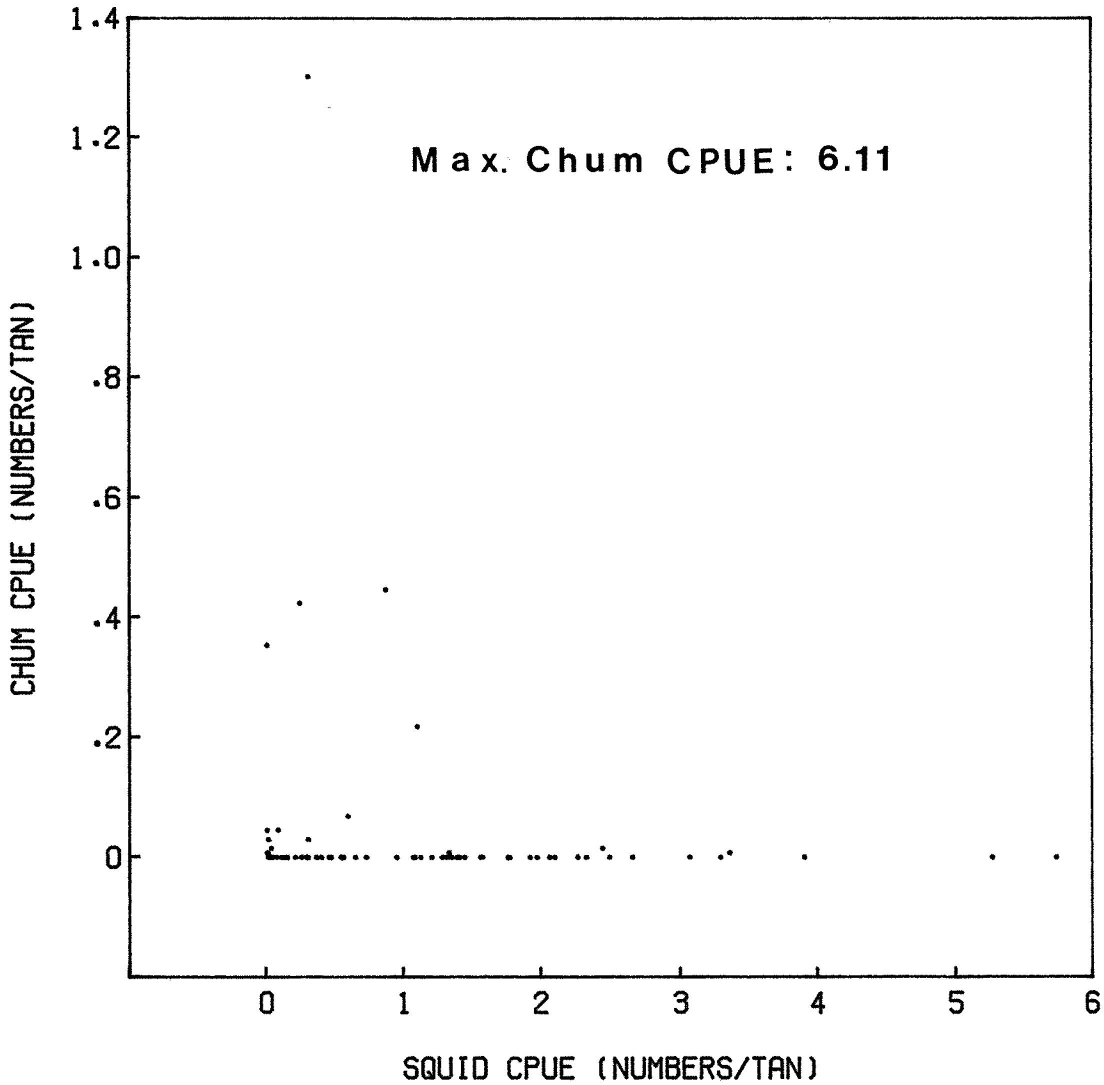


Fig. 5b. Plot showing correlation between chum CPUE and squid CPUE for research stations in which squid occurred between 170°E and 145°W and south of 48°N during May, June, July and August, 1982-85.

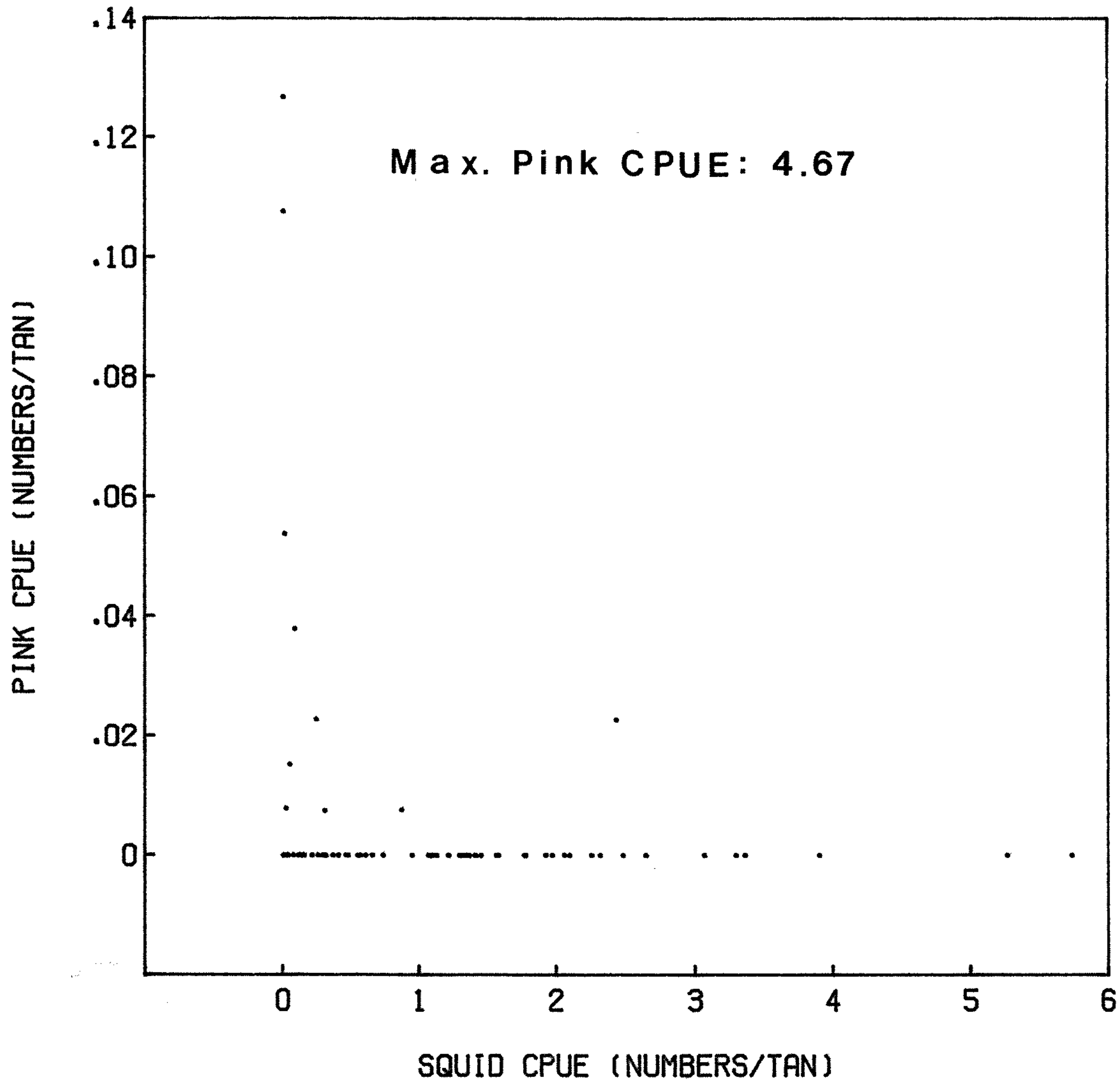


Fig. 5c. Plot showing correlation between pink CPUE and squid CPUE for research stations in which squid occurred between 170°E and 145°W and south of 48°N during May, June, July and August, 1982-85.

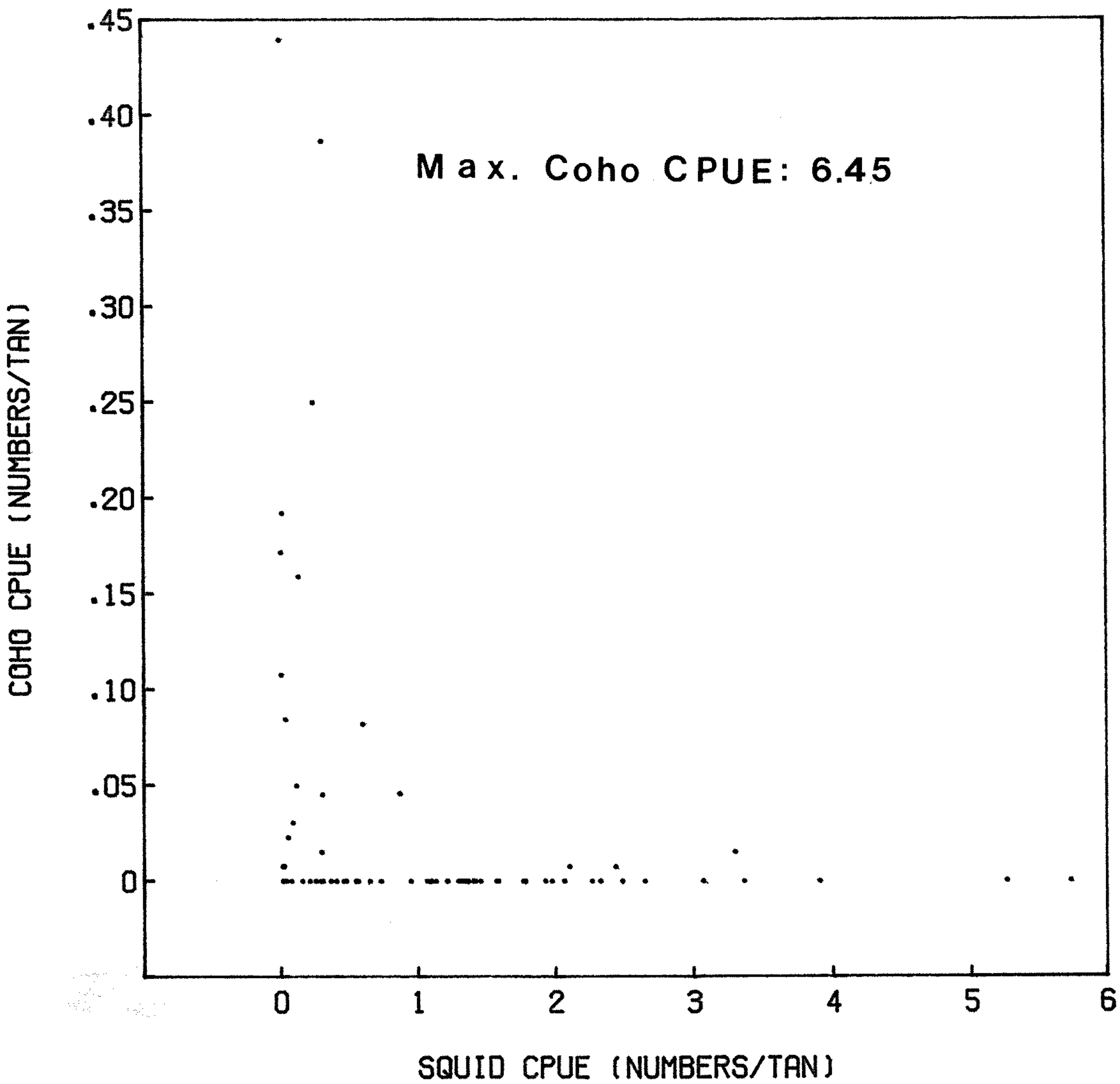


Fig. 5d. Plot showing correlation between coho CPUE and squid CPUE for research stations in which squid occurred between 170°E and 145°W and south of 48°N during May, June, July and August, 1982-85.

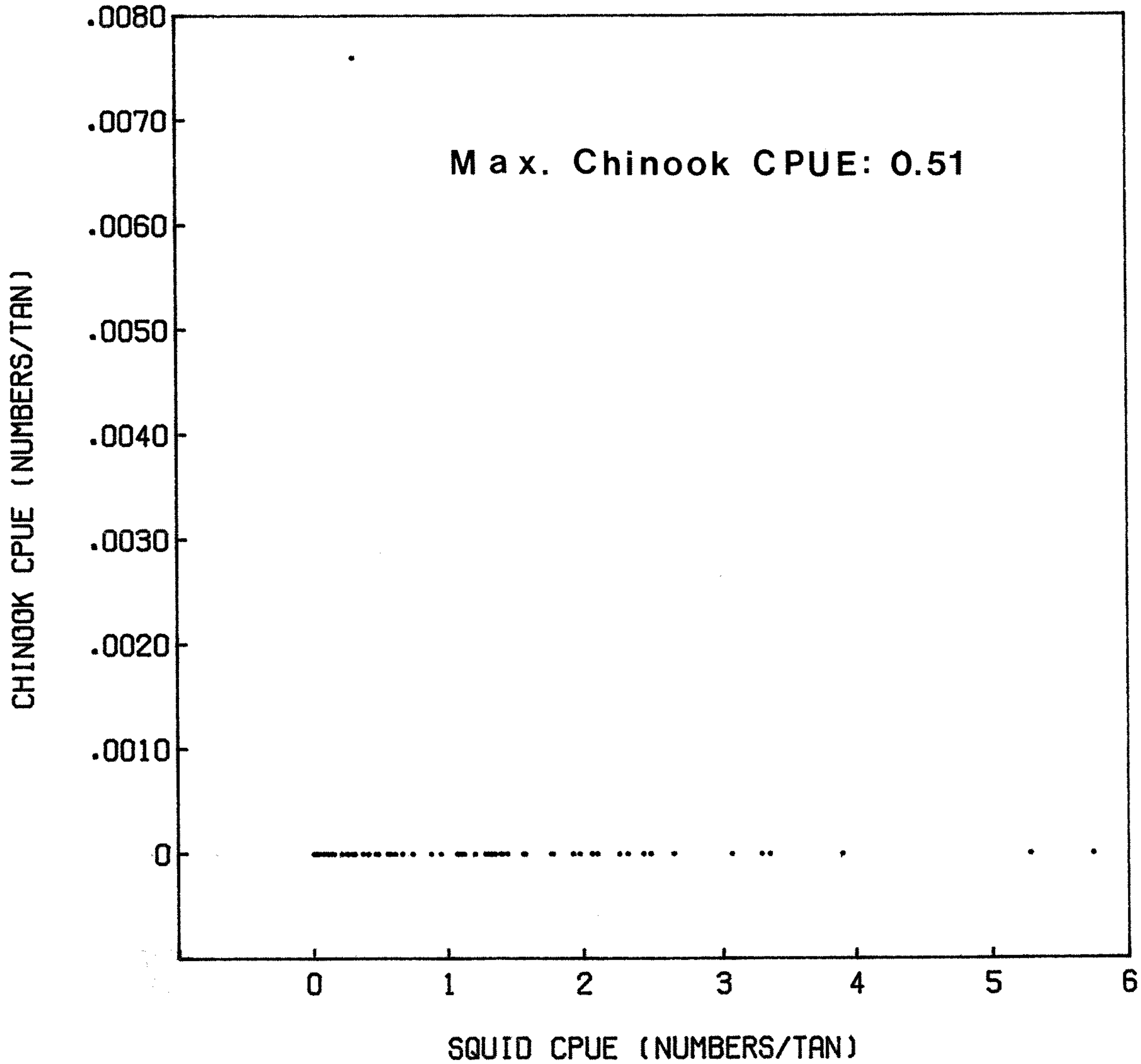


Fig. 5e. Plot showing correlation between chinook CPUE and squid CPUE for research stations in which squid occurred between 170°E and 145°W and south of 48°N during May, June, July and August, 1982-85.

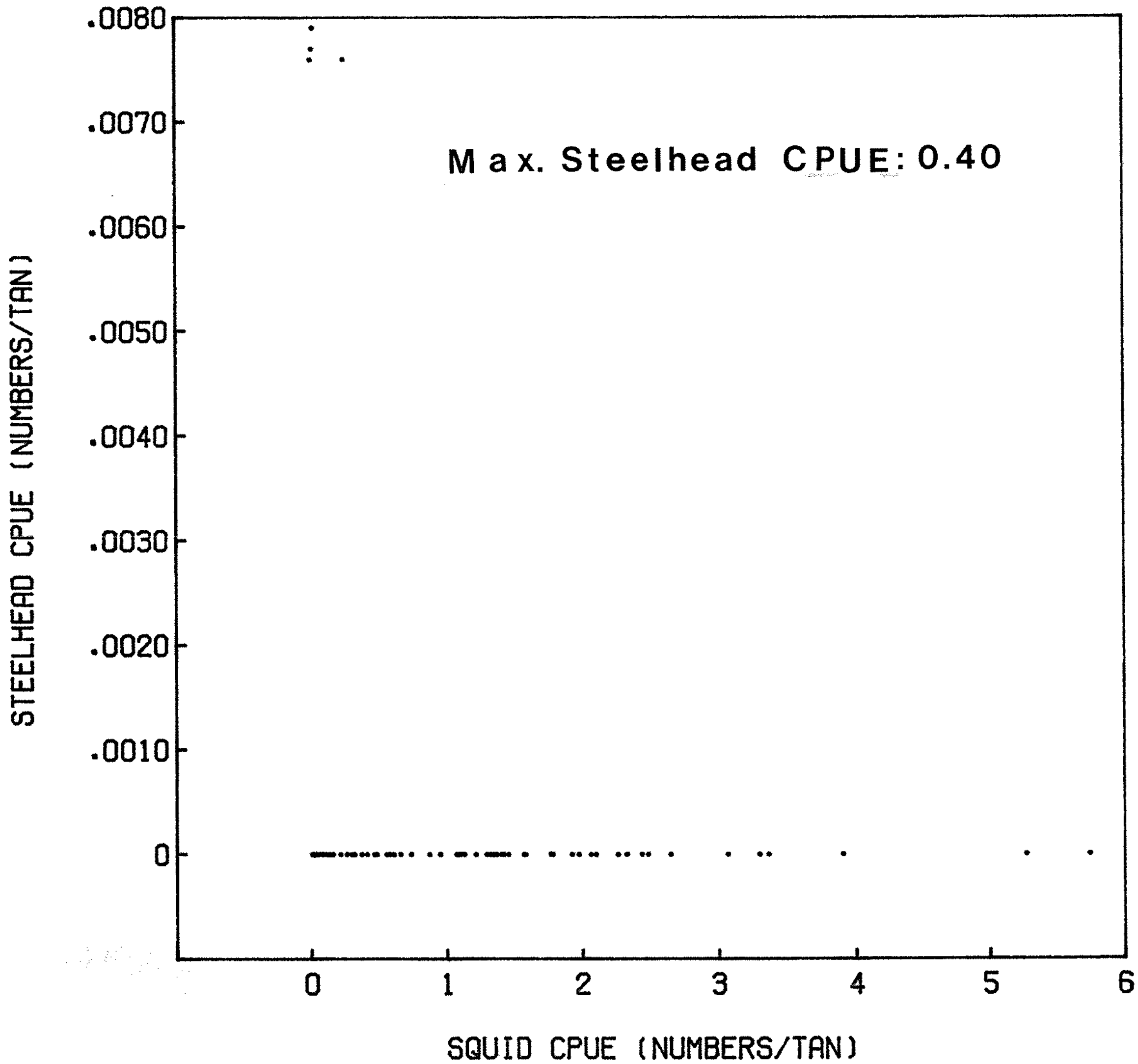


Fig. 5f. Plot showing correlation between steelhead CPUE and squid CPUE for research stations in which squid occurred between 170°E and 145°W and south of 48°N during May, June, July and August, 1982-85.

Appendix Table 1. Total catches, frequency of capture, and catches per tan of flying squid in gillnets fished by Japanese salmon research vessels in the month of May, 1982-85, stratified by recorded sea surface temperature. Data are for the commercial-type ("A") and variable-mesh ("C") gillnets combined (see text).

SURFACE TEMP.	NO. OPERATIONS		NO. SQUID	CPUE
	TOTAL	W/SQUID		
1.0 - 1.9	0	0	0	--
2.0 - 2.9	0	0	0	--
3.0 - 3.9	5	0	0	.00000
4.0 - 4.9	29	0	0	.00000
5.0 - 5.9	36	0	0	.00000
6.0 - 6.9	14	0	0	.00000
7.0 - 7.9	10	0	0	.00000
8.0 - 8.9	7	0	0	.00000
9.0 - 9.9	4	1	1	.00190
10.0 - 10.9	2	0	0	.00000
11.0 - 11.9	2	1	12	.04545
12.0 - 12.9	0	0	0	--
13.0 - 13.9	0	0	0	--
14.0 - 14.9	0	0	0	--
15.0 - 15.9	0	0	0	--
16.0 - 16.9	0	0	0	--
17.0 - 17.9	0	0	0	--
18.0 - 18.9	0	0	0	--
19.0 - 19.9	0	0	0	--
20.0 - 20.9	0	0	0	--
21.0 - 21.9	0	0	0	--
22.0 - 22.9	0	0	0	--
23.0 - 23.9	0	0	0	--

Appendix Table 2. Total catches, frequency of capture, and catches per tan of flying squid in gillnets fished by Japanese salmon research vessels in the month of June, 1982-85, stratified by recorded sea surface temperature. Data are for the commercial-type ("A") and variable-mesh ("C") gillnets combined (see text).

SURFACE TEMP.	NO. OPERATIONS TOTAL	NO. OPERATIONS W/SQUID	NO. SQUID	CPUE
1.0 - 1.9	0	0	0	--
2.0 - 2.9	0	0	0	--
3.0 - 3.9	0	0	0	--
4.0 - 4.9	4	0	0	.00000
5.0 - 5.9	5	0	0	.00000
6.0 - 6.9	21	0	0	.00000
7.0 - 7.9	23	0	0	.00000
8.0 - 8.9	15	0	0	.00000
9.0 - 9.9	5	0	0	.00000
10.0 - 10.9	4	2	35	.07709
11.0 - 11.9	5	5	344	.56393
12.0 - 12.9	0	0	0	--
13.0 - 13.9	1	1	75	.56818
14.0 - 14.9	1	1	5	.03968
15.0 - 15.9	1	1	10	.07937
16.0 - 16.9	0	0	0	--
17.0 - 17.9	0	0	0	--
18.0 - 18.9	0	0	0	--
19.0 - 19.9	0	0	0	--
20.0 - 20.9	0	0	0	--
21.0 - 21.9	0	0	0	--
22.0 - 22.9	0	0	0	--
23.0 - 23.9	0	0	0	--

Appendix Table 3. Total catches, frequency of capture, and catches per tan of flying squid in gillnets fished by Japanese salmon research vessels in the month of July, 1982-85, stratified by recorded sea surface temperature. Data are for the commercial-type ("A") and variable-mesh ("C") gillnets combined (see text).

SURFACE TEMP.	NO. OPERATIONS TOTAL	NO. OPERATIONS W/SQUID	NO. SQUID	CPUE
1.0 - 1.9	0	0	0	--
2.0 - 2.9	0	0	0	--
3.0 - 3.9	0	0	0	--
4.0 - 4.9	0	0	0	--
5.0 - 5.9	0	0	0	--
6.0 - 6.9	5	0	0	.00000
7.0 - 7.9	21	0	0	.00000
8.0 - 8.9	22	0	0	.00000
9.0 - 9.9	22	2	7	.00246
10.0 - 10.9	14	4	806	.51045
11.0 - 11.9	11	3	392	.29765
12.0 - 12.9	9	6	1543	1.56174
13.0 - 13.9	12	7	1217	.91229
14.0 - 14.9	6	5	228	.34545
15.0 - 15.9	6	6	1143	1.61669
16.0 - 16.9	6	6	1081	1.62312
17.0 - 17.9	0	0	0	--
18.0 - 18.9	7	7	891	1.06071
19.0 - 19.9	4	4	1060	2.18107
20.0 - 20.9	3	3	562	1.59659
21.0 - 21.9	0	0	0	--
22.0 - 22.9	0	0	0	--
23.0 - 23.9	0	0	0	--

Appendix Table 4. Total catches, frequency of capture, and catches per tan of flying squid in gillnets fished by Japanese salmon research vessels in the month of August, 1982-85, stratified by recorded sea surface temperature. Data are for the commercial-type ("A") and variable-mesh ("C") gillnets combined (see text).

SURFACE TEMP.	NO. OPERATIONS TOTAL	NO. OPERATIONS W/SQUID	NO. SQUID	CPUE
1.0 - 1.9	0	0	0	--
2.0 - 2.9	0	0	0	--
3.0 - 3.9	0	0	0	--
4.0 - 4.9	0	0	0	--
5.0 - 5.9	0	0	0	--
6.0 - 6.9	0	0	0	--
7.0 - 7.9	0	0	0	--
8.0 - 8.9	2	0	0	.00000
9.0 - 9.9	0	0	0	--
10.0 - 10.9	2	1	49	.18561
11.0 - 11.9	0	0	0	--
12.0 - 12.9	0	0	0	--
13.0 - 13.9	0	0	0	--
14.0 - 14.9	0	0	0	--
15.0 - 15.9	0	0	0	--
16.0 - 16.9	0	0	0	--
17.0 - 17.9	0	0	0	--
18.0 - 18.9	0	0	0	--
19.0 - 19.9	0	0	0	--
20.0 - 20.9	0	0	0	--
21.0 - 21.9	0	0	0	--
22.0 - 22.9	1	1	64	.73563
23.0 - 23.9	0	0	0	--