SURFACE TEMPERATURES AND SALMON DISTRIBUTION RELATIVE TO THE JAPANESE DRIFTNET FISHERY FOR FLYING SQUID (Ommastrephes bartrami)

by

R.L. Burgner,[1] R.W. Mercer,[2] and R.L. Major[2]

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[1]Fisheries Research Institute
School of Fisheries
University of Washington
Seattle, Washington 98195
U.S.A.

[2]Northwest and Alaska Fisheries Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112
U.S.A.

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Introduction

In recent years the reported incidence of net-marked coho and chinook salmon in troll fishery catches off southeastern Alaska has raised concern in the United States that one or more high seas driftnet fisheries may be intercepting salmon returning to the U.S. and Canadian west coast. Enquiry by U.S. scientists revealed that there are recently developed high seas driftnet fisheries operated by Japanese fishermen and directed toward catching squid and albacore in convention waters. At the 1981 annual meeting of the INPFC Sub-Committee on Salmon the United States requested information on these fisheries (Appendix 1A of 1981 Sub-Committee report). Information on these fisheries was provided by Japan for review by the Ad Hoc Salmon Research Coordinating Group at its March 1982 meeting in Tokyo. Documents were provided on:

(1) The squid drift gillnet fishery.

(2) The marlin and others drift gillnet fishery (which includes albacore).

(3) Exploratory research on pomfret (a directed fishery has not developed).

Of the two recently developed fisheries, that for flying squid (Ommastrephes bartrami) is more likely to have had an incidental catch of salmon because of mesh sizes and times and areas of fishing, types

of boats used, and amount of gear deployed per vessel. The reported total effort in tan days deployed in 1981 was almost twice that of the landbased and mothership salmon driftnet fisheries combined. The squid drift gillnet fishery was assigned by Fishery Agency of Japan to fish only in areas east of 170°E in 1979, and beginning in August 1981, it has been regulated to fish in areas north of 20°N between 170°E and 145°W. Northern limits change monthly in consideration of the migration of salmon, trout, and squid. Catching of salmon and trout is now prohibited, and Japan reported that after August 1, 1981, there was no record of incidental catches of salmonids in the reports of catch results submitted by the fishermen. Further, the Fishery Agency inspected landings at the designated ports and found no evidence of landing of salmon or trout by this fishery (Fishery Agency of Japan 1982).

Japan indicated that the placement of eastern and northern limits is the most effective regulation in the effort to prohibit fishing in areas where salmon and trout are distributed. This claim is based on information that squid inhabit waters warmer than 15°C and that salmon and trout are found in waters cooler than 15°C. The northern limits are said to have been set with considerable safety margin (Fishery Agency of Japan 1982a). However, Canadian and U.S. spokesmen at the 1982 Ad Hoc Group meeting expressed continued concern about the potential interception of North American salmonids by the squid fishery. The gear used is very similar to salmon driftnets but greater in amount, and the fishery location partially overlaps the pre-1978 landbased driftnet fishery area.

The purpose of this document is to provide preliminary examinations of data pertinent to evaluating the adequacy of the monthly northern limits of the squid driftnet fishery as a means of protecting salmon.

Data Sources

Data examined included (1) the monthly distribution of 15°C surface temperature observations in the North Pacific; (2) the southernmost occurrence of coho and chinook salmon as defined by INPFC research vessels, 1962-70; (3) catches of these species in the landbased driftnet fishery, 1979-81; (4) data on capture of salmon in Japanese research vessel operations, stratified by recorded sea surface temperature; and (5) reports on temperature preferences of O. bartrami.

Monthly climatological mean and extreme positions for the 15°C sea surface isotherms were prepared using Volume II of the U.S. Navy Marine Climatic Atlas of the World (NAVAIR 50-1C-529, Rev. 1977). This volume is based on data collected between 1854 and 1972. Mean and extreme positions for the 12°C and 16°C isotherms are presented in the Atlas. Extremes graphically represent boundaries containing 98% of all observations for each sea surface temperature for the month in question. Means and extremes for the 15°C isotherms were graphically interpolated between the published 12°C and 16°C means and extremes, respectively.

Information on southernmost distribution of coho and chinook salmon is from Godfrey, Henry, and Machidori (1975) and Major, et al. (1978).

Data on Japanese research vessel catches of salmon stratified according to sea surface temperature are for all reported operations,

1972-81. Only the catch data for commercial-type gear (A) were included in the analysis. The data include sampling in the North Pacific west of 165°W, along 145°W in 1980-81, sampling in the Okhotsk Sea, 1972-76, and sampling in the Bering Sea. Sampling occurred in the months March-October, but was conducted primarily in the months April-August.

Results and Discussion

Figures 1a-g portray for each fishing month, June-December, the following: (1) The squid fishing area (shaded); (2) the historical mean of the 15°C isotherm (solid line); (3) the ranges including 98% of the 15°C observations (light dotted lines); (4) the southernmost occurrence of coho and chinook salmon as defined by INPFC research vessels, 1962-70 (heavy dotted line); and (5) 2°x5° areas sampled south of this line in which sampling was conducted but no coho or chinook were encountered (indicated by zeros).

The figures show that in a year of average temperature, there would be considerable stretches of sub-15° water (salmon water) exposed to the squid fishery, particularly during September-December. In years when the 15°C isotherm lies south of the mean (approximately half the time), the amount of salmon water exposed to the squid fishery would be even greater, sometimes considerably so.

The real question, however, is how often salmon--rather than waters suitable for salmon--are likely to be encountered by the squid driftnet vessels fishing along the northern boundary of the monthly fishing areas. Figures 1a-g would seem to suggest that the distribution of coho and

chinook does not extend far enough southward to pose much of a problem. This is somewhat misleading, however, because fishing by research vessels--directed at locating main concentrations of salmon rather than the limits of their distribution--often did not fish southward until they ran out of salmon. (Note the relative absence of zeros in Figures 1a-g--zeros denoting areas where fishing took place but where no coho or chinook were encountered.) Information on October-December southern distribution of coho and chinook is particularly scant.

In some instances the actual performance of the landbased fishery for salmon contradicts the information provided by the research vessels. Research vessels, for example, reported no catches of coho and chinook in 2°x5° area 7042E in July, whereas the landbased fishery reports substantial catches there--269,958, 625,109, and 228,647 coho and chinook in 1979, 1980, and 1981, respectively (Fishery Agency of Japan 1980, 1981, 1982b). Moreover, in each of the three years, roughly one-half the landbased fleet was concentrated in area 7042E (52, 66, and 43% for the three years, in order). From the catches (of coho, chinook, and other salmon) and the distribution of the fleet, it can be concluded that salmon are expected to be abundant in 7042E in July. It would not be unlikely, therefore, to expect salmon to occur in reasonable numbers south of 42°N as well (waters legally fished by squid gillnetters).

Information is incomplete as to the ranges of surface temperatures in which salmon are seasonally encountered in the ocean. The best series of data is provided by the catch information of Japan's salmon research vessels. The 1972-81 data on salmon catches and sea surface

temperatures are examined here in a preliminary analysis. Table 1 presents the frequency of capture of salmon in the commercial-type gear used by the research vessels, stratified by recorded surface temperature. Salmon were reported captured in about 50% of the operations in surface temperatures between 15° and 17.9°C, and in 24% of the sets made in waters 18°C and above. However, almost all of the operations in which salmon were encountered at surface temperatures over 15°C were conducted in the Okhotsk Sea in late-season cruises. Salmon were taken in only three of 63 operations in the North Pacific at recorded surface temperatures over 15°C. Table 2 presents the frequency of capture by species for all operations. Table 3 presents the catches per tan stratified by temperature and restricted to longitudes east of the southern tip of Kamchatka Peninsula, which should be more representative of high seas distributions. Captures of pink, chum, and coho extended into warmer waters than for sockeye and chinook.

In describing the squid driftnet fishery regulations, Fishery Agency of Japan (1982a) states that flying squid inhabit waters warmer than 15°C. Evidence suggests, however, that the 15°C surface isotherm is not a reliable northern boundary restricting drift gillnetting of squid. Several sources of information indicate that there may in fact be substantial overlap in distribution of salmonids and O. bartrami. During 1981 test fishing for O. bartrami off British Columbia, Canada, salmon and steelhead catches occurred in surface temperatures up to 15.4°C and a peak salmon catch was experienced in 15°C water. On the other hand, O. bartrami were taken in commercial quantities in surface waters which ranged down to 14°C (the lowest surface temperature in

waters fished) and the largest squid catch was taken in waters of 14.4°C surface temperature (Bernard 1981).

Reports from Japan (Murata and Ishii 1977; Naito, et al., 1977) indicate that O. bartrami are caught by gillnets in surface temperatures ranging down to 8°C and that abundant catches occur in surface water temperatures down to 12°C. The largest concentrations of O. bartrami are reported (Okutani 1977) to occur where warm and cool waters (Kuroshio and Oyashio currents) converge. Naito, et al. (1977) report that peak gillnet catches of O. bartrami occur where warm surface water overlies colder (5°C at 50 meters) subarctic water.

This information indicates that peak O. bartrami catches are most likely in surface water temperatures below 15°C. Drift gillnet vessels fishing for squid, then, could be expected to fish in surface water temperatures below 15°C when possible.

There thus appears to be considerable potential for incidental interception of salmonids by the drift gillnet squid fishery as it now exists. The monthly northern boundaries may not adequately protect salmonids in view of the large variability in the position of the 15°C surface isotherm. Additionally, from the reports on occurrence of O. bartrami in gillnets, and from the 1981 distribution of catch and effort, it would seem likely that a portion of the driftnet fleet may fish in as cool surface waters (down to 12°C) as possible within the present boundaries. The long-term mean position of the 12°C isotherm approaches the northern boundary of the squid fishing area for some months (e.g., Figs. 2a, 2b). Deviations of the 12°C surface isotherm in years of cooler than average temperatures may extend well inside the boundaries of the squid fishery.

Conclusions

(1) Current time-area regulations do not restrict the squid driftnet fishery to waters warmer than 15°C. Vessels may at times be fishing legally in waters well below 15°C.

(2) Past data from research vessels of Japan, United States, and Canada do not adequately define the monthly southern boundary of salmon distribution. Information for fall and early winter (September-December) is particularly weak.

(3) Further analyses of research vessel data are needed to better define expected frequency of high seas capture of salmon and steelhead at temperatures encountered in the vicinity of the squid fishery.

Recommendations

(1) That joint agency efforts be made to analyze and summarize available data on seasonal distribution of salmon and steelhead on the high seas with respect to statistical area and temperature.

(2) That further analyses of existing data on sea temperatures be made for the area of the squid fishery.

(3) That observations be made by time and area on the actual temperatures encountered by the squid fleet, the incidence of salmon and steelhead encountered in the driftnets, the amount of gear fished, and the squid catches.

(4) That plans be laid to obtain information on salmon occurrence in the squid fishery area in months and areas where data are inadequate.

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Table 1. Frequency of capture of salmon in commercial-type gear of Japanese salmon research vessels, 1972-1981, stratified by recorded surface temperature.

Surface temperature (°C)	Number of operations	No. in which salmon were caught	% in which salmon were caught
0.0 - 0.9	5	3	60.0
1.0 - 1.9	81	74	91.4
2.0 - 2.9	236	233	98.7
3.0 - 3.9	610	603	98.9
4.0 - 4.9	851	847	99.5
5.0 - 5.9	801	799	99.8
6.0 - 6.9	690	686	99.4
7.0 - 7.9	777	774	99.6
8.0 - 8.9	778	774	99.5
9.0 - 9.9	561	542	96.6
10.0 - 10.9	369	344	93.2
11.0 - 11.9	265	230	86.8
12.0 - 12.9	149	122	81.9
13.0 - 13.9	85	65	76.5
14.0 - 14.9	76	44	57.9
15.0 - 15.9	36	17	47.2
16.0 - 16.9	31	17	54.8
17.0 - 17.9	16	9	56.3
$\geq$ 18.0	29	7	24.1

Table 2. Frequency of capture of salmon in commercial-type gear of Japanese salmon research vessels, 1972-1981, stratified by recorded surface temperature and recorded by species.

Surface temperature (°C)	Number of operations	Percent in which salmon were caught				
		Sockeye	Chum	Pink	Coho	Chinook
0.0–0.9	5	60.0	40.0	0.0	0.0	0.0
1.0–1.9	81	75.3	91.4	21.0	1.2	24.7
2.0–2.9	236	89.4	96.2	37.3	0.4	29.7
3.0–3.9	610	92.5	96.7	73.6	3.1	48.2
4.0–4.9	851	86.7	98.9	93.3	12.7	59.3
5.0–5.9	801	78.9	99.6	97.8	28.6	72.4
6.0–6.9	690	68.0	99.0	95.9	59.9	74.3
7.0–7.9	777	58.7	99.0	94.5	80.7	77.6
8.0–8.9	778	52.8	98.8	94.1	85.5	71.1
9.0–9.9	561	45.1	94.1	83.8	85.6	58.1
10.0–10.9	369	40.7	91.1	69.1	79.9	47.7
11.0–11.9	265	41.9	82.6	59.2	72.5	38.5
12.0–12.9	149	34.9	75.8	57.7	59.1	29.5
13.0–13.9	85	17.6	60.0	55.3	52.5	17.6
14.0–14.9	76	9.2	48.7	51.3	31.6	13.2
15.0–15.9	36	0	36.1	44.4	16.7	8.3
16.0–16.9	31	0	22.6	54.8	12.9	3.2
17.0–17.9	16	0	31.3	56.3	6.3	0
≥ 18.0	29	3.4	10.3	24.1	3.4	3.4

Table 3. Catches per tan of Japanese research vessels stratified by sea surface temperature for N. Pacific east of 157°E longitude and Bering Sea combined, 1972-81. Average catches per tan of gear "A" were calculated as the sum of the year CPUE (1972-81) divided by the number of years in which at least one set was made in the temperature interval.

Surface temperature (°C)	Catch per tan					
	Sockeye	Chum	Pink	Coho	Chinook	Total
0-0.9	0.006	0	0	0	0	0
1-1.9	0.182	0.297	0.023	0	0.0004	0.503
2-2.9	0.845	0.680	0.116	0	0.003	1.644
3-3.9	0.779	0.937	0.590	0	0.009	2.315
4-4.9	0.699	0.872	1.602	0.006	0.013	3.192
5-5.9	0.702	1.210	2.655	0.061	0.032	4.660
6-6.9	0.604	1.410	4.284	0.214	0.050	6.562
7-7.9	0.966	1.131	4.474	0.492	0.070	7.133
8-8.9	1.772	1.049	2.856	0.362	0.069	6.108
9-9.9	0.538	1.029	1.968	0.787	0.052	4.374
10-10.9	0.257	0.662	0.612	0.468	0.018	2.017
11-11.9	0.441	0.750	0.240	0.365	0.015	1.811
12-12.9	0.209	0.795	0.066	0.201	0.004	1.275
13-13.9	0.090	0.209	0.128	0.094	0.001	0.522
14-14.9	0	0.005	0.0003	0.003	0	0.008
15-15.9	0	0.004	0.0006	0.0007	0	0.005
16-16.9	0	0	0	0	0	0
17-17.9	0	0	0	0	0	0
$\geq$ 18	0	0	0	0	0	0

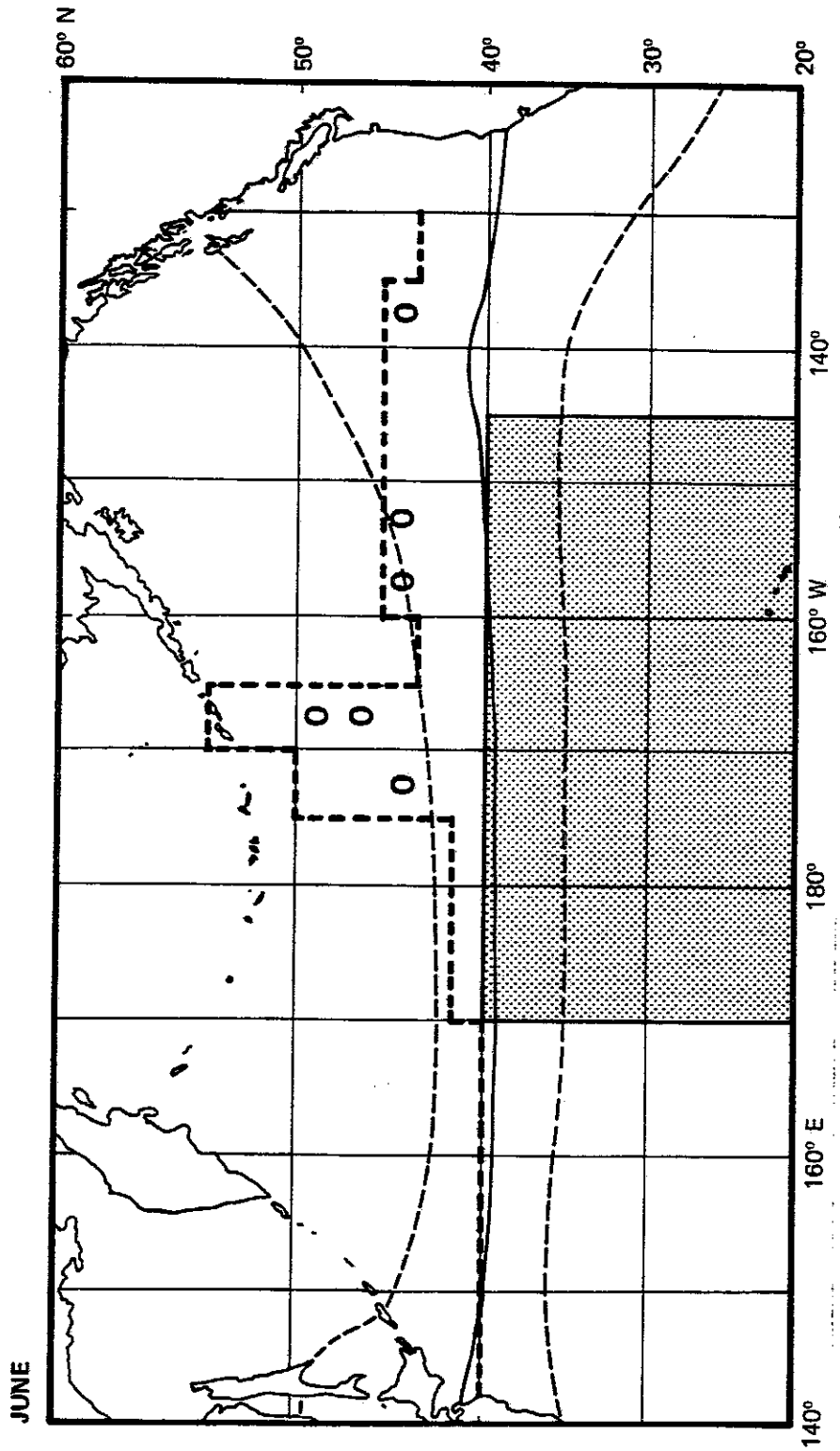

Fig. 1a. Southernmost locations where coho and chinook salmon were taken by INPFC research vessels in June, 1962-70 (heavy broken line) and the 15°C surface water isotherm (historical mean indicated by a solid line and 98% range of observations indicated by a light broken line). Areas (2x5°) where research vessel fishing took place but where no coho or chinook were taken are indicated by O. The shaded area is the current June squid driftnet fishery zone.

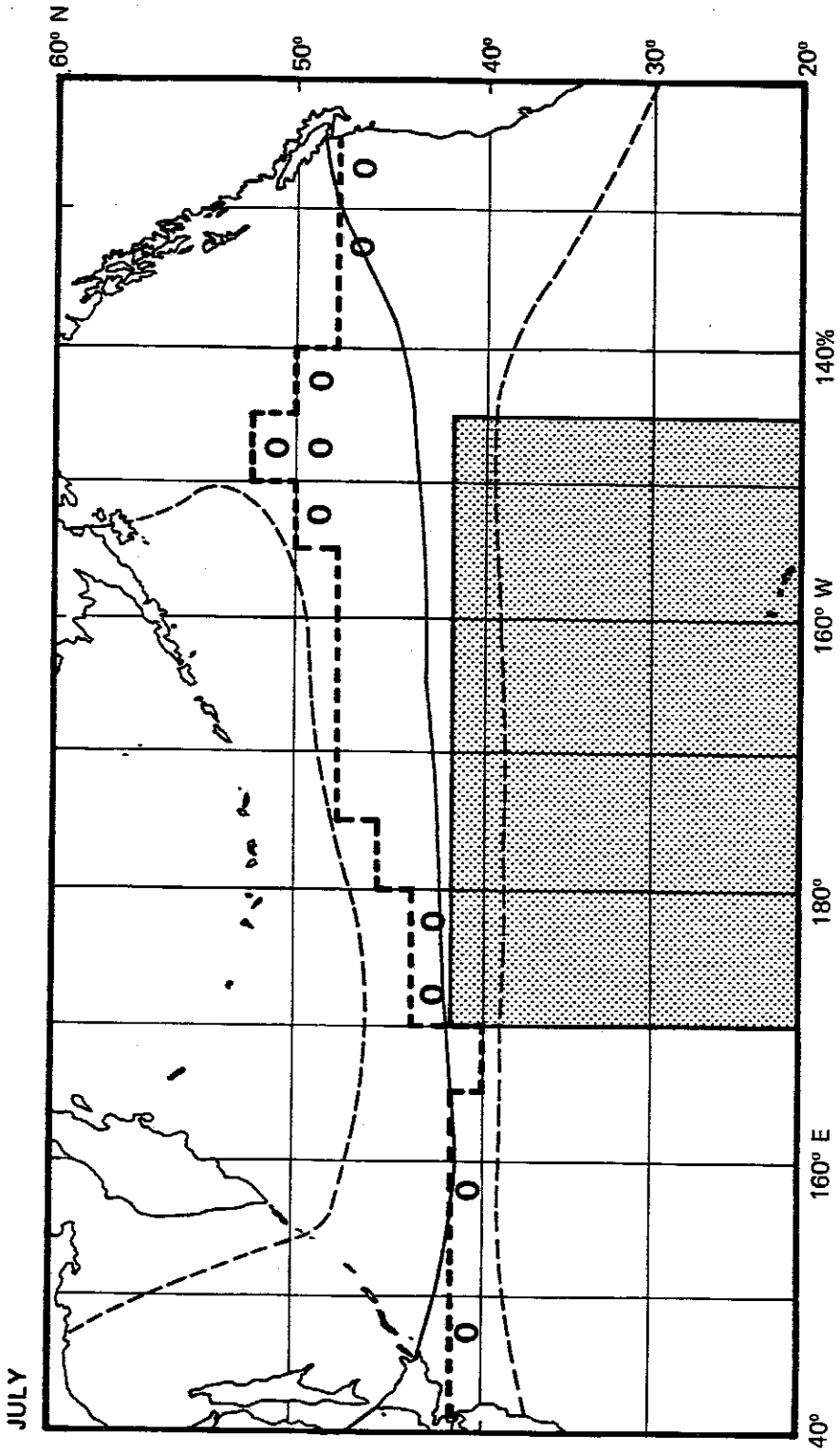

Fig. 1b. Southernmost locations where coho and chinook salmon were taken by INPFC research vessels in July, 1962-70 (heavy broken line) and the 15°C surface water isotherm (historical mean indicated by a solid line and 98% range of observations indicated by a light broken line). Areas (2x5°) where research vessel fishing took place but where no coho or chinook were taken are indicated by O. The shaded area is the current July squid driftnet fishery zone.

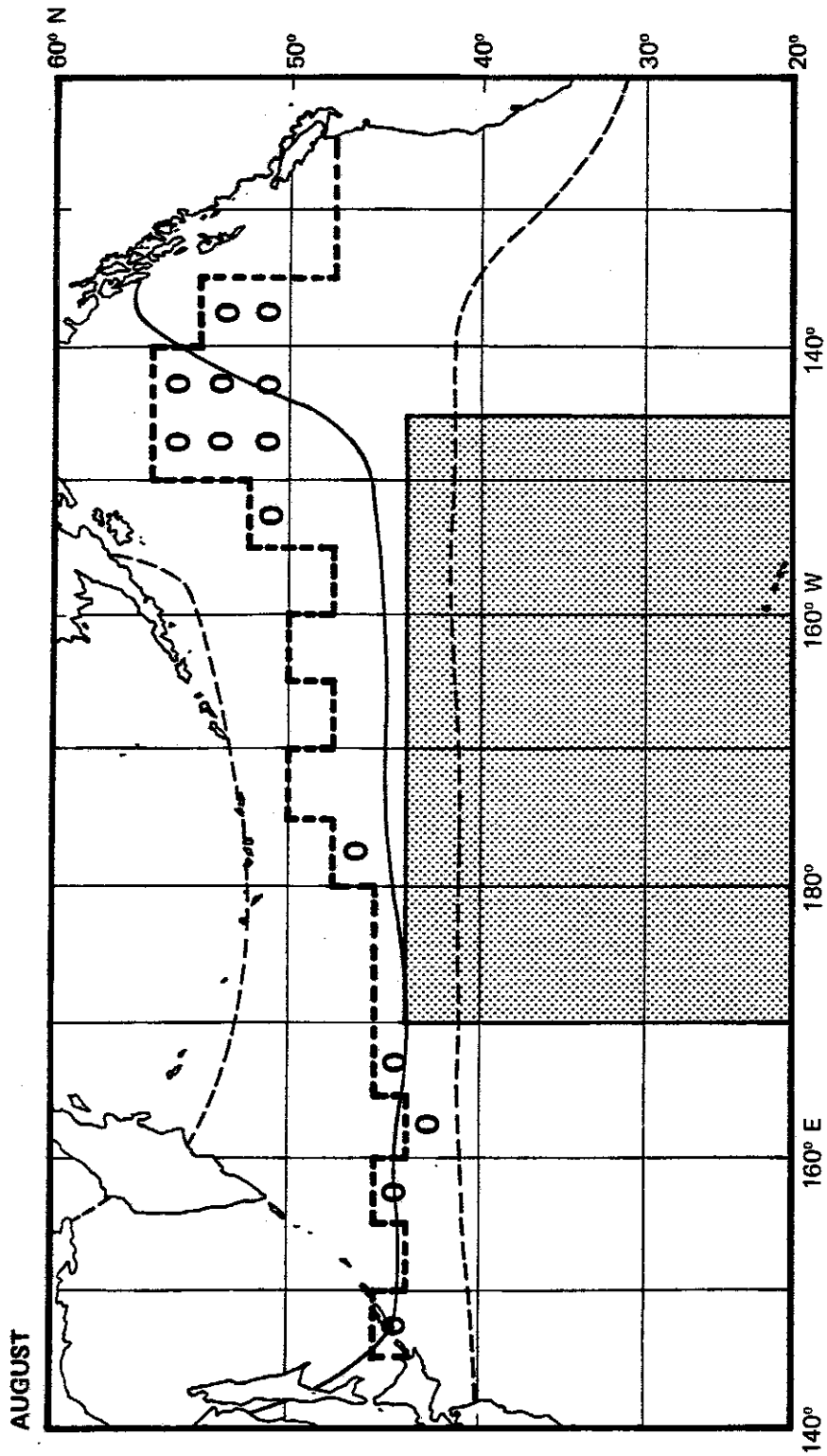

Fig. 1c. Southernmost locations where coho and chinook salmon were taken by INPFC research vessels in August, 1962-70 (heavy broken line) and the 15°C surface water isotherm (historical mean indicated by a solid line and 98% range of observations indicated by a light broken line). Areas (2x5°) where research vessel fishing took place but where no coho or chinook were taken are indicated by O. The shaded area is the current August squid driftnet fishery zone.

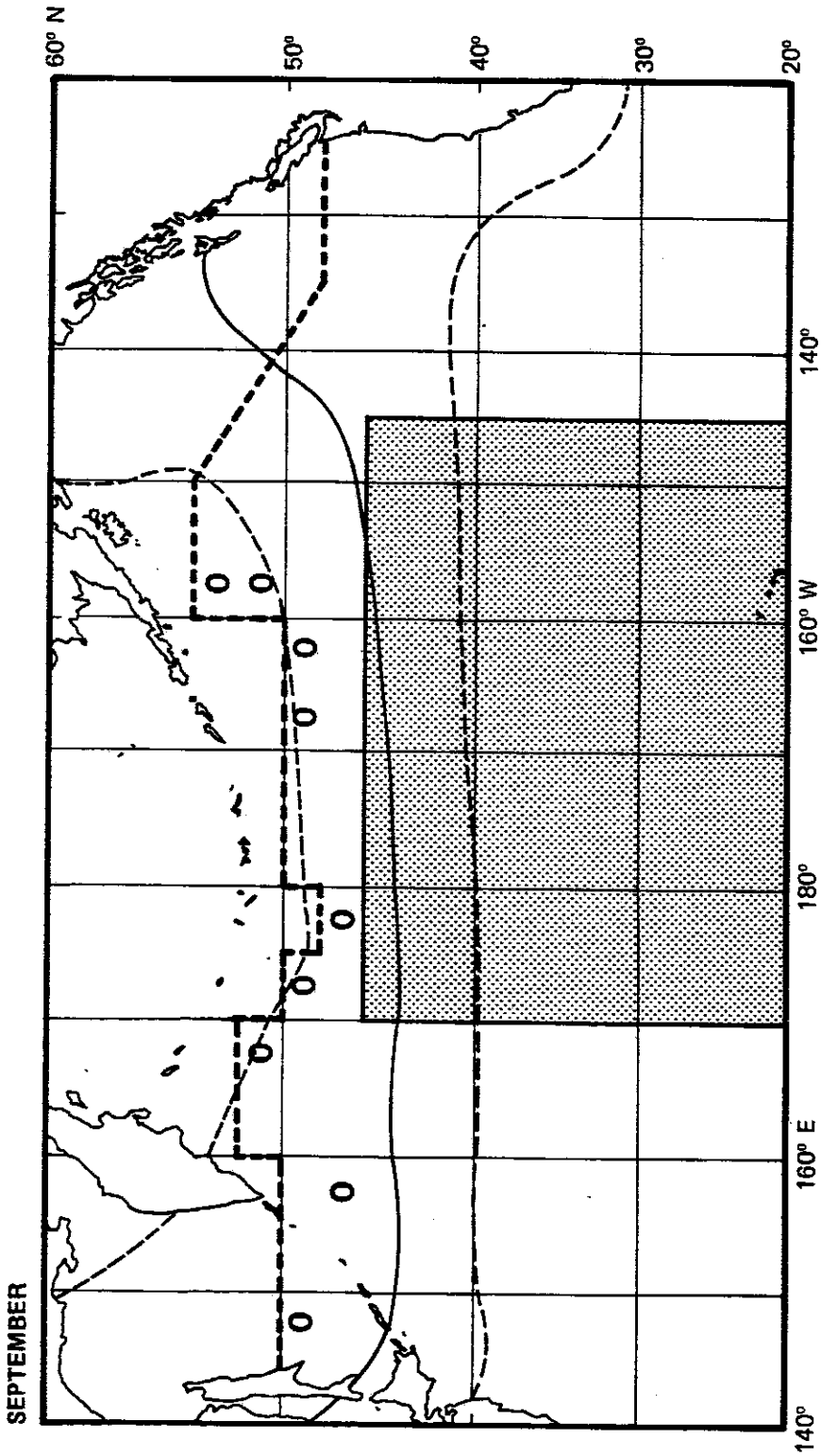

Fig. 1d. Southernmost locations where coho and chinook salmon were taken by INPFC research vessels in September, 1962-70 (heavy broken line) and the 15°C surface water isotherm (historical mean indicated by a solid line and 98% range of observations indicated by a light broken line). Areas (2x5°) where research vessel fishing took place but where no coho or chinook were taken are indicated by O. The shaded area is the current September squid driftnet fishery zone.

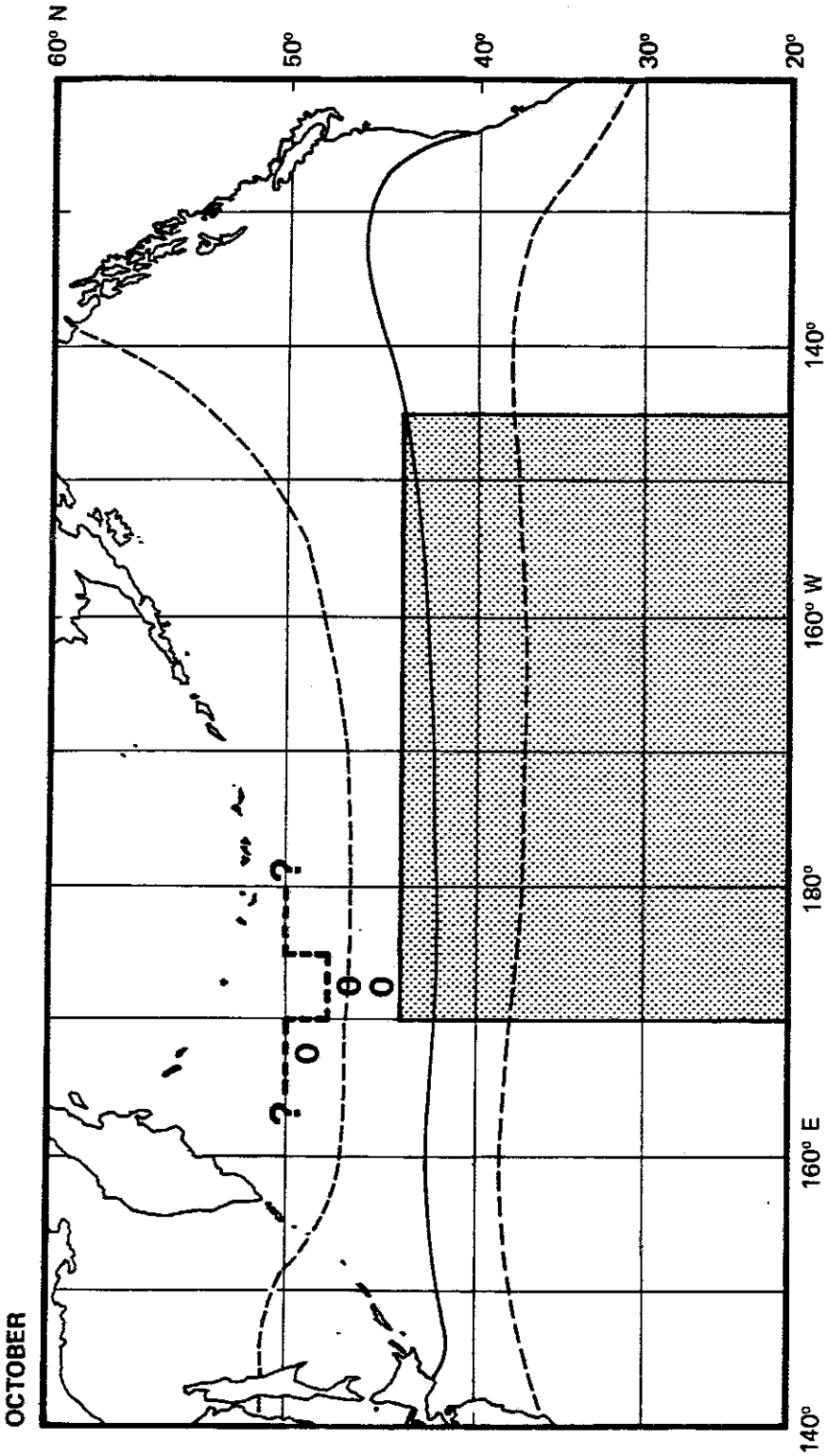

Fig. 1e. Southernmost locations where coho and chinook salmon were taken by INPFC research vessels in October, 1962-70 (heavy broken line) and the 15°C surface water isotherm (historical mean indicated by a solid line and 98% range of observations indicated by a light broken line). Areas (2x5°) where research vessel fishing took place but where no coho or chinook were taken are indicated by O. The shaded area is the current October squid driftnet fishery zone.

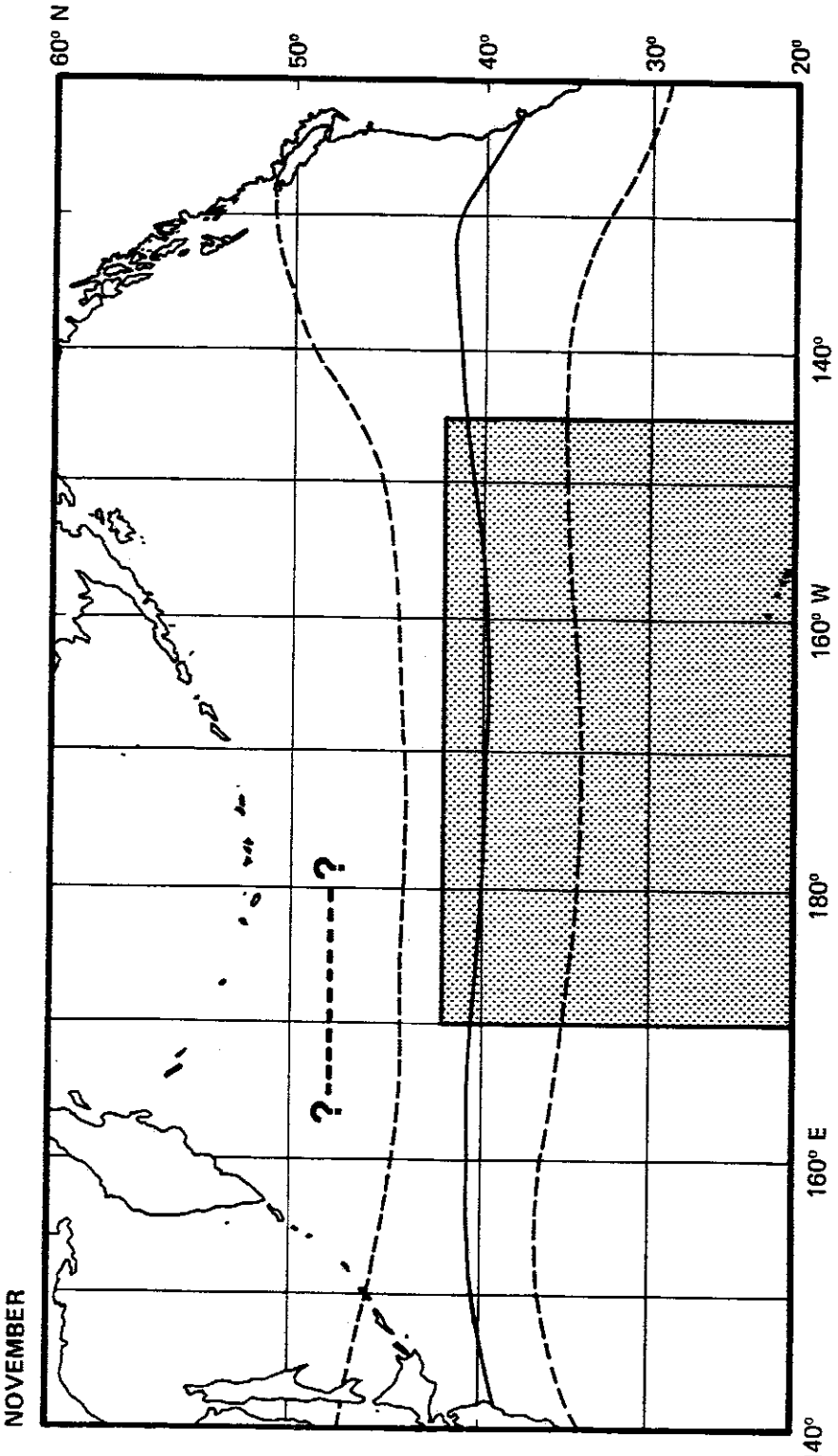

Fig. 1f. Southernmost locations where coho and chinook salmon were taken by INPFC research vessels in November, 1962-70 (heavy broken line) and the 15°C surface water isotherm (historical mean indicated by a solid line and 98% range of observations indicated by a light broken line). Areas (2x5°) where research vessel fishing took place but where no coho or chinook were taken are indicated by O. The shaded area is the current November squid driftnet fishery zone.

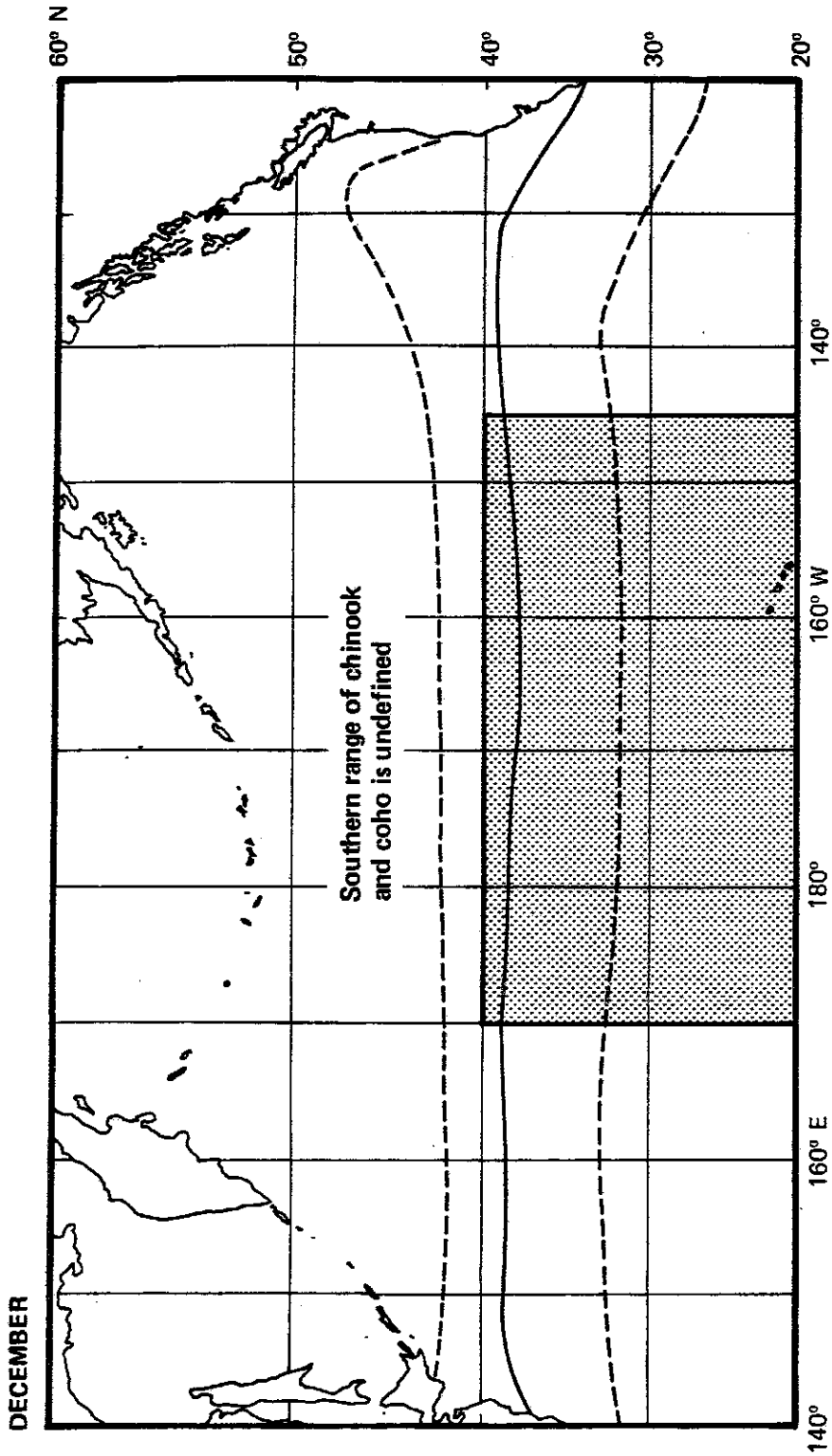

Fig. 1g. Southernmost locations where coho and chinook salmon were taken by INPFC research vessels in December, 1962-70 (heavy broken line) and the 15°C surface water isotherm (historical mean indicated by a solid line and 98% range of observations indicated by a light broken line). Areas (2x5°) where research vessel fishing took place but where no coho or chinook were taken are indicated by O. The shaded area is the current December squid driftnet fishery zone.

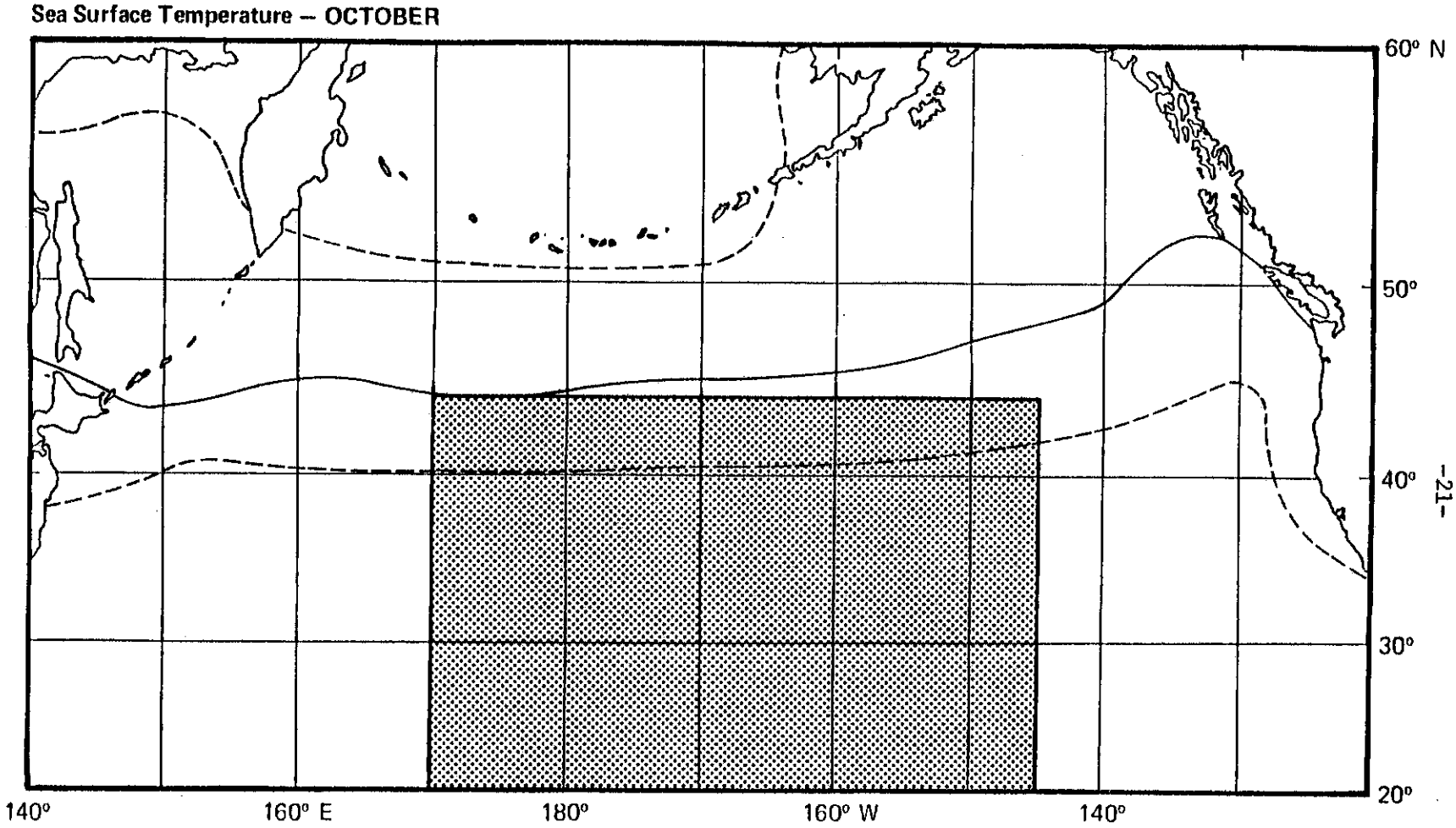

Fig. 2a. Long-term mean of the 12°C surface water isotherm for October (solid line) and 98% range of observations (broken lines). The shaded area is the current October squid driftnet fishery zone.

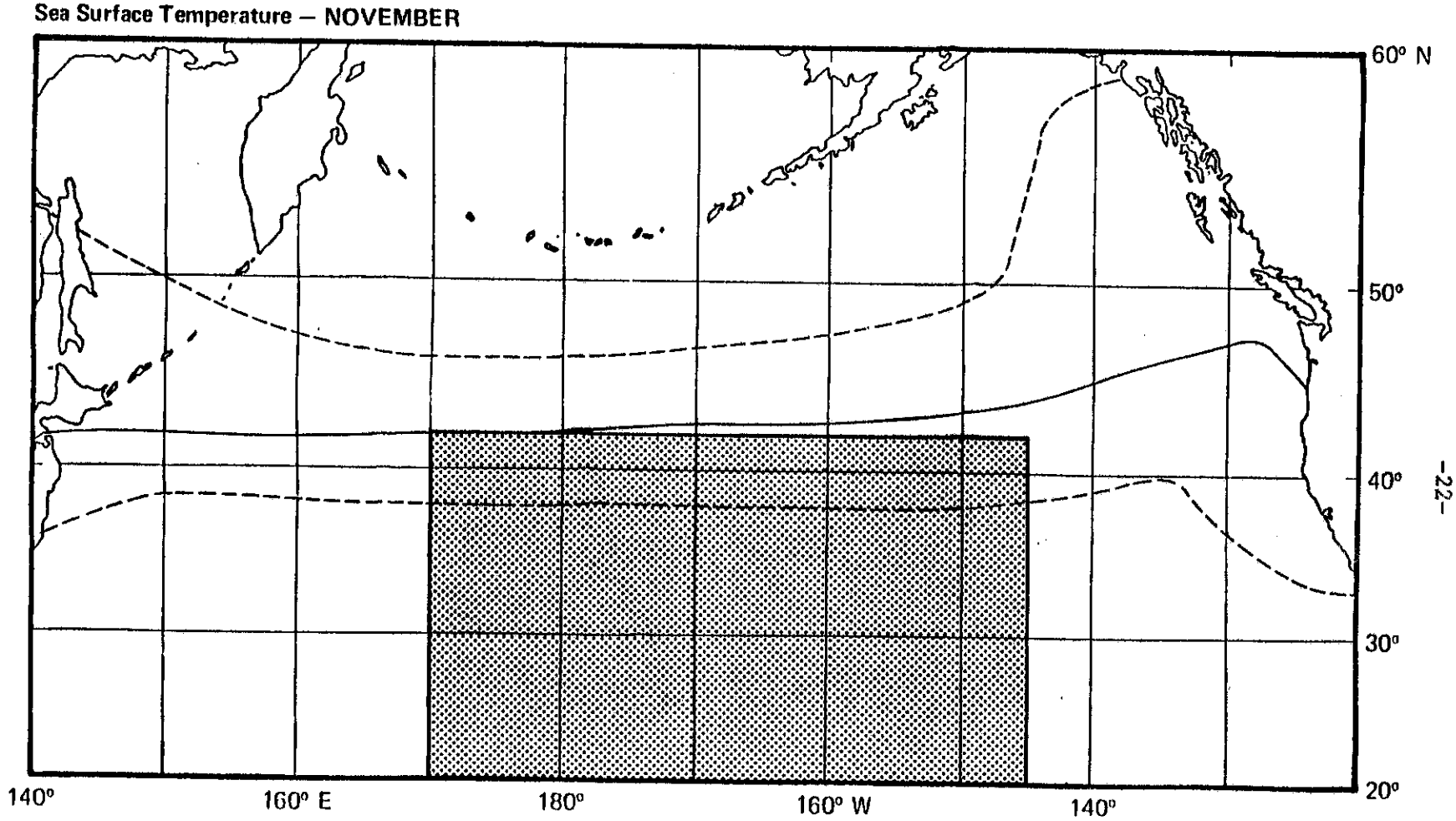

Fig. 2b. Long-term mean of the 12°C surface water isotherm for November (solid line) and 98% range of observations (broken lines). The shaded area is the current November squid driftnet fishery zone.