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Distribution and Abundance of Juvenile Pollock From Historical Shrimp Trawl Surveys in the Western Gulf of Alaska

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DISTRIBUTION AND ABUNDANCE OF JUVENILE POLLOCK FROM HISTORICAL SHRIMP TRAWL SURVEYS IN THE WESTERN GULF OF ALASKA

by

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INTRODUCTION

Fisheries Oceanography Coordinated Investigations (FOCI) is a cooperative project involving scientists from the National Oceanic and Atmospheric Administration's (NOAA) Pacific Marine Environmental Laboratory (PMEL) and Alaska Fisheries Science Center (AFSC), and investigators from several other research facilities and universities. The goal of FOCI is to gain an understanding of the physical and biological processes that contribute to recruitment variability of walleye pollock (*Theragra chalcogramma*) in Shelikof Strait. A primary focus of FOCI research is the question of when relative levels of recruitment are established in the life cycle of walleye pollock. Processes impacting survival of pollock during the larval stage are believed to be the most important factors affecting recruitment. Through research of these processes, FOCI investigators aim to improve information available to fisheries managers by providing better forecasts of year-class strength.

Recruitment variability appears to be the major factor driving changes in stock biomass of pollock in the Gulf of Alaska (Alton et al. 1987, Megrey 1989). In the 1970s there was a marked increase in pollock recruitment. The commercial fishery responded to the increased stock biomass with intense interest. Pollock fishery catches peaked in 1984 at 307,000 metric tons (t). Declining recruitment levels in the 1980s resulted in a collapse of the harvest to 60,000-70,000 t during 1987-89 (Hollowed and Megrey 1990).

This study addresses the question of when relative recruitment levels are established. The objectives are to: 1) extract information on the growth, distribution, and abundance of age-0 pollock, and 2) develop indices of juvenile pollock abundance and compare them with recruitment levels. The investigation made use of data generated from shrimp and juvenile pollock surveys conducted in the Shelikof Strait region between 1975 and 1988. Gulf of Alaska shrimp surveys spanning 1975 to 1983 were used where catch data on juvenile pollock were available. Between 1980 and 1982, juvenile pollock data were collected through the participation of groundfish biologists on shrimp surveys directed jointly by the National Marine Fisheries Service (NMFS) and the Alaska Department of Fish and Game (ADF&G)(Smith et al. 1984). After 1982, the joint NMFS-ADF&G surveys were terminated. In 1984, surveys resumed under the Young-of-the-Year (YOY) Project which targeted juvenile pollock with the goal of improving predictions of year-class abundance. All data utilized in this report were collected using a standard piece of gear: an 18.6 m, high-opening shrimp trawl. Since the area covered and the objectives of the historical shrimp trawl surveys varied from year to year and the catchability of juvenile pollock is unknown, we consider this data as semiquantitative. However, given the variability in observed levels of recruitment from 1975 to 1988, prerecruit signals should be apparent in the juvenile survey data.

MATERIALS AND METHODS

An area covering approximately 167,000 km^2 in the western Gulf of Alaska was divided into three regions (Fig. 1). These divisions were made because the entire area was not surveyed each year. The subset of trawling stations used in this study included all hauls falling within the boundaries of the three regions. Several hauls from outside the region were eliminated, as well as hauls with poor performance levels, and where pollock were caught but not counted. The range of trawl dates and the number of trawls made per year are recorded by region in Table 1. The size and horsepower of all the survey vessels are listed in Table 2.

The ADF&G planned the random stratified design of the 1975-83 surveys prioritizing shrimp survey objectives. The basic sampling gear was the same for every year; a 18.6 m, high-opening shrimp trawl set 30 cm off bottom and rigged with a 16.8 m tickler chain. The operative path of the trawl was 9.8 m wide by 3.8 m high. The stretched net mesh size was 32 mm. Each trawl consisted of a near-bottom tow approximately 15 to 30 minutes in duration and the area swept was generally between 10,000 and 20,000 m^2.

The 1984-88 YOY surveys were designed to answer varying research questions, but the main objective of the surveys was to study the distribution of juvenile pollock. The 1984 survey was the pilot study for the YOY surveys. The basic sampling gear was the 18.6 m, high-opening shrimp trawl with a 3 mm mesh liner in the codend. The effective opening of the trawl is unknown, but the original version's opening measured 9.8 m x 3.8 m. The 1984 survey included trawls made in daylight and at night in Chiniak Bay (Region III, Fig. 1) and in offshore waters. The trawls were carried out both in midwater and near bottom, and were approximately 10 minutes in duration.

The 1985-88 YOY surveys expanded into other areas of the Shelikof region. After the 1984 survey all trawls were made during daylight hours and the trawl equipment was modified to control mud accumulation in the codend during bottom tows. Trawls were carried out on acoustical sign believed to be juvenile pollock. Preliminary analyses indicated that there was no relationship between pollock catch and acoustical sign density (H. Shippen, AFSC. 7600 Sand Point Way N.E. Seattle, WA 98115-0070. Pers. commun., September 1989) and for the purpose of this study we treated the data as being randomly sampled. All data were extracted from the Resource Assessment and Conservation Engineering (RACE) Division data base Gulf of Alaska Master Index on the Burroughs [1] mainframe. Distribution plots of catch per unit effort (CPUE) were generated for each year. Haul records for the subset of 1975 to 1988 shrimp and YOY cruises were selected from the Master Index and assigned to their corresponding regions with the Assign Strata program. The CPUE program was run to create the plotwork files needed to work the

1 Reference to trade name does not imply endorsement by the National Marine Fisheries Service, NOAA.

Map program. Input to the CPUE program included haul records, which provide area data (distance and net width), and pollock catch records, which contain the number of pollock for each haul. The output plotwork files provided annual CPUE values (number of pollock per km^2) for each station. CPUE distribution plots were mapped for each year.

Distribution plots of age-0 pollock were created using the Limit CPUE and Map programs. Length frequency data were only available from 1980 to 1988. The age-0 pollock were selected from length frequency records as the size category 5-13 cm. The Limit CPUE program generated age-0 CPUE values by deriving the proportion of age-0 pollock in each catch, and then multiplying by total CPUE. Age-0 pollock length frequencies were plotted using the Biomass and Plot/LF programs. CPUE and length frequency data were used in the Biomass program to derive population estimates for each size category. Population estimates were plotted by length category with the Plot/LF program. Age-1 fish in the size category 14-28 cm were treated similarly.

Autumn age-0 and age-1 abundance indices were generated by multiplying the average annual CPUE for each of the three western Gulf of Alaska regions by the respective area. For years in which total pollock (ages 0-2), but no age-0 data were available (i.e., 1975-78), or where age-0 data were limited (1983), the number of age-0 fish was estimated from the regression between age-0 and total pollock abundance from 1980-88 by region (including 1982, regions I and II; and 1984, region III only). This relationship was

$$Y = -1.12 + 0.95X \quad (R = 0.90, n = 21). \qquad (1)$$

In years where data were missing from a given area, the median value for that area, from years where data were available, was substituted.

A multivariate nested analysis of covariance (ANCOVA) model was used to estimate the gear effect caused by a fine mesh liner used in the 1984-88 YOY surveys. Smaller length categories would be underestimated for early survey years when no fine mesh liner was used. The model was fit to data from region II only because data with both gear types were sparse from the other regions. The data set only included trawls after 14 September because larger size juveniles were not represented in most earlier tows, producing empty cells in the ANCOVA. Figure 2 shows the region II length distributions for the different years and gear types. Log transformation reduced the heteroscedasticity of the data. The model was

$$\ln(freq(g,y,d)_i + 1) = a + g_i + y_i + d_i + e_i \qquad (2)$$

where $freq(g,y,d)_i$ is the vector of length frequencies (in numbers) for 1-cm length categories over the length range 5-13 cm for gear (g), year (y), and date (d) at station (i) and error (e) is distributed as a N(0,1) random variable.

The model demonstrated a significant gear effect (Table 3). The gear corrections were derived from the difference between the length distributions for the two gear types. This gear correction was applied to the length frequencies of years prior to 1984 when the fine mesh liner was not used. The corrected length frequencies were used to derive new age-0 abundance values. However, in general, the conclusions reached in this study were not affected by the gear corrections.

For the years 1975-79, age-0 levels of abundance were derived from the regression between age-0 and total pollock abundance as noted above. The length distribution for these age-0 fish was estimated by the average of the length frequency distributions for 1980-82. The gear effect was applied to the estimated length frequencies to obtain the corrected 1975-79 age-0 abundance.

Because surveys sometimes occurred in different months, age-0 abundance values were standardized to an estimated number on the reference date of 15 September. An assumed mortality rate of 0.01/day was multiplied by the difference between the median survey date and the reference date for each region by year (0.01/day was approximated for juvenile gadids by Houde 1987 and is near the value of 0.015/day for late larval pollock from Yoklavitch and Bailey 1990). This correction factor was then added to the corresponding abundance index value to obtain a mortality corrected abundance. The correction had relatively minor effects. Age-1 abundance was derived only from years where length frequencies were available and were not subjected to gear or mortality corrections as these effects would be minor.

A multiple-regression model was tested to determine if any significant density- or temperature-dependent relationships could be found when accounting for temporal variation. The model was

$$l_{i,y} = a + j_{i,y} + t_{i,y} + d_{i,y} \qquad (3)$$

where l is the mean length in area (i) and year (y), j is julian date, t is sea-surface temperature, and d is the density of age-0 pollock (sea-surface temperature is from the Comprehensive Ocean-Atmosphere Data Set (COADS), Alan Macklin, PMEL. 7600 Sand Point Way N.E., Seattle, WA 98115-0700, Pers. commun., January 1991). The model was applied separately to the 1980-82 (without liner) and 1985-88 (with liner) data sets to account for gear effect.

RESULTS

Length Characteristics

Length composition varied between years and regions (Fig. 3). The length composition data posed several problems. The data were limited to 1980-88, there was variation in the timing of surveys, and the addition of a fine mesh liner affected the catch of smaller size classes from 1985-88. No significant density- or temperature-dependent growth relationships were shown in the results of the multiple-regression model (Equation 3). The model was significant only for the 1985-88 data set

($r = 0.81$, F-ratio $= 4.915$, $p < 0.03$), and date was the only significant variable ($t = 31.3$, $p < 0.01$). The significance levels for temperature and density were $t = 1.27$, $p < 0.24$, and $t = 1.52$, $p < 0.17$, respectively.

Distribution

Only age-0 juvenile distributions are discussed here. Distributions of all juveniles and age-1 fish are shown in the Appendix. There were apparent interannual differences in distribution of age-0 pollock (Figs. 1a-h). In 1980, there were few catches of age-0 pollock along the Alaska Peninsula west of the Semidi Islands. There were high catches of age-0 pollock along the peninsula from the Semidi Islands to the Shumagin Islands in 1981. In 1982, there was no survey west of Kodiak Island. In 1984, stations were confined to the northeast of Kodiak Island. High catches were distributed equally between nearshore and offshore areas in 1985, but the cruise did not go beyond the Shumagin Islands. Catches in 1985 were relatively high around Kodiak Island. The 1986 survey produced low catches in all areas. In 1987, surveys extended beyond the Shumagin Islands, catches were distributed equally offshore and nearshore, and there were relatively low catches from the stations around Kodiak Island. Catches were spread equally between near and offshore areas in 1988, and catches were high north of Kodiak Island as well as in the Shumagin Island area.

Abundance

There was no consistent pattern in the regional abundance index for total pollock; density patterns shifted among regions and years (Table 4). The pollock median abundance indices for all years in regions I, II, and III were 4.54×10^9, 7.90×10^9, and 4.86×10^9, respectively. The abundance index for age-1 pollock also showed no consistent dominance for any one region over the time series (Table 5). The median age-1 abundance indices for all years were 2.58×10^8, 1.09×10^9, and 5.55×10^8 in regions I, II and III, respectively. From years when all regions were surveyed, 28% of all age-1 pollock were caught in region I, 49% were in region II, and 23% were in region III.

Data on age-0 pollock were available only from 1980 to 1988. Comparing years when all strata were sampled, 81% of the pollock caught were age-0 juveniles. The percentage of total pollock which were age-0 was 80% in region I, 81% in region II, and 81% in region III. The distribution of age-0 pollock across regions was as follows: 33% in region I, 45% in region II, and 22% in region III. The highest abundance levels were consistently in regions II and III, except in 1987 when regions I and II had the highest abundance level (Table 6). Annual comparisons of abundance between regions demonstrated weak or negative correlations, all of which were statistically insignificant (I vs. II, $r = -0.38$; II vs. III, $r = 0.13$; I vs. III, $r = 0.04$). The median age-0 abundance indices for all years were 7.49×10^8,

3.30×10^8, and 3.70×10^8 for regions I, II, and III, respectively.

In general, the correction factors developed for gear-related catchability and seasonal effects due to mortality had an effect on age-0 abundance, but not one that changed trends or conclusions (Fig. 4). The age-0 and age-1 abundance indices are shown in Figure 5 and are compared with age-2 recruitment indices. The age-2 recruitment indices are an average of the two series (one tuned to the bottom trawl survey and one tuned to the hydroacoustic midwater survey data) presented in Hollowed and Megrey (1990). From the 1980-88 series, where accurate estimates of age-0 and age-1 pollock are available, both age-0 and age-1 abundance indices are significantly correlated to the estimated number of age-2 recruits. Linear and Spearman's rank correlation coefficients show that age-0 and age-2 indices are correlated ($r = 0.69$, $n = 11$, $p < 0.01$; Spearman's rank correlation $r = 0.80$, $p < 0.005$). Correlation coefficients for age-1 and age-2 indices are significant ($r = 0.66$, $n = 7$, $p < 0.05$; Spearman's rank correlation $r = 0.75$, $p < 0.05$).

DISCUSSION

The age-0 and age-1 surveys reflected the abundance of age-2 recruits exceptionally well, especially when considering the problems with the data sources. This correlation has several important implications. First, relative recruitment levels appear to be established within the first 5 months after spawning. Second, the variability of age-0 recruits is great and represents a strong signal in the dynamics of the population. Finally, prerecruit surveys can be conducted to provide a prediction of year-class strength.

The data used in this study came from two major sources, the shrimp surveys and YOY pollock surveys. Shrimp trawl surveys from 1975 to 1983 utilized a stratified random design. Sampling stations were located primarily nearshore and gear was fished near bottom. In the pollock surveys of 1984-88, the same gear was used, but sampling was based on fish sign from the echo sounder, extended farther offshore, and included midwater tows. We have treated all data as random samples based on the following justification: 1) the shrimp trawl surveys were not directed at juvenile pollock, nor was the stratification based on pollock abundance; 2) there was no relation between echo sign and catches of pollock in the YOY surveys; and 3) there was no clear onshore/offshore gradient of pollock abundance. There were differences between years in the extent and timing of the surveys, and in the bottom/midwater distribution of tows; these are factors which could compromise the quantitative nature of the data. For example, a difference of a month between surveys can result in changes in abundance estimates not only due to mortality, but due to growth-related catchability, and possibly onshore/offshore or midwater/bottom ontogenetic distributional shifts. Since the age-0 index reflected age-2 recruitment in spite of these problems, the recruitment signal appears to be strong.

Relative distributions of age-0 juveniles were consistent with larval distributions from preceding months; however, relative abundance in the different regions changed from year to year with no one region consistently having the most fish. For example, in 1985 most age-0 pollock were located in region II, with high numbers in region III around Kodiak Island. This distribution is consistent with the 1985 larval distribution (Incze et al. 1989). By contrast, in 1987 most juveniles were in region II, but high numbers of age-0 fish were located in region I southwest of the Shumagin Islands. This distribution is again consistent with larval distributions from the 1987 June-July surveys (Hinckley et al. 1991). The indication that larval and later juvenile distributions are similar suggests that juvenile surveys can be planned using prior information on larval distributions. In terms of designing a prerecruit survey, these results indicate that no one region adequately represents the population, but that a wide geographic area must be surveyed. An attempt to index the population by surveying a small area will not capture the true dynamics of the population due to interannual shifts in distribution. For example, we formulated an age-0 abundance index in Pavlov Bay, which was intensively surveyed for many years. This index was not correlated with the overall age-0 abundance index or with the number of age-2 recruits ($r = 0.23$ and $r = -0.35$, respectively).

The juvenile size composition data were limited in terms of elucidating factors affecting growth of walleye pollock. There appears to be a strong compensatory relationship between stock biomass and recruitment of pollock in the western Gulf of Alaska (Megrey 1989). Factors which might generate such a relationship include temperature and density-dependent growth in the juvenile phase. The model tested in this study showed no significant density- or temperature-dependent growth in the time series examined. As the nature of the data may be limiting for this analysis, the results of the model runs do not disprove the importance of temperature and density in the population dynamics of walleye pollock.

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LIST OF TABLES

Table 1.--Cruise and station information from shrimp and juvenile fish trawl surveys used to estimate juvenile walleye pollock abundance.

Year	Vessel	Hauls	Region	Dates
1975	Oregon	103	I	9/7-10/19
	Oregon	56	II	10/09-10/31
		159		
1976	Oregon	98	I	9/8-10/7
	Oregon	58	II	10/7-10/28
		156		
1977	Oregon	106	I	8/21-9/16
	Oregon	40	II	9/14-9/23
		146		
1978	Oregon	106	I	8/25-9/23
	Oregon	37	II	9/21-10/5
		143		
1980	Oregon, Commander	119	I	8/12-9/15
	Oregon, Commander	78	II	9/01-9/16
	Resolution,	84	III	8/23-9/15
	Royal Baron			
		281		
1981	Chapman, Alaska	81	I	9/04-9/14
	Resolution, Alaska	53	II	9/02-10/3
	Resolution, Alaska	147	III	9/03-9/30
		281		
1982	Royal Baron	31	II	9/11-9/22
	Royal Baron	108	III	8/24-9/23
		139		
1984	Chapman	46	III	9/04-9/12
1985	Alaska	7	I	9/02-9/03
	Alaska	36	II	8/29-9/06
	Alaska	59	III	8/23-9/09
		102		
1986	John N. Cobb	11	I	9/03-9/07
	John N. Cobb	26	II	9/09-9/19
	John N. Cobb	60	III	9/17-10/8
		97		
1987	Alaska	44	I	8/13-8/26
	Alaska	21	II	8/26-9/12
	Alaska	34	III	8/29-9/19
		99		
1988	Alaska	32	I	8/18-8/29
	Alaska	16	II	8/30-9/04
	Alaska	20	III	9/05-9/10
		68		

Table 2.--Vessel length and horsepower.

Vessel Name	Length (m)	Horsepower
Alaska	30.4	600
Chapman	39.0	1165
Commander	23.2	600
John N. Cobb	28.5	325
Oregon	30.4	600
Resolution	27.4	565
Royal Baron	30.5	750

Table 3.--Summary of multivariate analysis of variance with gear effect as the main factor for sample years 1984-88.

	Gear	Effect with gear	Date (covariate)
Wilk's lambda	0.640	0.398	0.816
Degrees of freedom	9,140	45,629	9,140
F statistic	8.739	3.202	3.519
Probability	0.000	0.000	0.001

Table 4.--Gear and mortality corrected and uncorrected total abundance indices for walleye pollock. The median for all years has been substituted for missing values (asterisks).

Survey Year	Region I		Region II		Region III		Sum I-III	
	Uncorr.	Gear+mort corr.	Uncorr.	Gear+mort corr.	Uncorr.	Gear+mort corr.	Uncorr.	Gear+mort corr.
1975	2.45E+09	4.43E+09	6.19E+09	13.26E+09	4.57E+09	4.86E+09 *	13.21E+09	22.55E+09
1976	9.31E+09	21.54E+09	8.21E+09	17.67E+09	4.57E+09	4.86E+09 *	13.88E+09	44.07E+09
1977	12.45E+09	25.14E+09	6.42E+09	10.51E+09	4.57E+09	4.86E+09 *	17.07E+09	40.51E+09
1978	3.09E+09	5.36E+09	7.99E+09	14.43E+09	4.57E+09	4.86E+09 *	15.65E+09	24.65E+09
1980	4.73E+09	4.75E+09	7.31E+09	7.89E+09	2.70E+09	4.17E+09	14.74E+09	16.51E+09
1981	3.41E+09	4.34E+09	5.42E+09	7.06E+09	7.16E+09	9.40E+09	15.99E+09	20.80E+09
1982	3.97E+09 *	4.54E+09 *	2.44E+09	5.20E+09	2.43E+09	4.02E+09	8.84E+09	13.76E+09
1984	-	-	-	-	6.36E+09	5.92E+09	-	-
1985	5.80E+08	5.50E+08	16.98E+09	15.04E+09	6.28E+09	5.55E+09	23.86E+09	21.14E+09
1986	9.67E+08	8.97E+08	7.95E+09	7.90E+09	2.85E+09	2.78E+09	11.77E+09	11.58E+09
1987	4.52E+09	3.49E+09	4.77E+09	4.25E+09	1.06E+09	1.01E+09	10.35E+09	8.75E+09
1988	5.69E+09	4.65E+09	3.30E+09	2.87E+09	7.24E+09	6.75E+09	16.23E+09	14.27E+09
Sum:	51.22E+09	79.69E+09	62.37E+09	106.08E+09	48.00E+09	53.08E+09	161.59E+09	238.85E+09
Median:	3.97E+09	4.54E+09	6.42E+09	7.90E+09	4.57E+09	4.86E+09		

Table 5.--Age-1 abundance indices for walleye pollock. The median for all years has been substituted for missing values (asterisks).

Survey Year	Region I	Region II	Region III	Sum I-III
1980	4.08E+09	5.97E+09	6.88E+08	10.74E+09
1981	1.53E+09	1.69E+09	5.23E+08	3.74E+09
1982	2.58E+08 *	1.06E+09	1.09E+09	2.41E+09
1984	- *	- *	1.63E+07	- *
1985	5.43E+07	6.13E+08	5.86E+08	1.25E+09
1986	8.08E+06	1.79E+09	2.04E+09	3.84E+09
1987	1.41E+06	7.79E+07	2.13E+08	2.92E+08
1988	4.62E+08	3.87E+06	6.52E+06	4.72E+08
Sum:	6.39E+09	1.12E+10	5.16E+09	22.75E+09
Median:	2.58E+08 *	1.06E+09 *	5.55E+08	

Table 6.--Gear and mortality corrected and uncorrected age-0 abundance indices for walleye pollock. The median for all years has been substituted for missing values (asterisks).

Survey Year	Region I		Region II		Region III		Sum I-III	
	Uncorr.	Gear+mort corr.	Uncorr.	Gear+mort corr.	Uncorr.	Gear+mort corr.	Uncorr.	Gear+mort corr.
1975	-	3.29E+09	-	11.81E+09	-	4.06E+09 *	-	19.16E+09
1976	-	19.92E+09	-	16.11E+09	-	4.06E+09 *	-	40.09E+09
1977	-	22.85E+09	-	9.05E+09	-	4.06E+09 *	-	35.96E+09
1978	-	4.08E+09	-	12.88E+09	-	4.06E+09 *	-	21.02E+09
1980	2.94E+06	2.02E+07	1.21E+09	1.79E+09	1.80E+09	3.27E+09	3.01E+09	5.08E+09
1981	7.48E+08	1.68E+09	3.10E+09	4.74E+09	6.35E+09	8.59E+09	10.20E+09	15.01E+09
1982	7.49E+08 *	3.38E+09 *	1.05E+09	3.82E+09	8.58E+08	2.46E+09	2.66E+09	9.66E+09
1984	-	-	-	-	6.31E+09	5.87E+09	-	-
1985	2.47E+08	2.17E+08	1.63E+10	14.34E+09	5.59E+09	4.86E+09	2.21E+10	19.42E+09
1986	7.49E+08	6.75E+08	4.90E+09	4.85E+09	5.57E+08	6.30E+08	6.21E+09	6.16E+09
1987	4.49E+09	3.46E+09	4.68E+09	4.16E+09	7.12E+08	6.60E+08	9.88E+09	8.28E+09
1988	5.20E+09	4.16E+09	3.30E+09	2.87E+09	6.93E+09	6.44E+09	15.43E+09	13.47E+09
Sum:	12.19E+09	63.73E+09	34.54E+09	86.42E+09	22.80E+09	43.15E+09	6.95E+10	193.31E+09
Median:	7.49E+08	3.38E+09	3.30E+09	4.85E+09	3.70E+09	4.06E+09		

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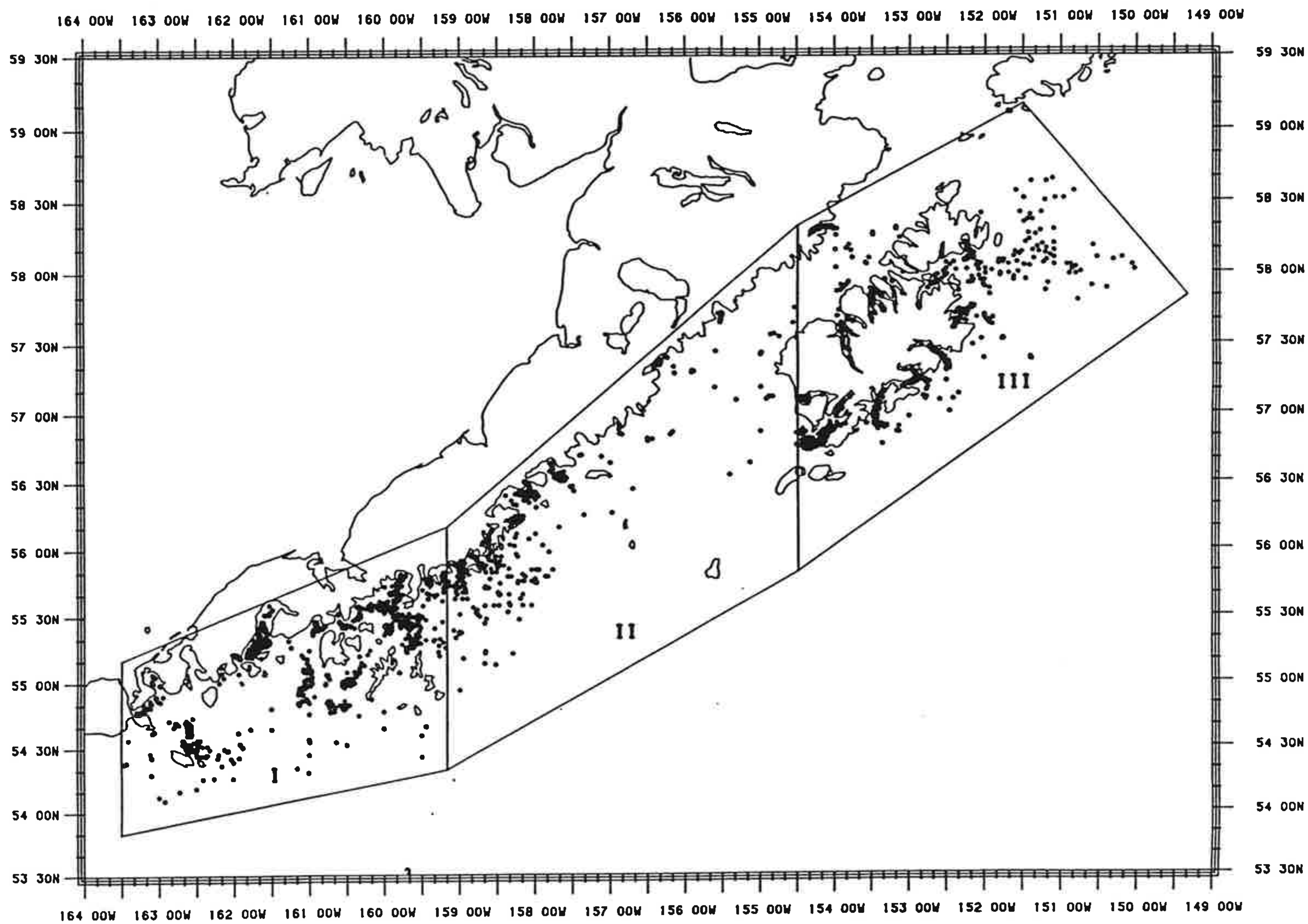

Figure 1.--Locations of sampling stations where walleye pollock were sampled, 1975-88, and regions used to calculate abundance indices.

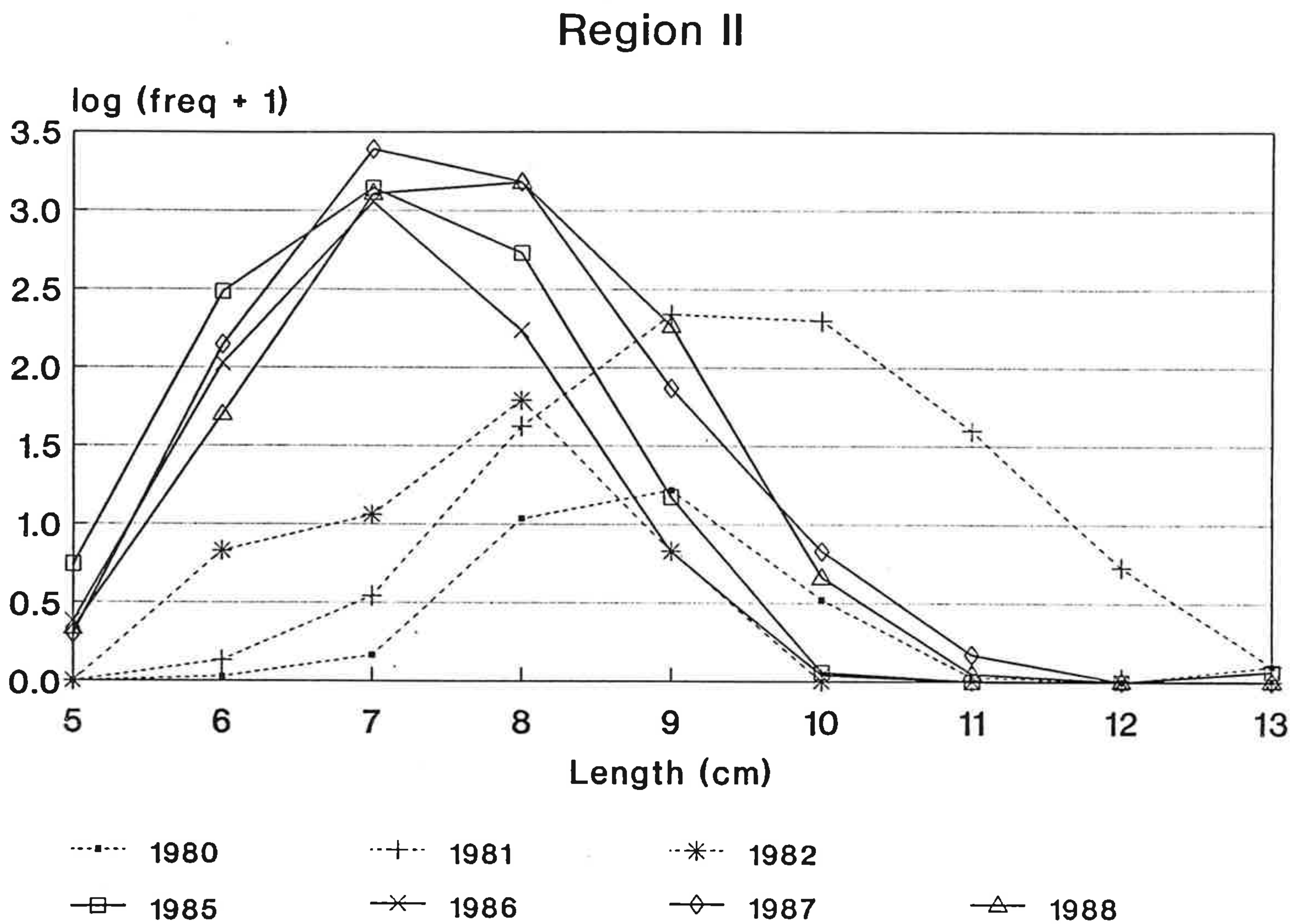

Figure 2.--Region II length distributions (input for model to estimate gear effect).

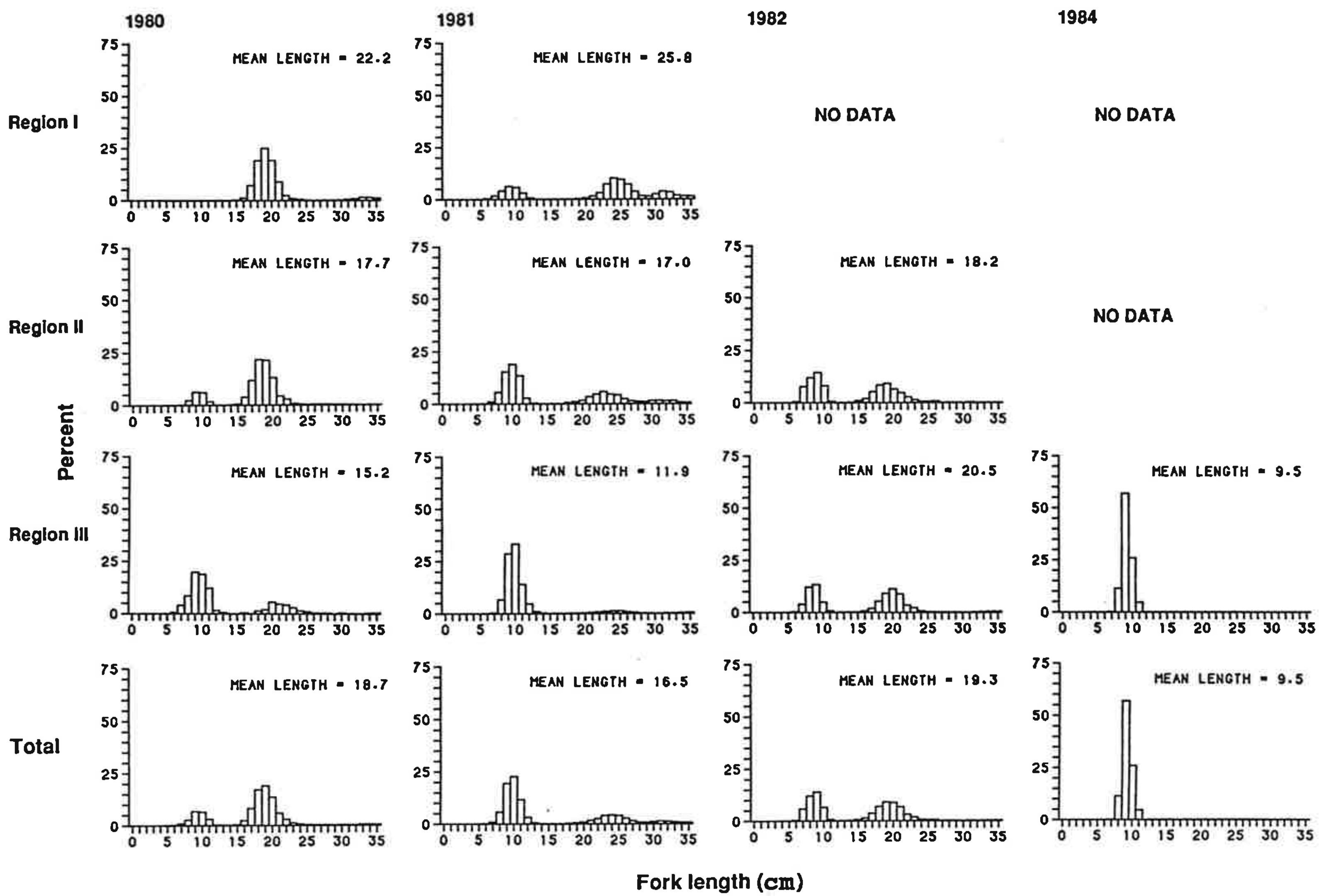

Figure 3a.--Length composition of walleye pollock by year and region.

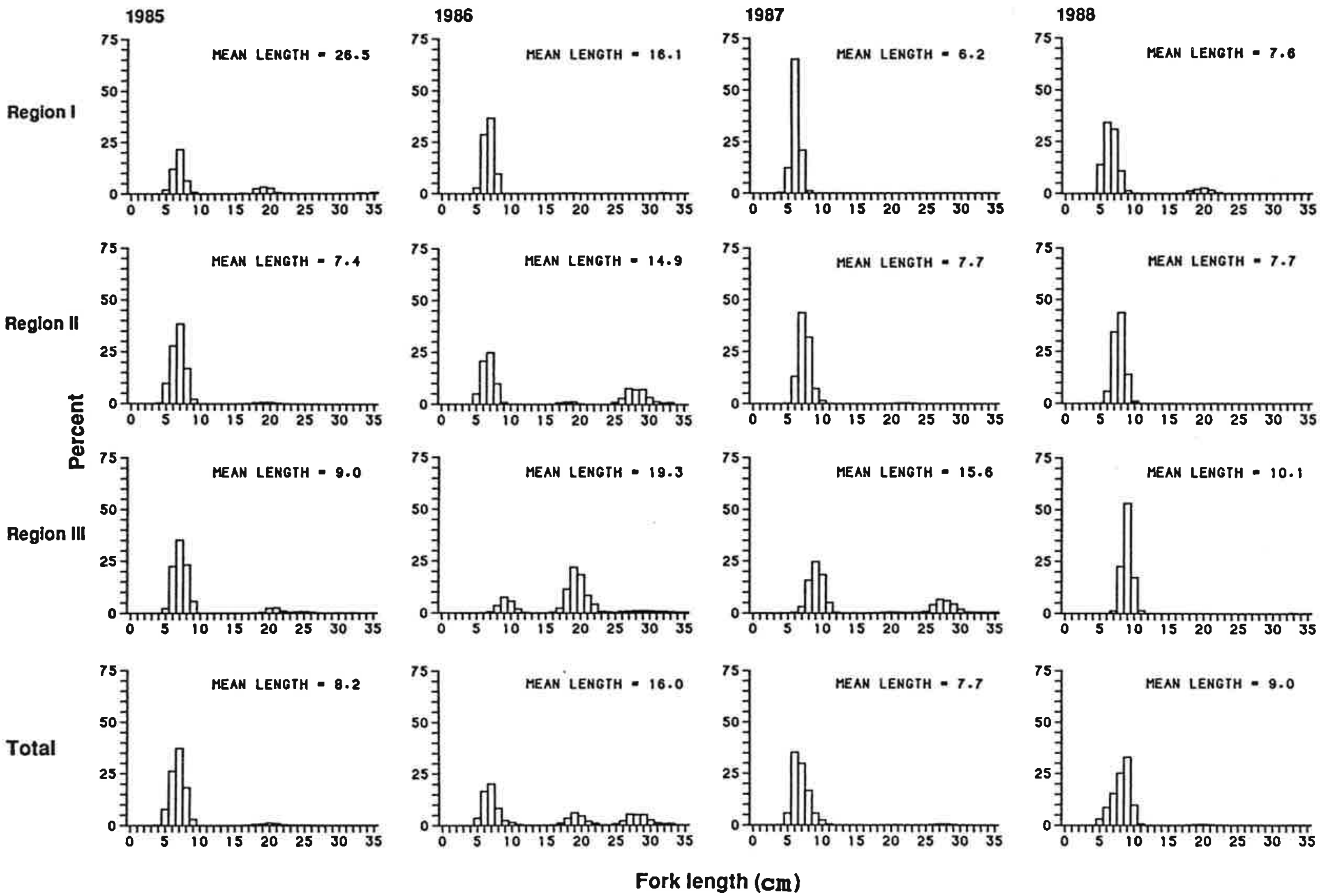

Figure 3b.--Length composition of walleye pollock by year and region.

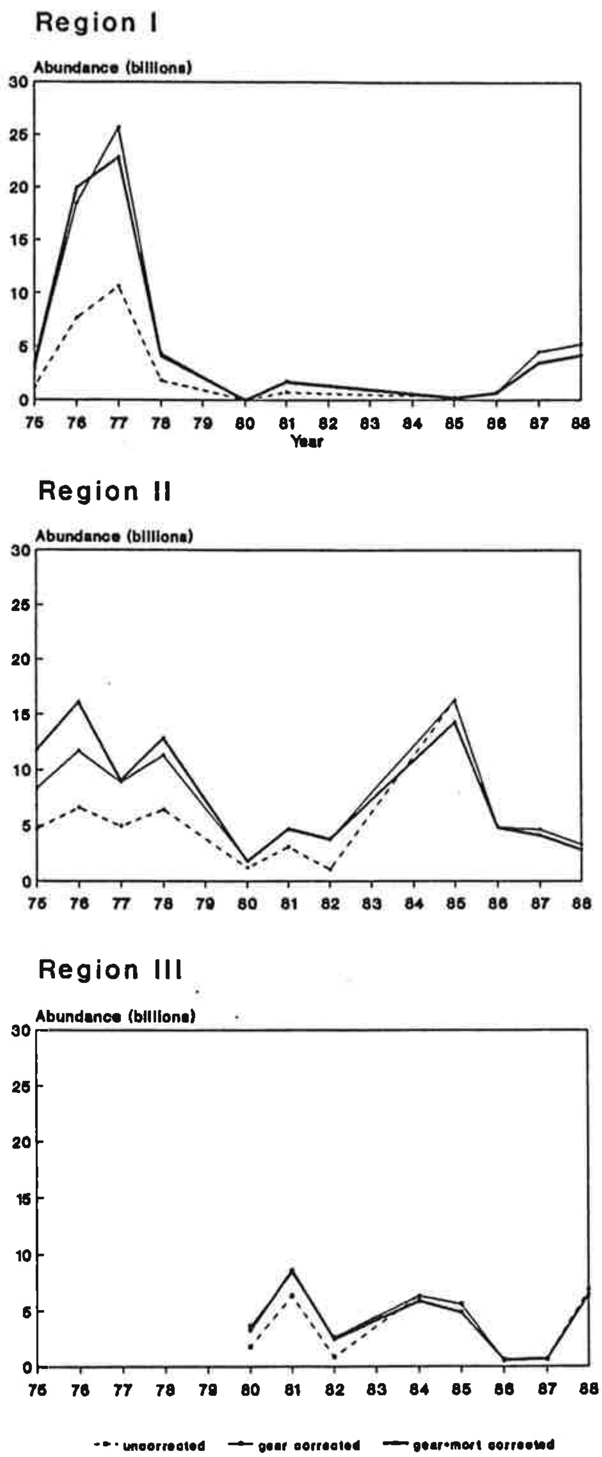

Figure 4.--Comparison of gear and mortality corrected and uncorrected abundance indices by region for age-0 walleye pollock.

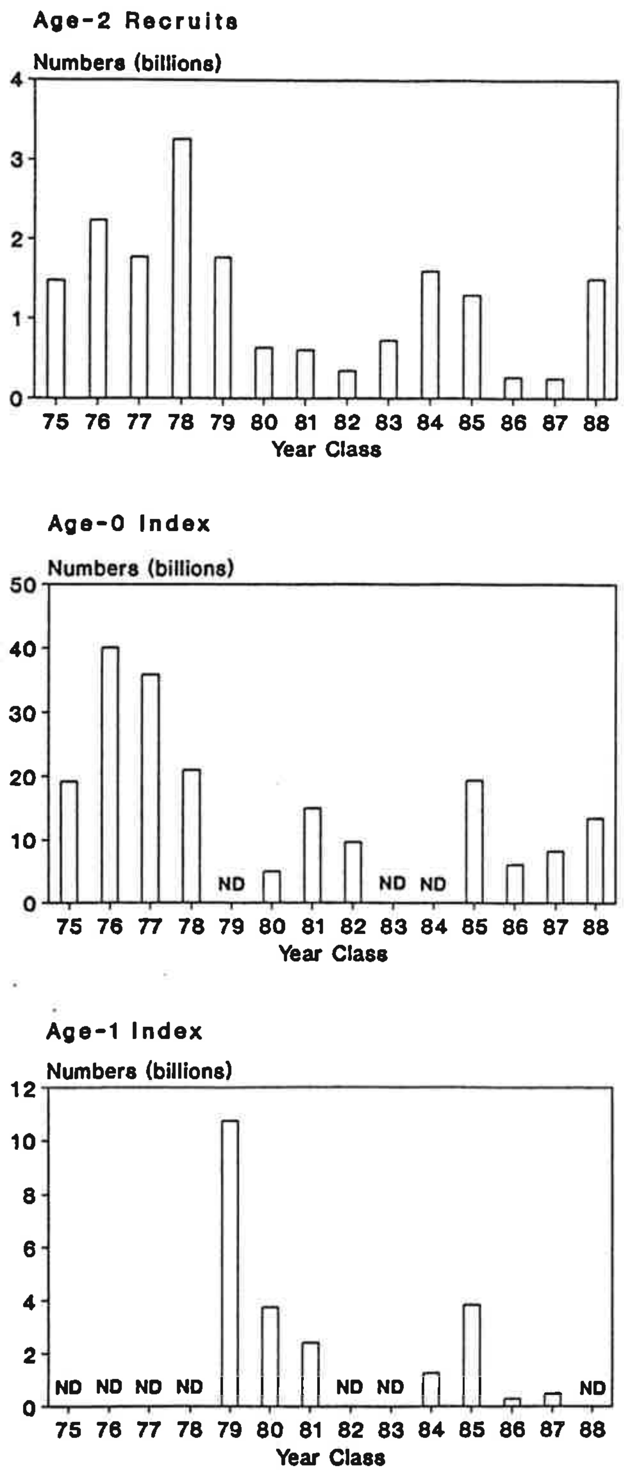

Figure 5.--Comparison of age-2, age-0, and age-1 abundance indices of walleye pollock.

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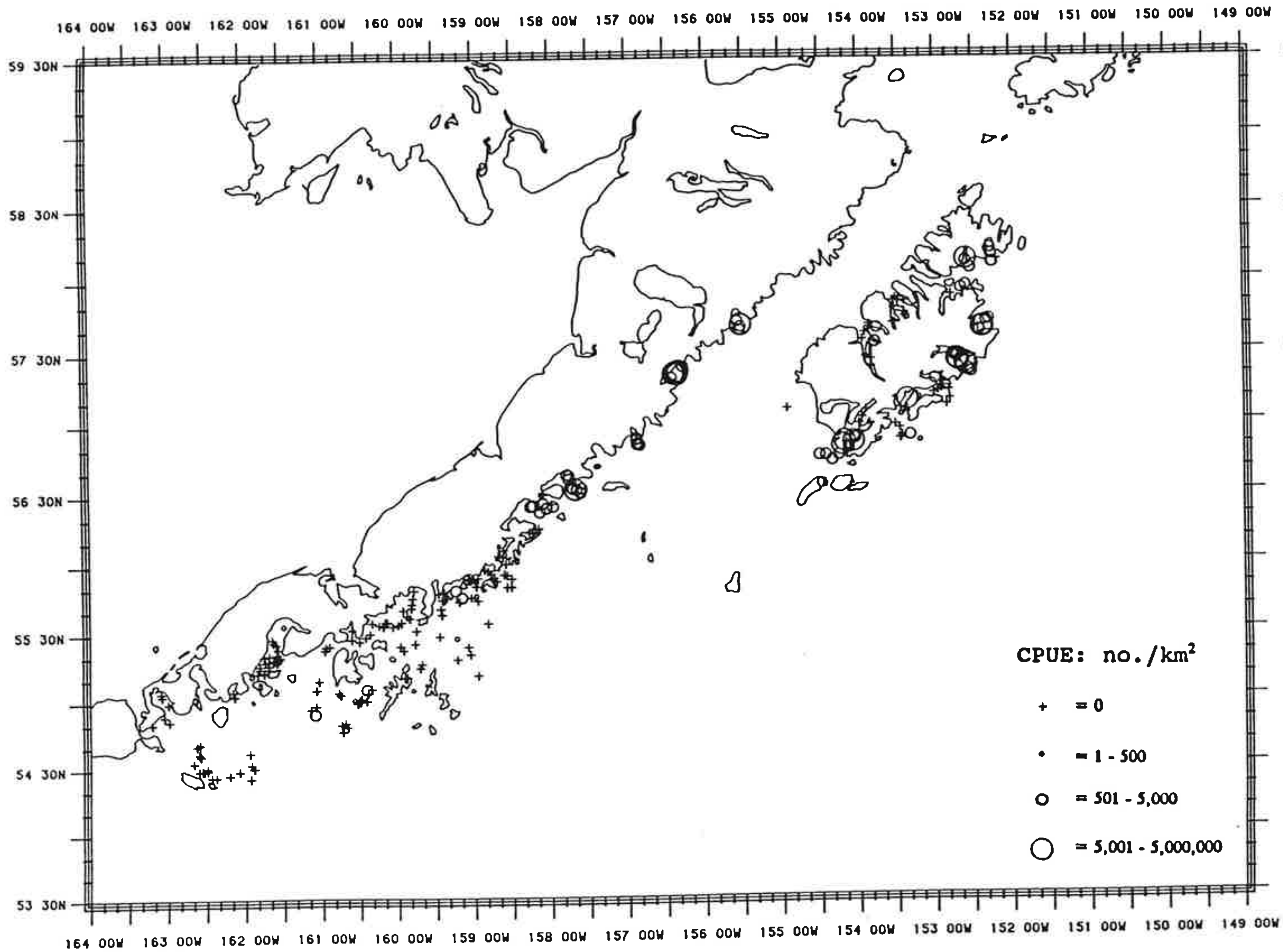
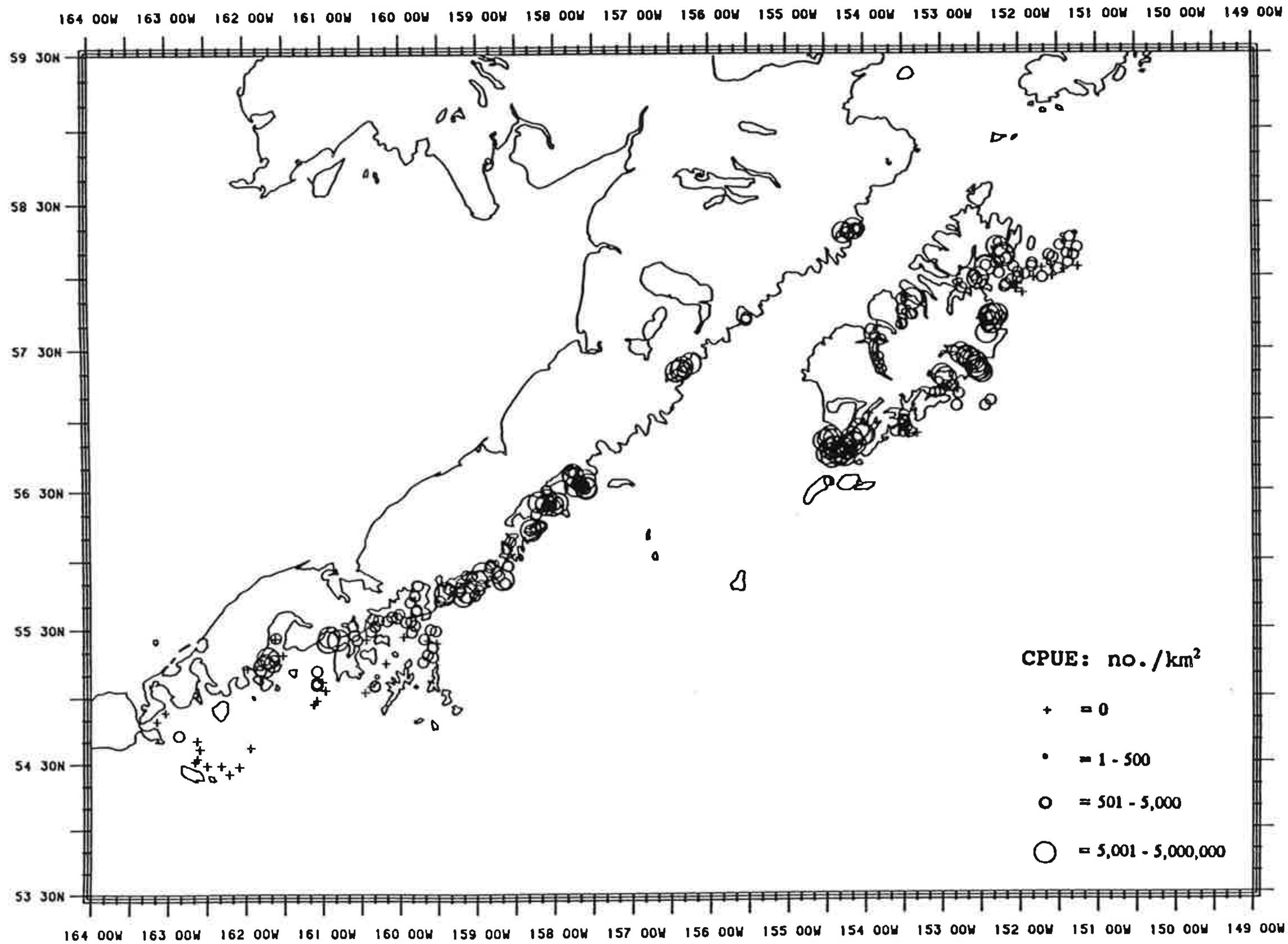
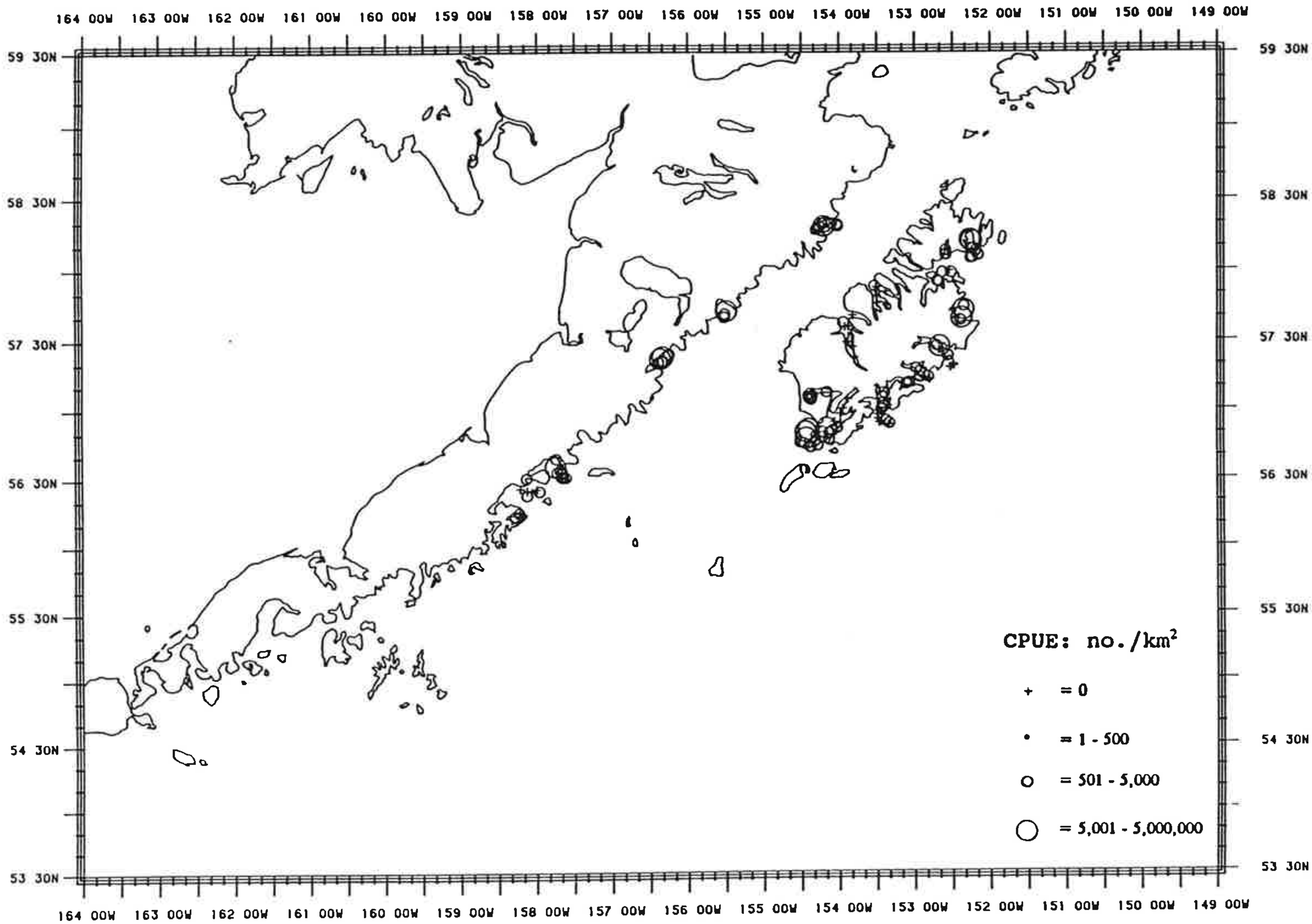


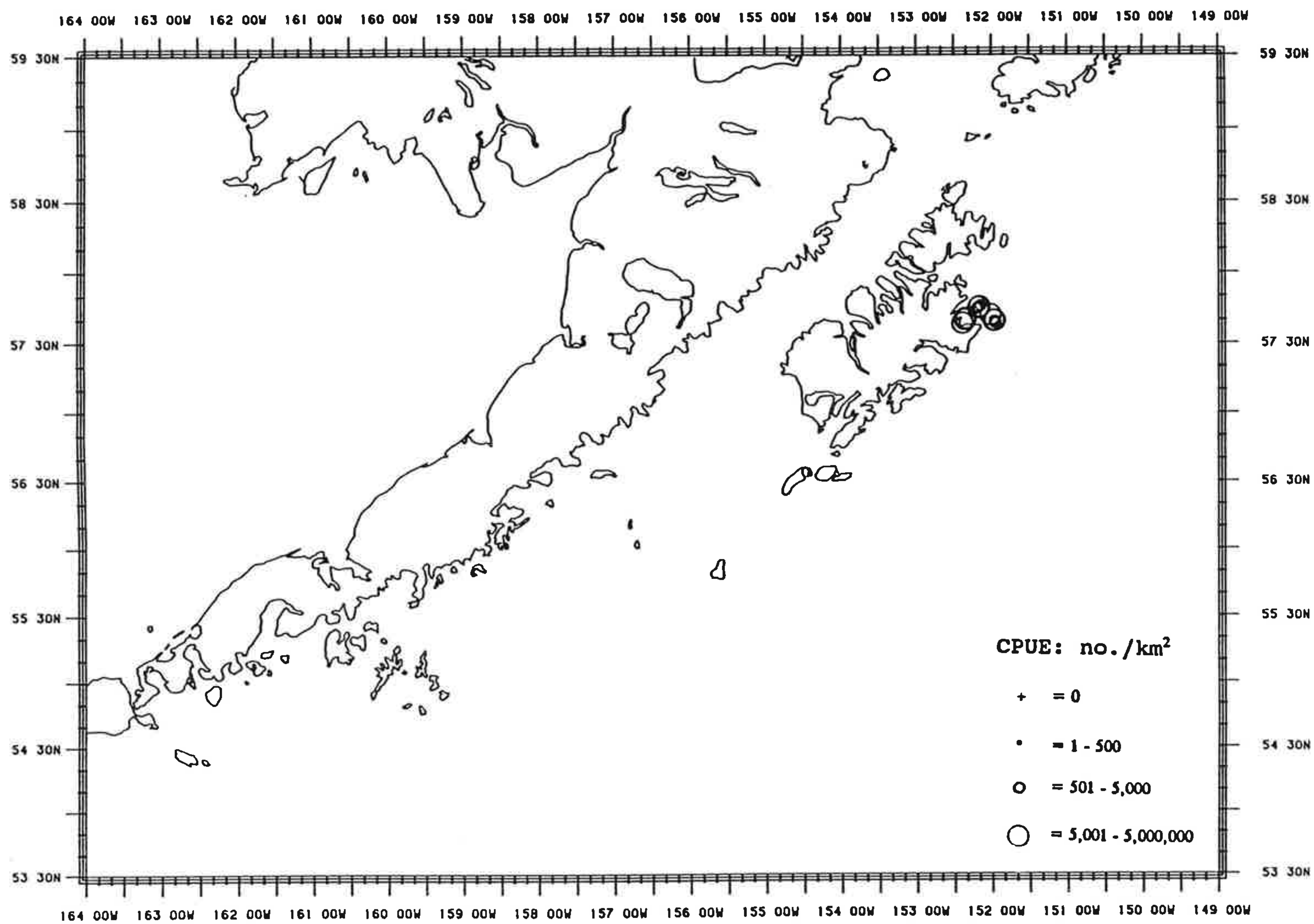
Appendix Figure 1a--Distribution of age-0 walleye pollock from shrimp trawls, 1980.



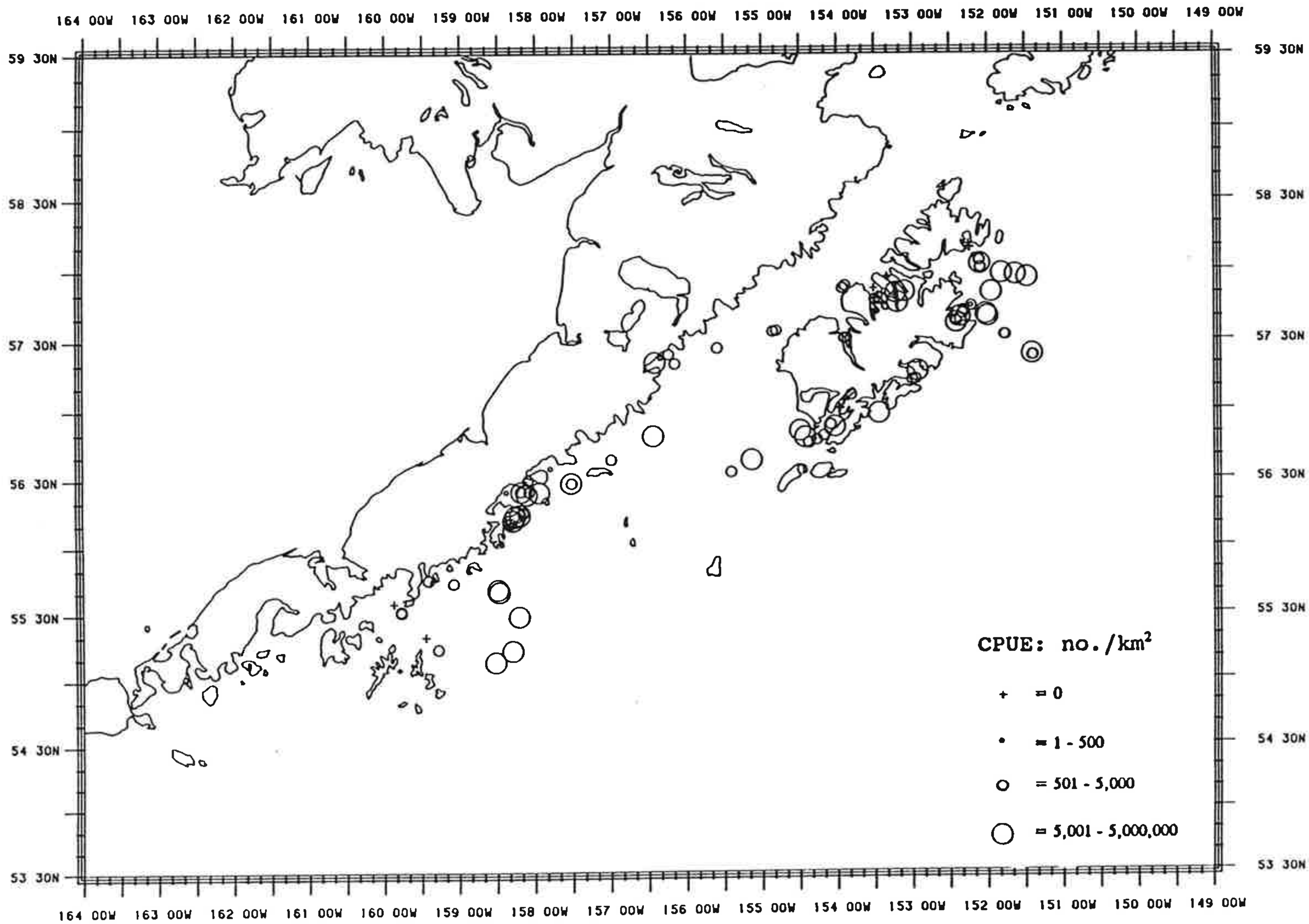
Appendix Figure 1b--Distribution of age-0 walleye pollock from shrimp trawls, 1981.



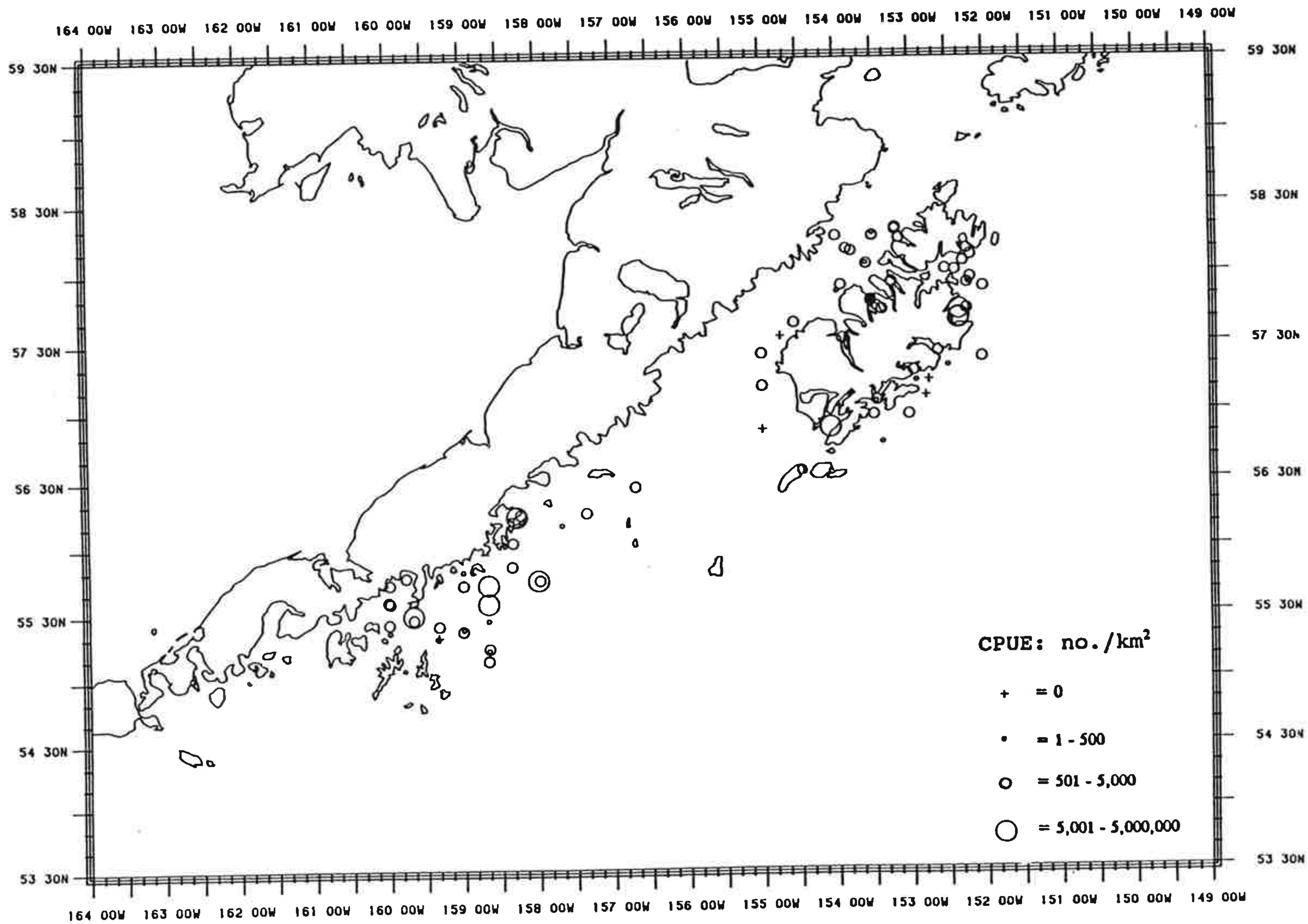
Appendix Figure 1c--Distribution of age-0 walleye pollock from shrimp trawls, 1982.



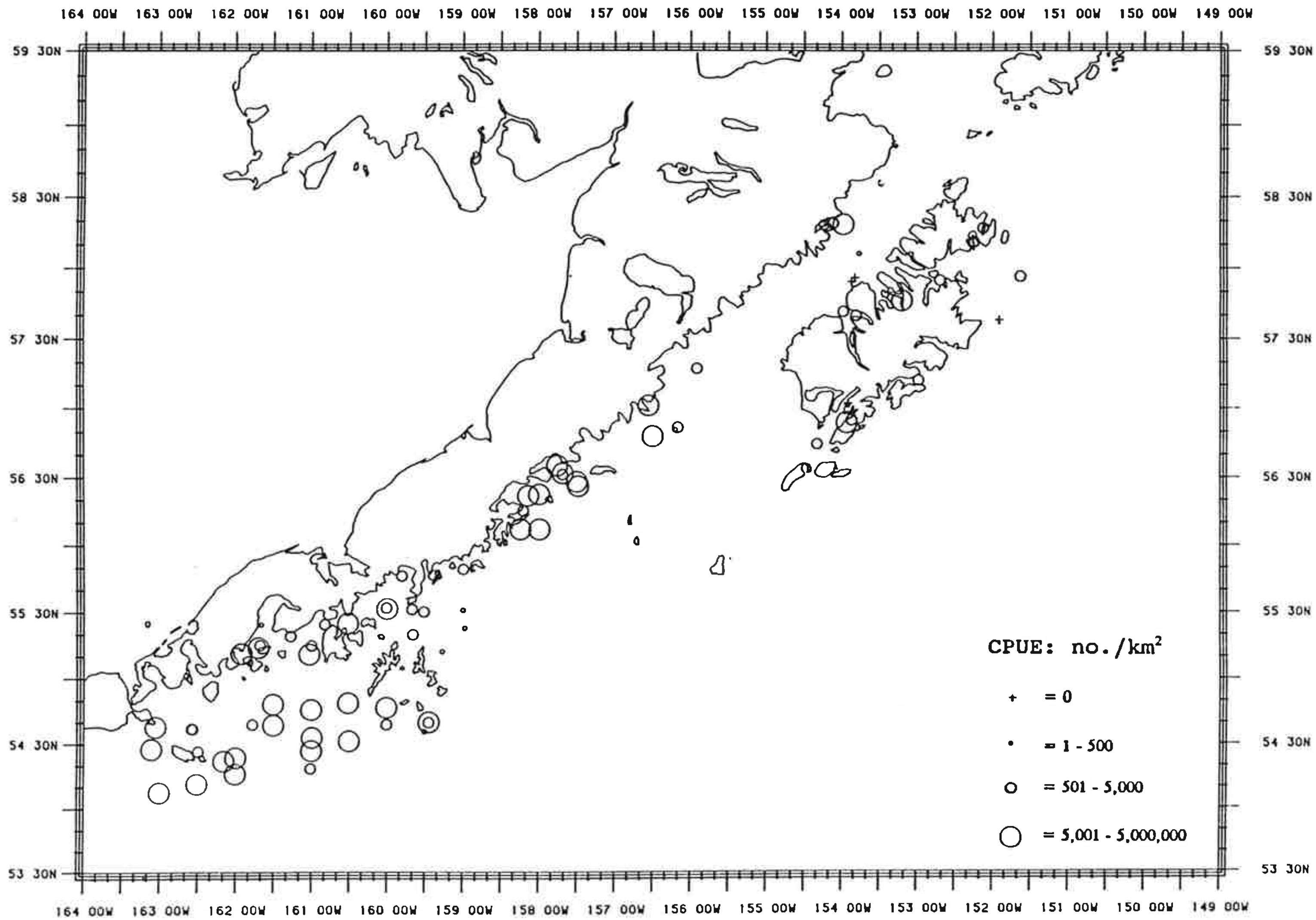
Appendix Figure 1d--Distribution of age-0 walleye pollock from shrimp trawls, 1984.



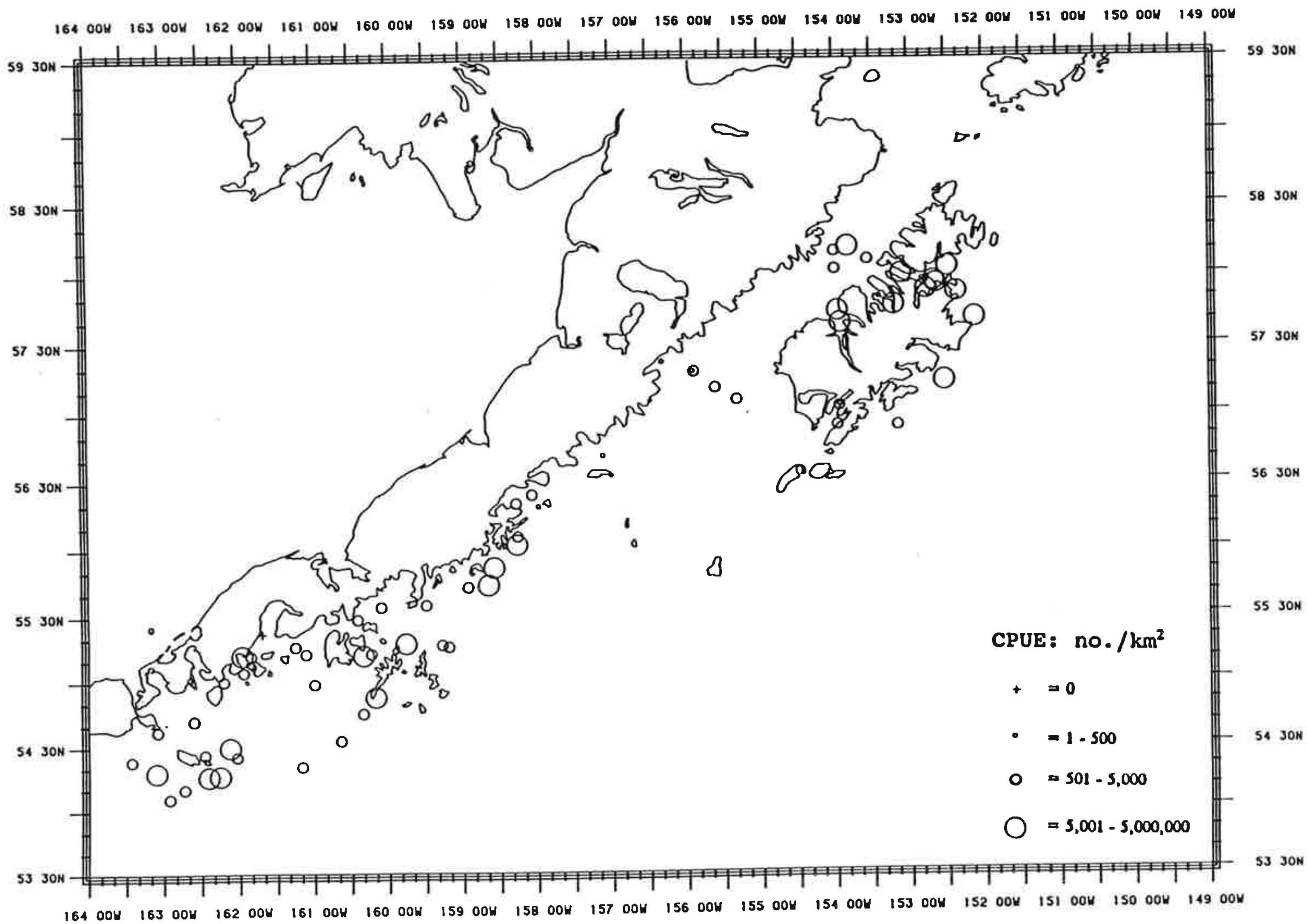
Appendix Figure 1e--Distribution of age-0 walleye pollock from shrimp trawls, 1985.



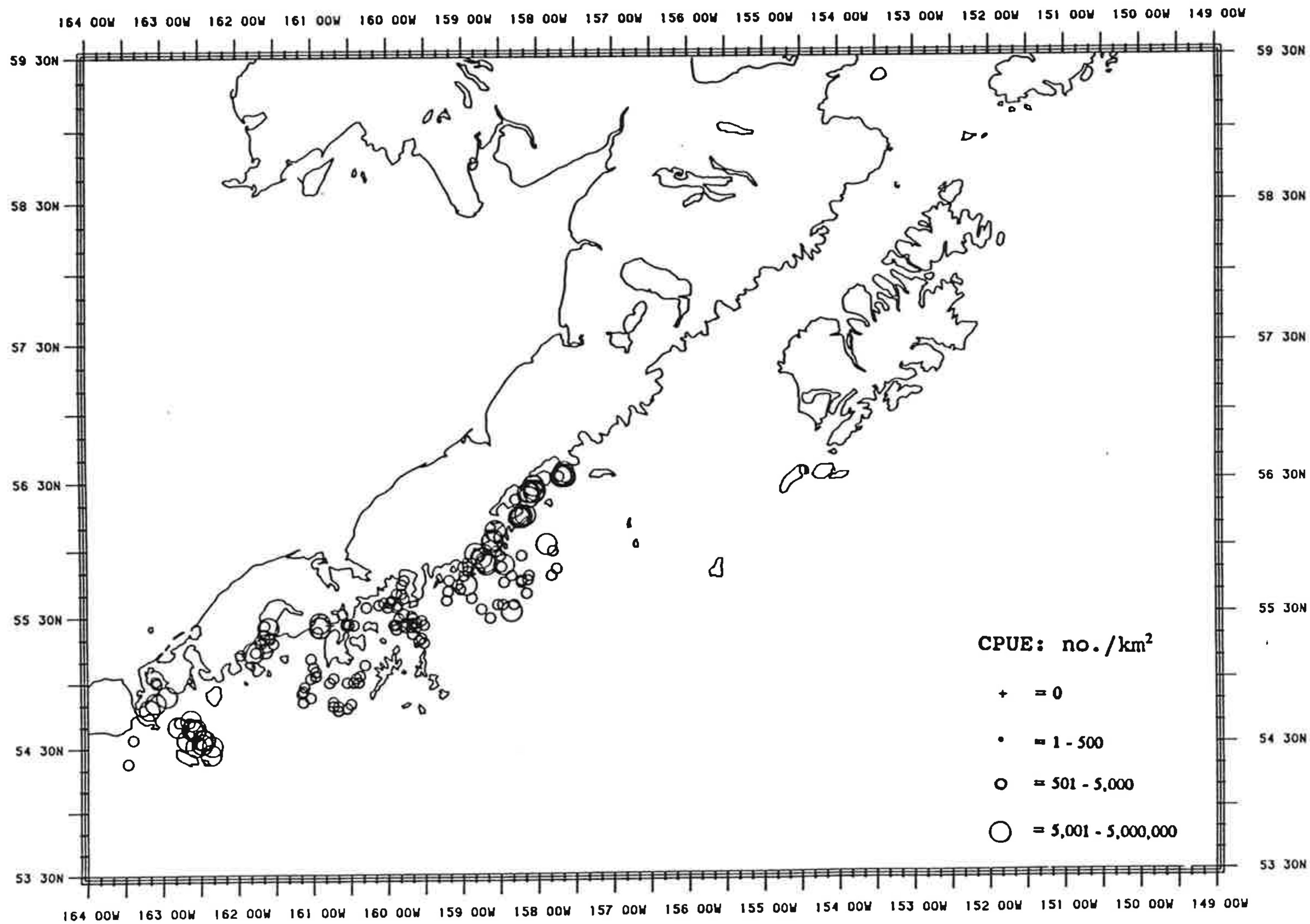
Appendix Figure 1f--Distribution of age-0 walleye pollock from shrimp trawls, 1986.



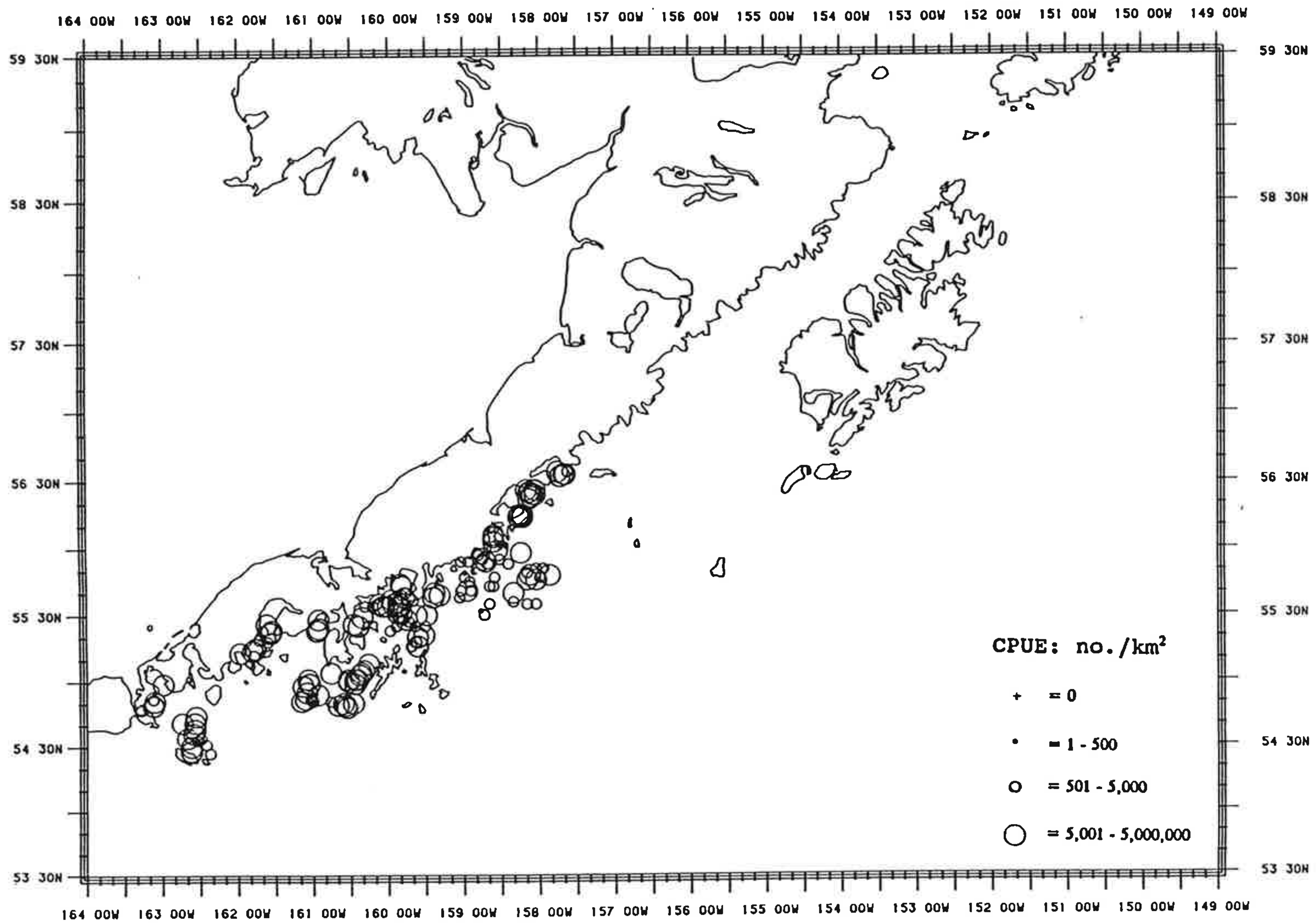
Appendix Figure 1g--Distribution of age-0 walleye pollock from shrimp trawls, 1987.



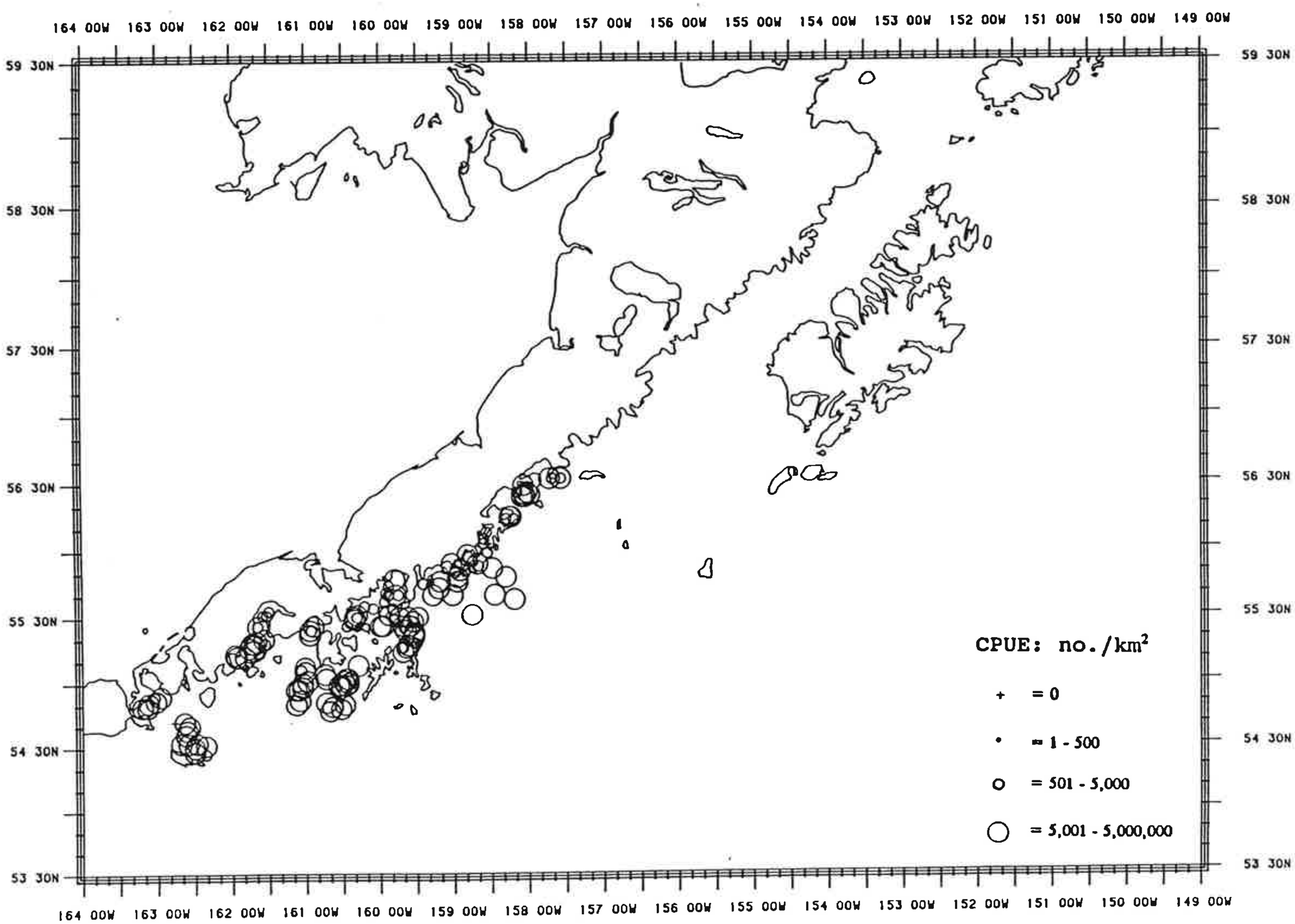
Appendix Figure 1h--Distribution of age-0 walleye pollock from shrimp trawls, 1988.



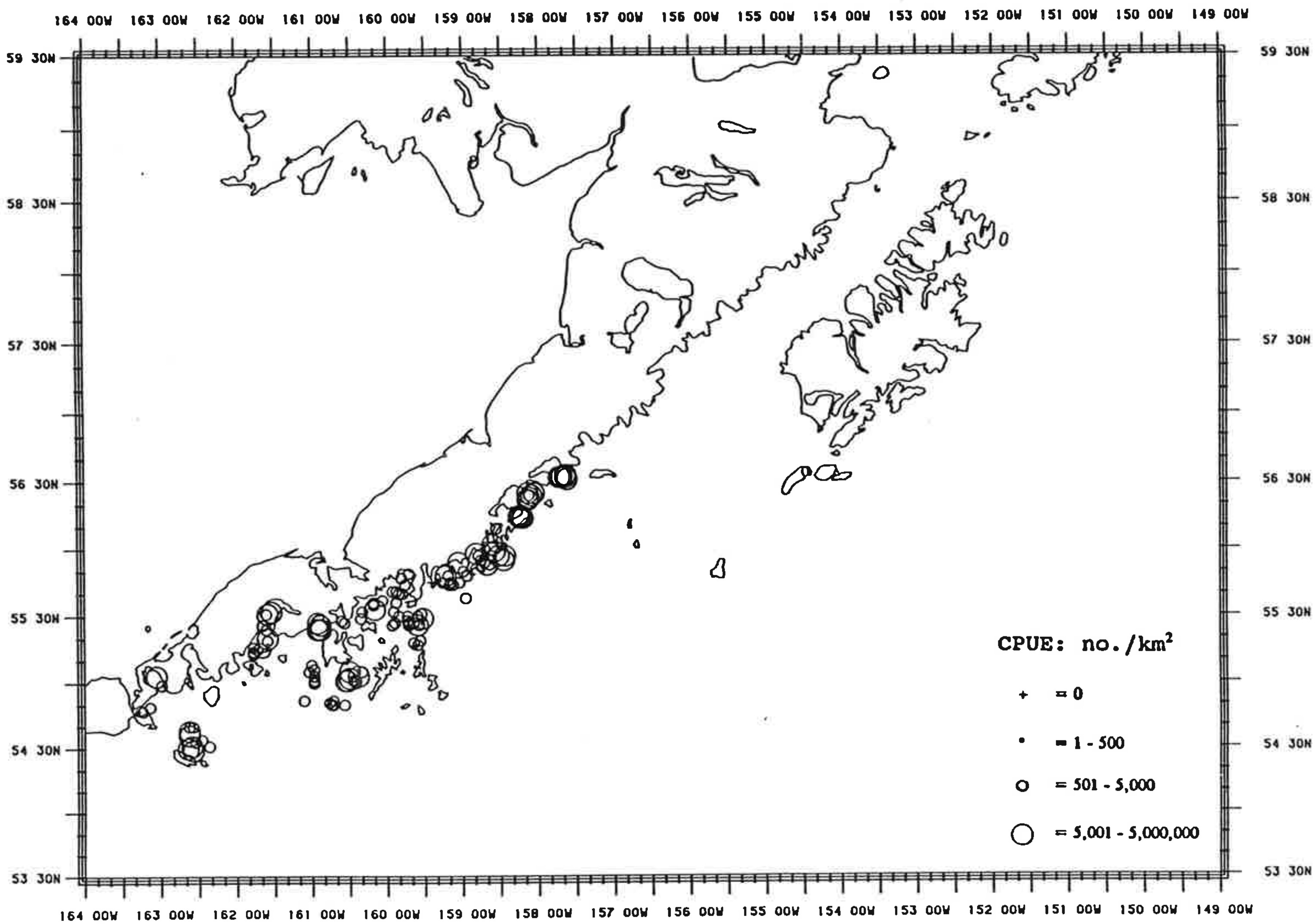
Appendix Figure 2a--Distribution of total walleye pollock from shrimp trawls, 1975.



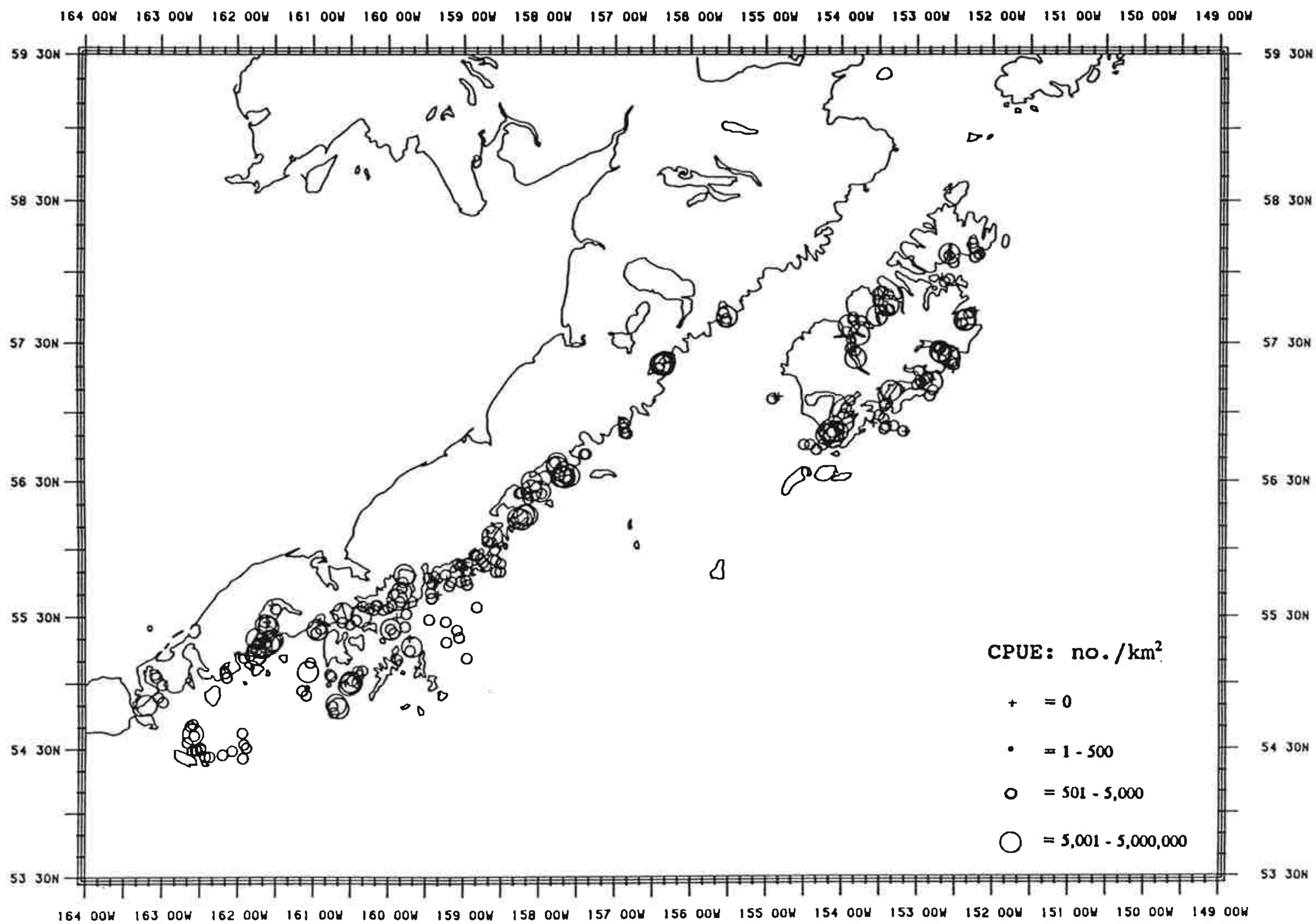
Appendix Figure 2b--Distribution of total walleye pollock from shrimp trawls, 1976.



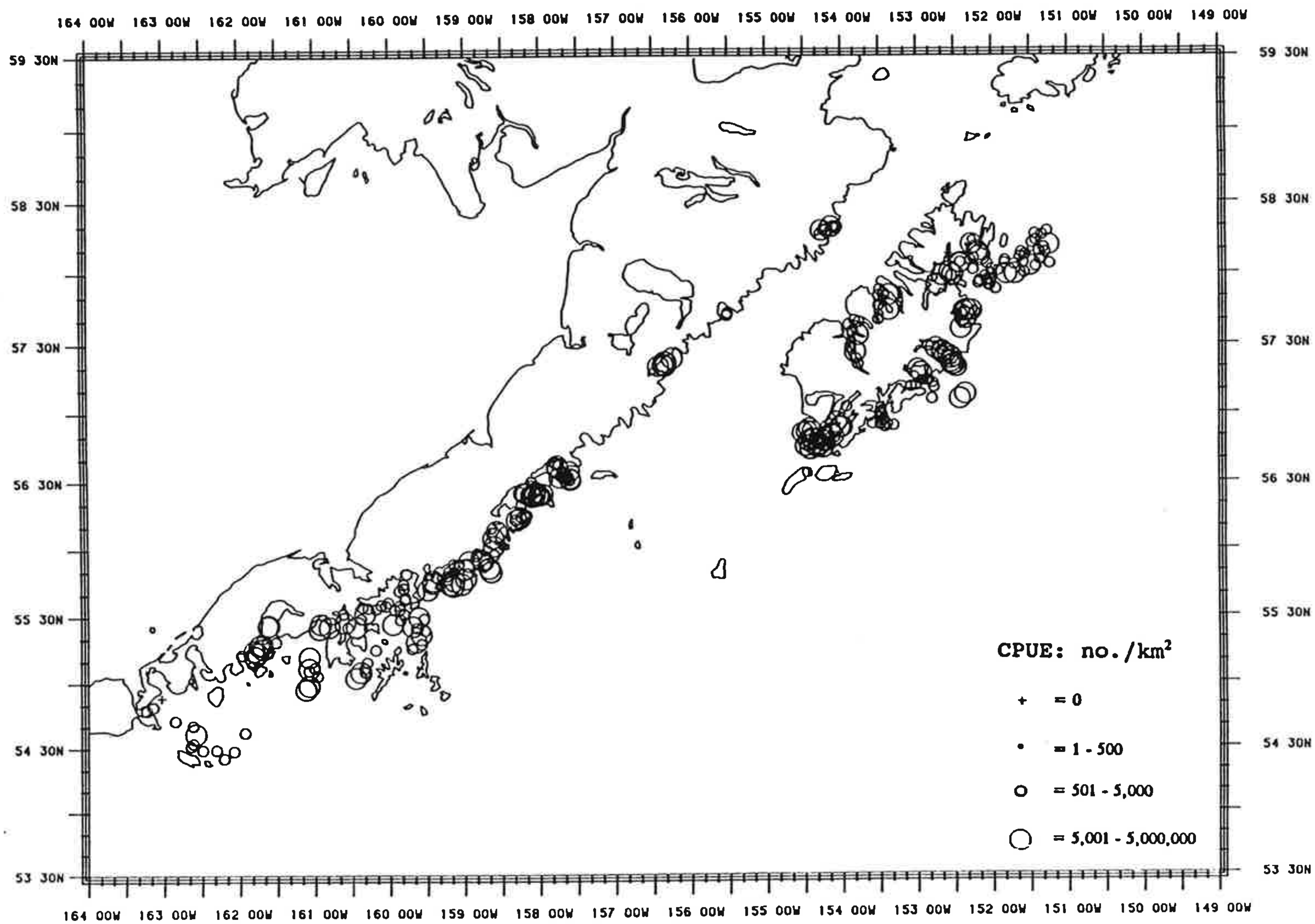
Appendix Figure 2c--Distribution of total walleye pollock from shrimp trawls, 1977.



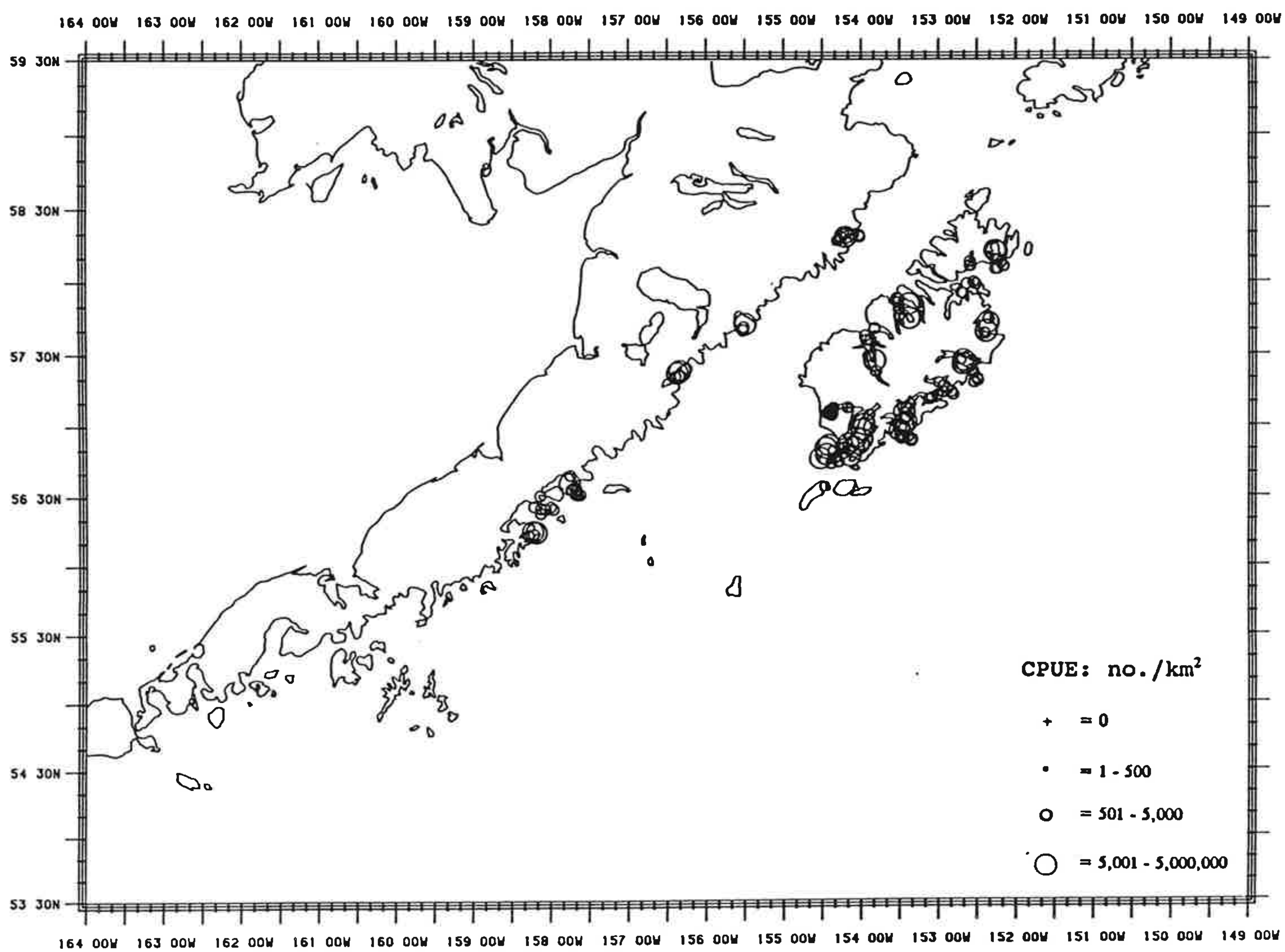
Appendix Figure 2d--Distribution of total walleye pollock from shrimp trawls, 1978.



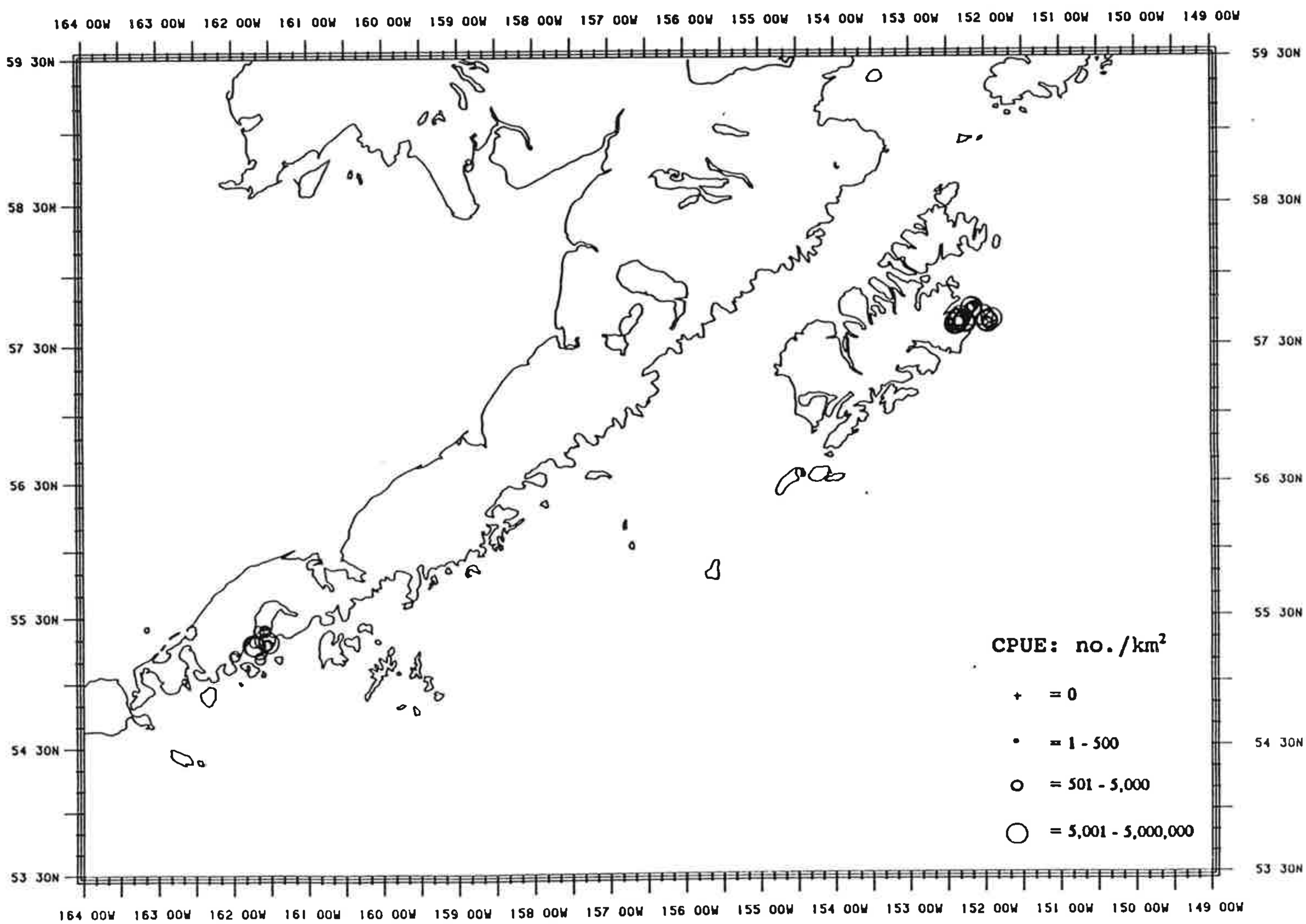
Appendix Figure 2e--Distribution of total walleye pollock from shrimp trawls, 1980.



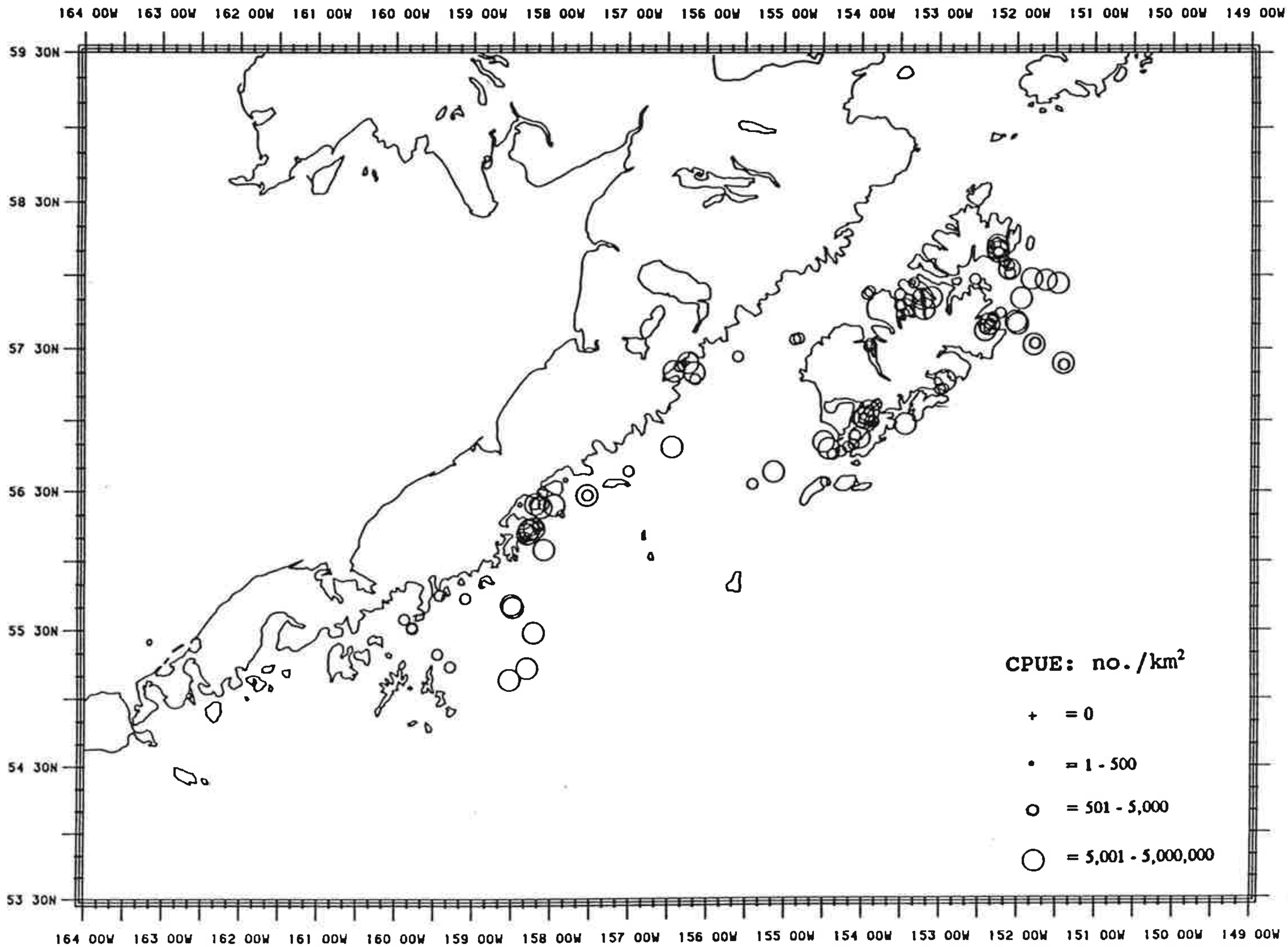
Appendix Figure 2f--Distribution of total walleye pollock from shrimp trawls, 1981.



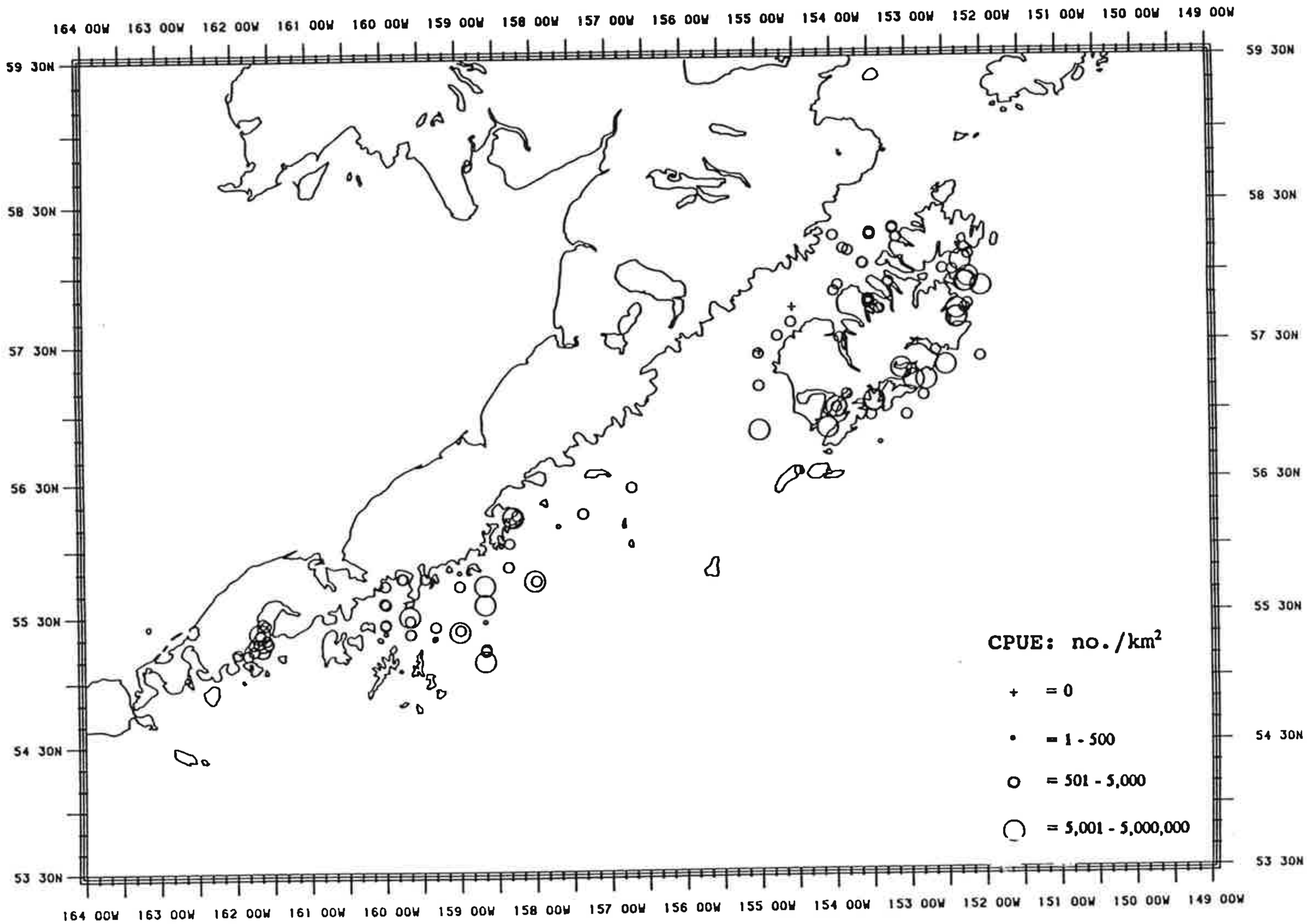
Appendix Figure 2g--Distribution of total walleye pollock from shrimp trawls, 1982.



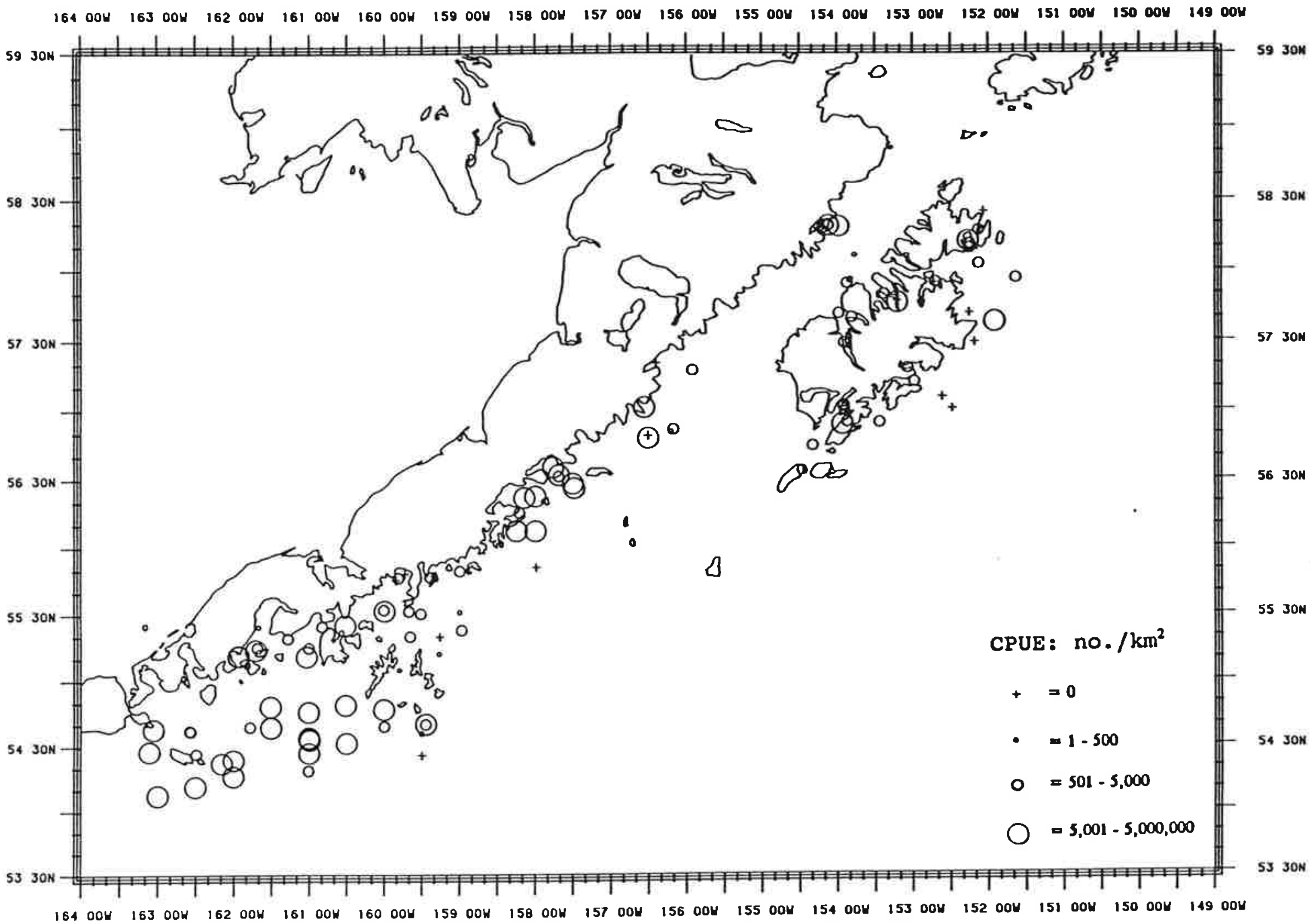
Appendix Figure 2h--Distribution of total walleye pollock from shrimp trawls, 1984.



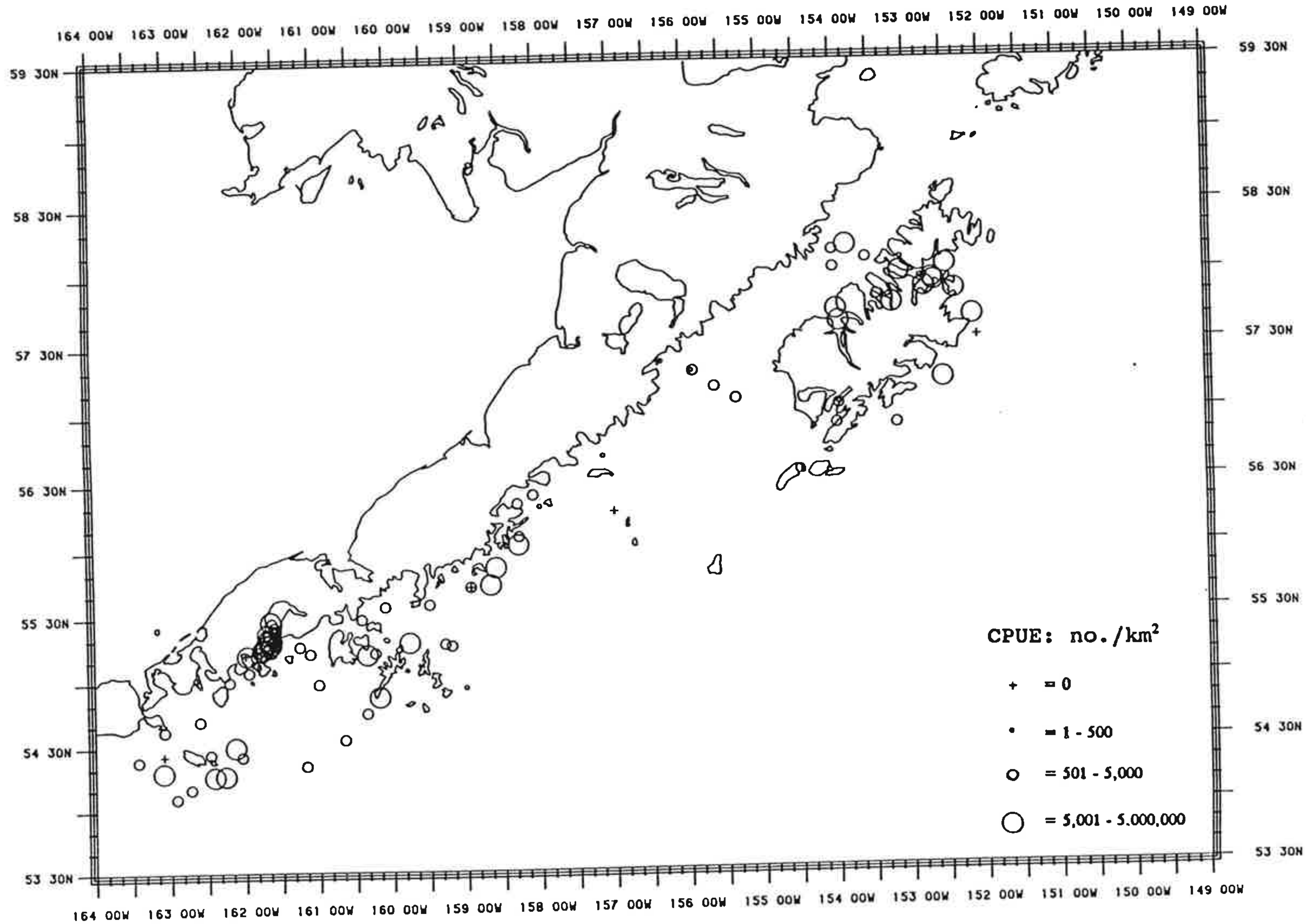
Appendix Figure 2i--Distribution of total walleye pollock from shrimp trawls, 1985



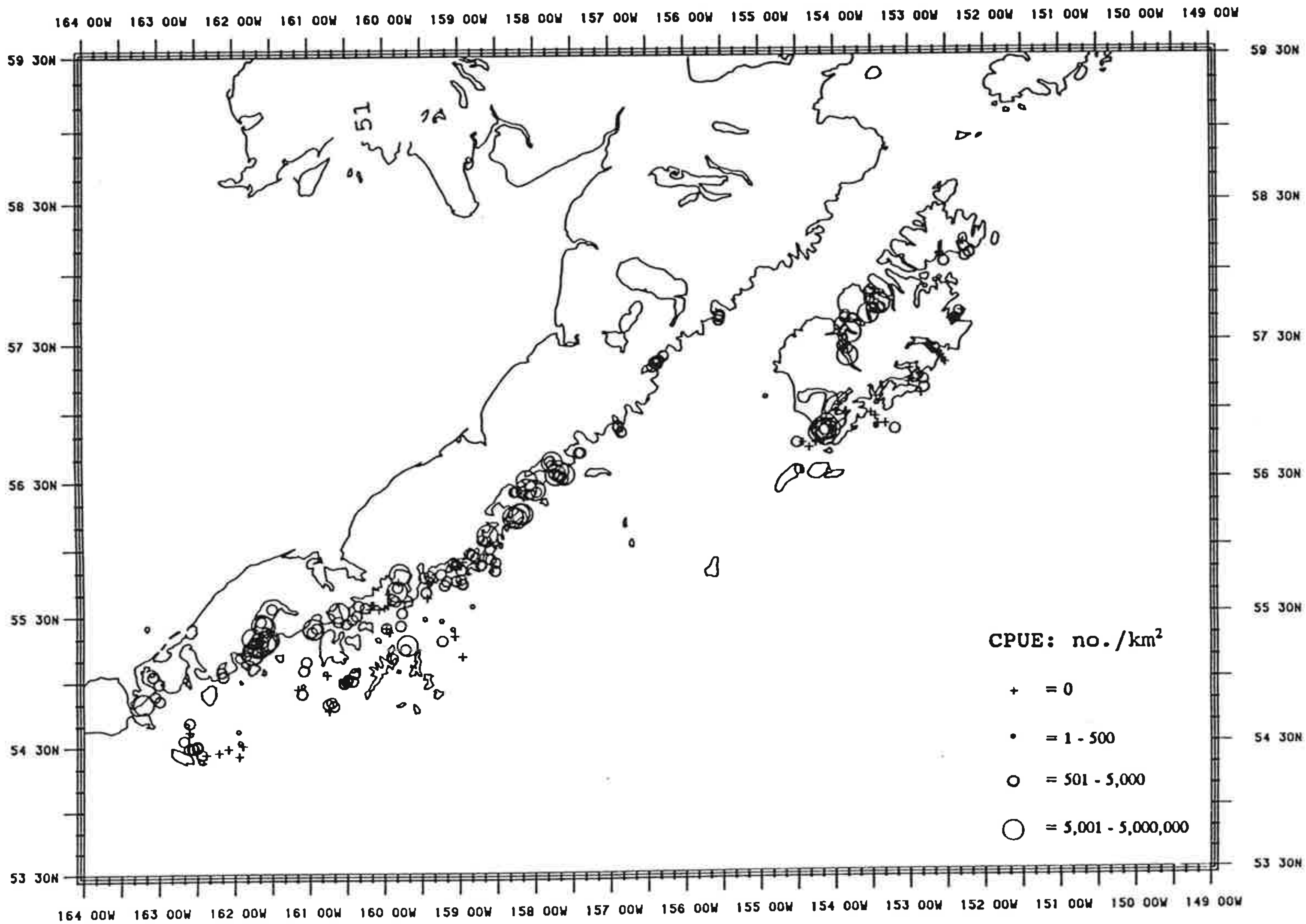
Appendix Figure 2j--Distribution of total walleye pollock from shrimp trawls, 1986.



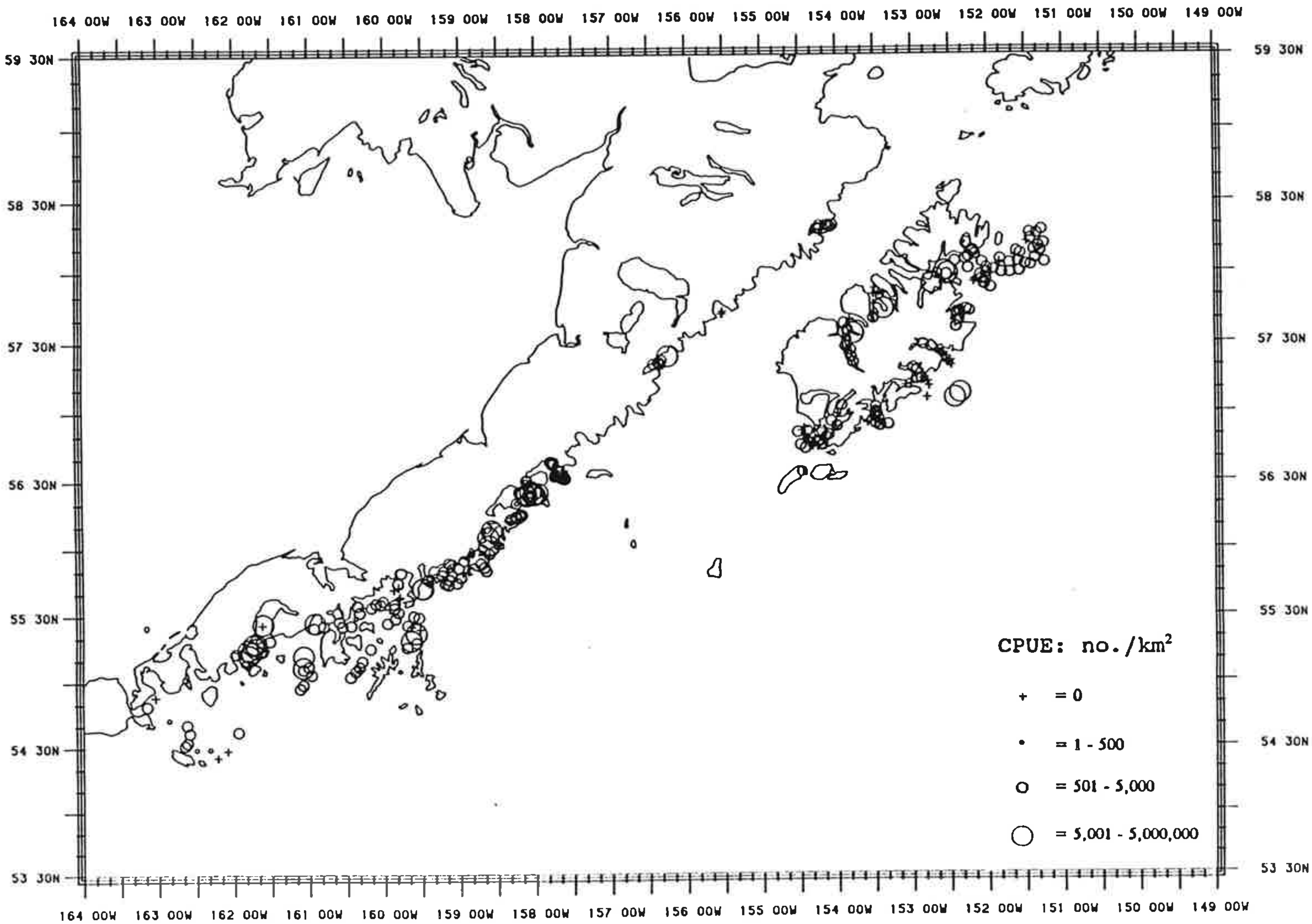
Appendix Figure 2k--Distribution of total walleye pollock from shrimp trawls, 1987.



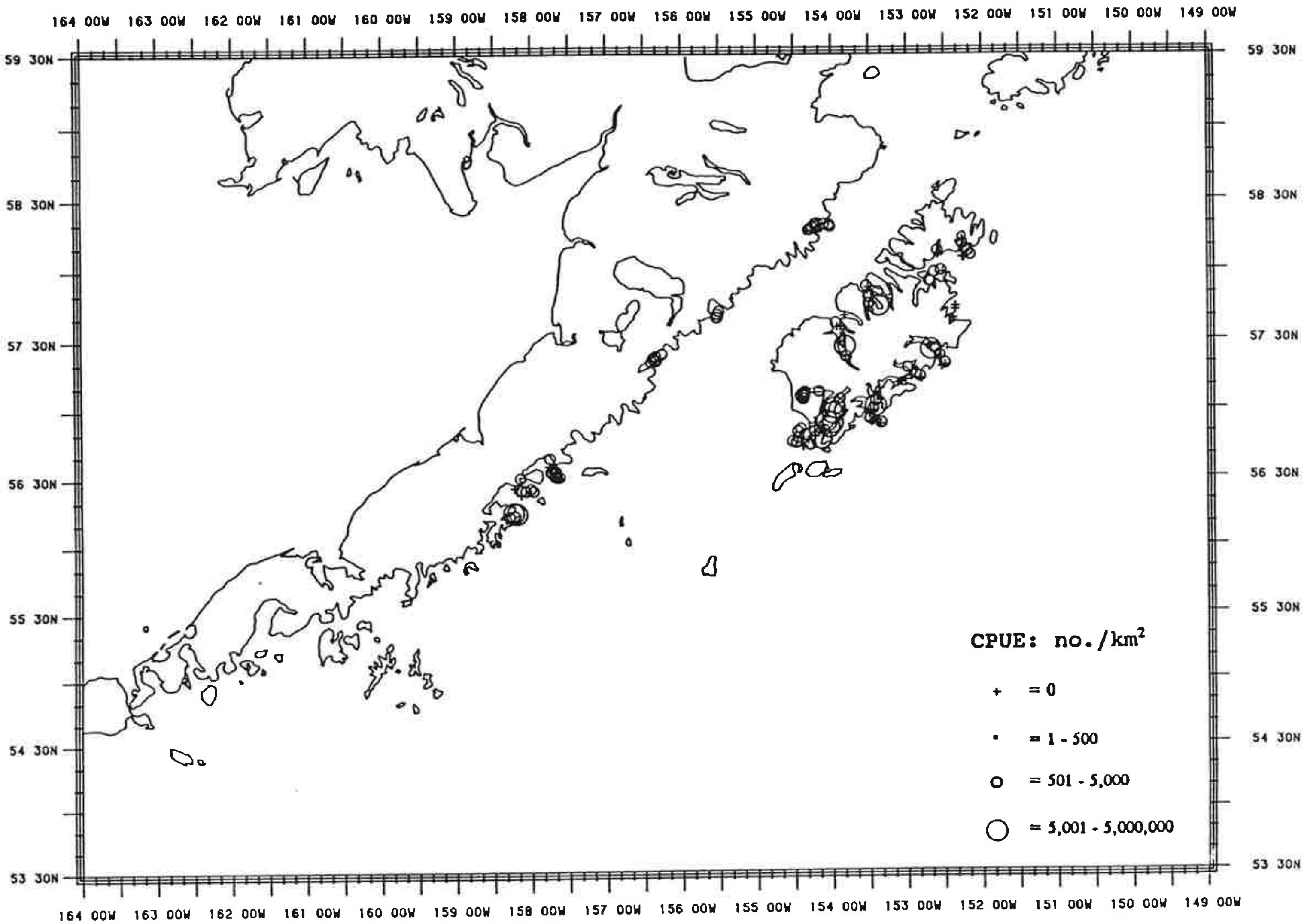
Appendix Figure 21--Distribution of total walleye pollock from shrimp trawls, 1988.



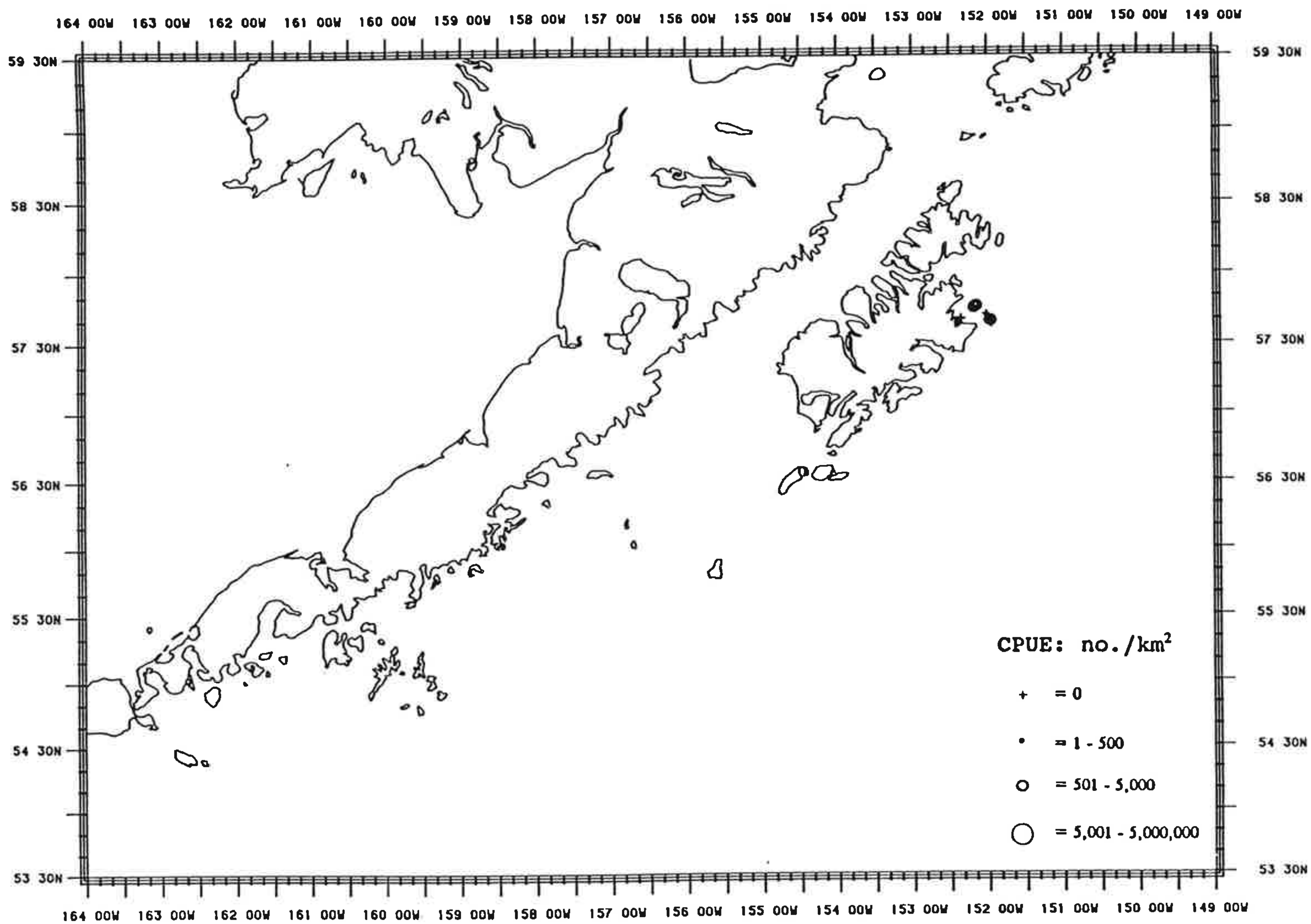
Appendix Figure 3a--Distribution of age-1 walleye pollock from shrimp trawls, 1980.



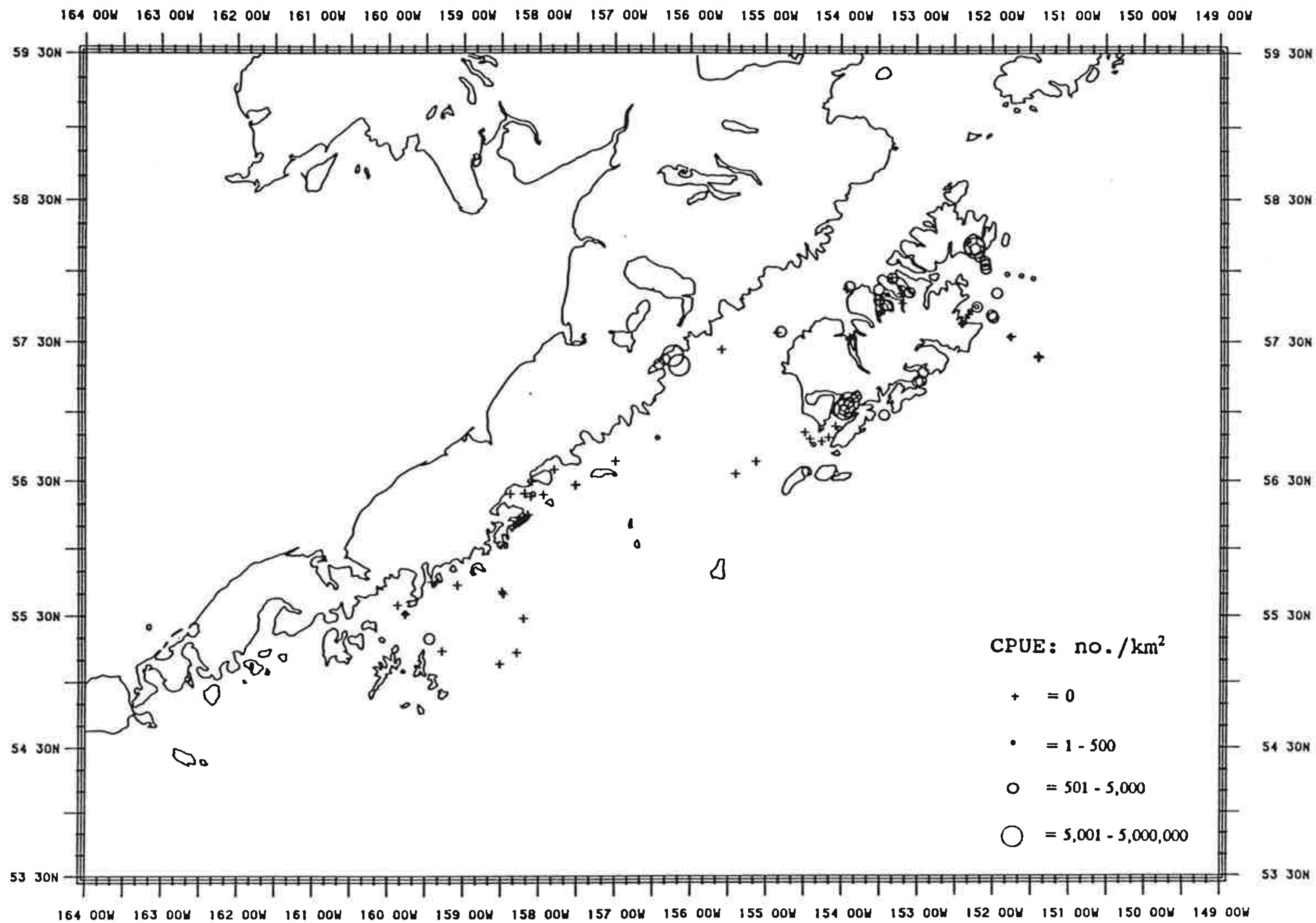
Appendix Figure 3b--Distribution of age-1 walleye pollock from shrimp trawls, 1981.



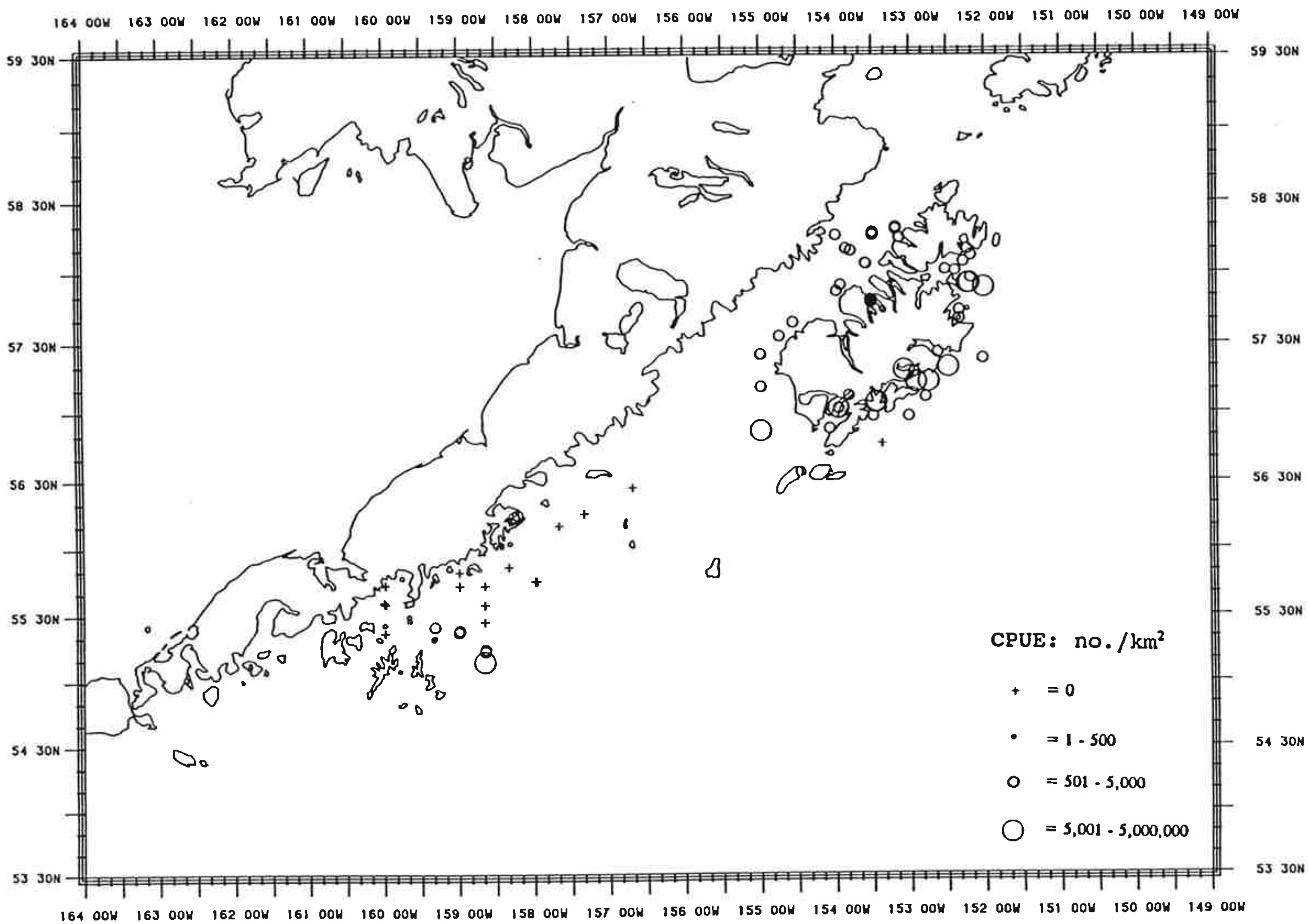
Appendix Figure 3c--Distribution of age-1 walleye pollock from shrimp trawls, 1982.



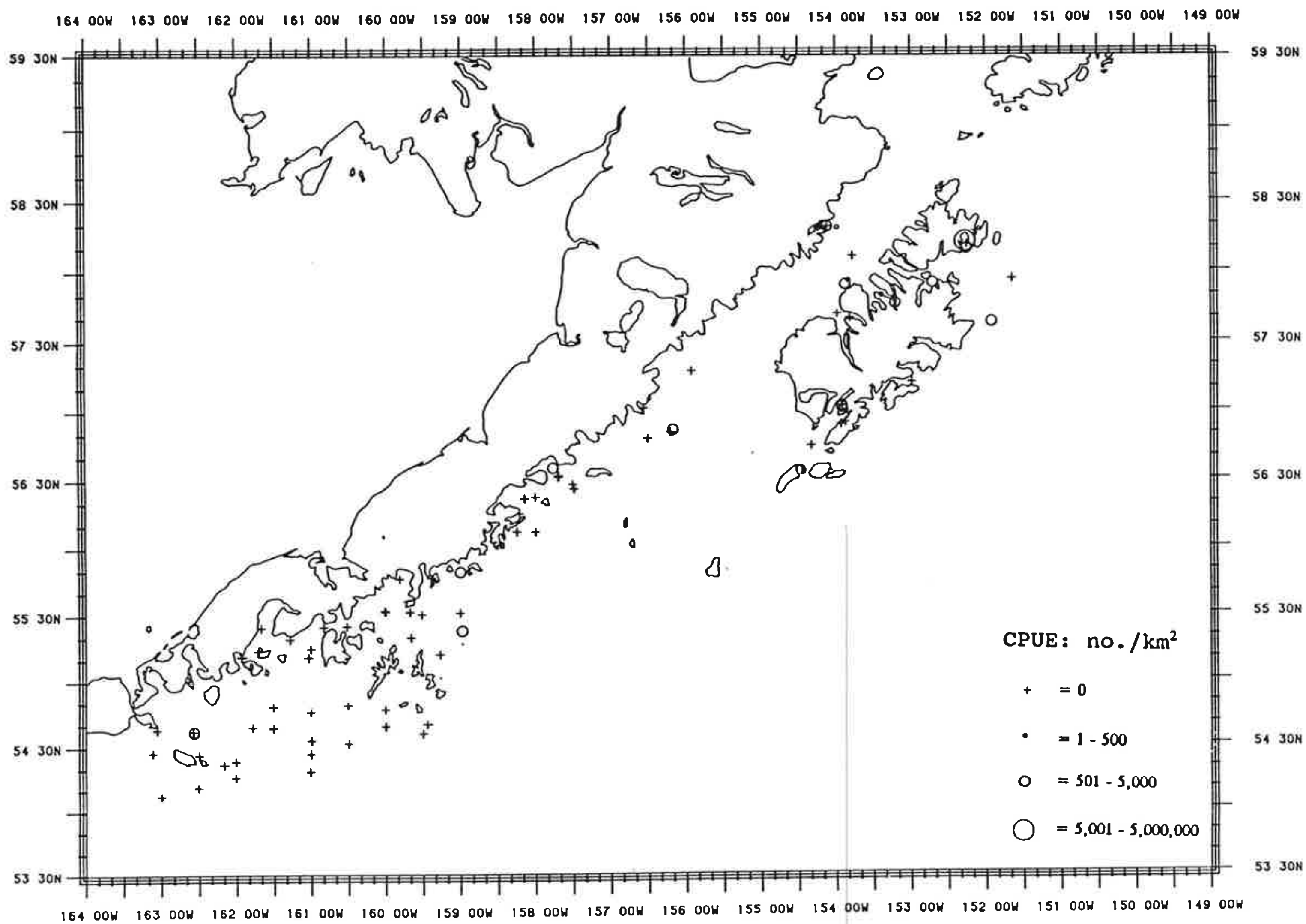
Appendix Figure 3d--Distribution of age-1 walleye pollock from shrimp trawls, 1984.



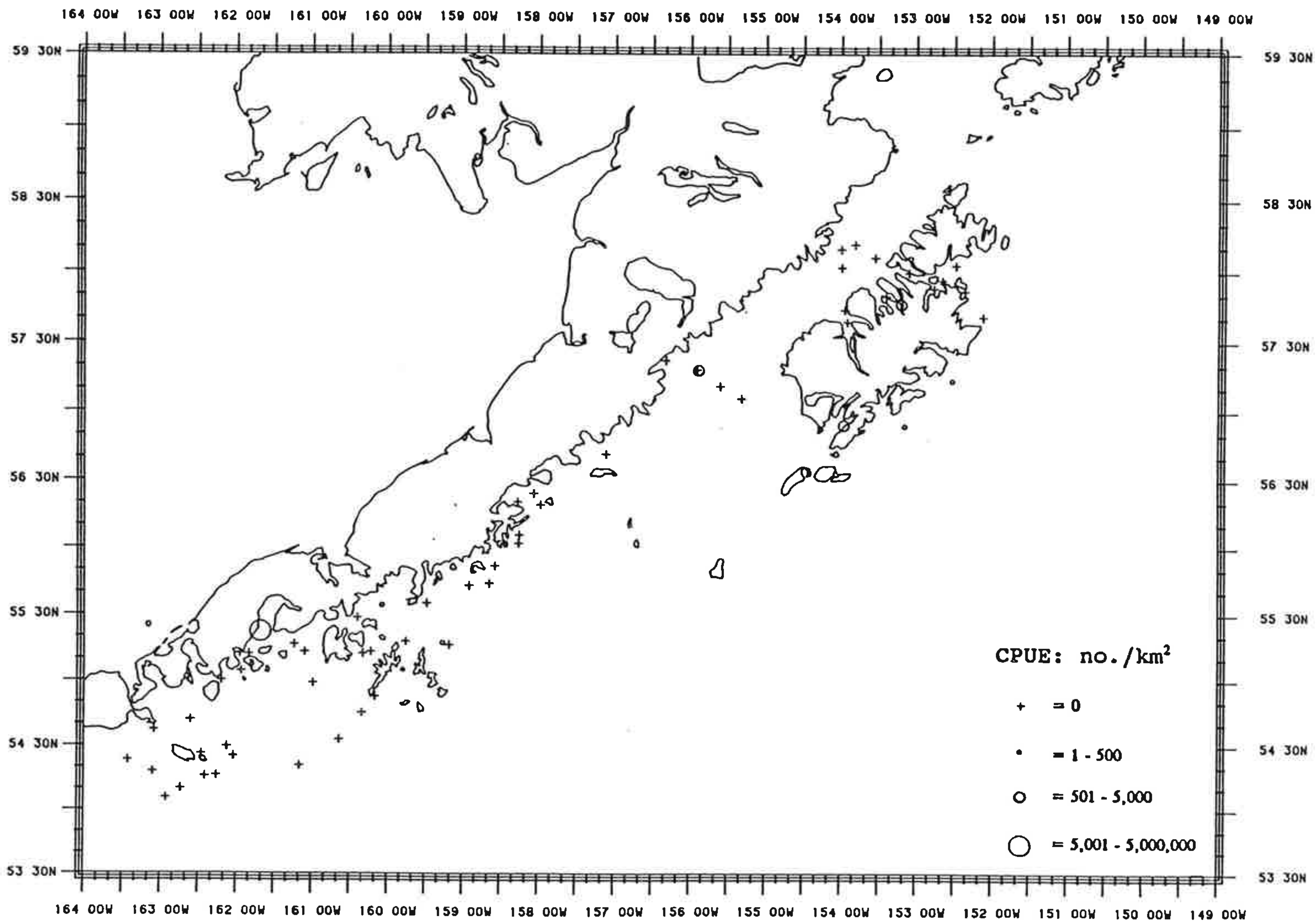
Appendix Figure 3e--Distribution of age-1 walleye pollock from shrimp trawls, 1985.



Appendix Figure 3f--Distribution of age-1 walleye pollock from shrimp trawls, 1986.



Appendix Figure 3g--Distribution of age-1 walleye pollock from shrimp trawls, 1987.



Appendix Figure 3h--Distribution of age-1 walleye pollock from shrimp trawls, 1988.