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Analysis of Crab Data from the 1985 NMFS Survey of the Northeast Bering Sea and Norton Sound

September 1986

NOTICE

ANALYSIS OF CRAB DATA FROM THE 1985 NMFS SURVEY OF THE NORTHEAST BERING SEA AND NORTON SOUND

by

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ABSTRACT

In September and October 1985, the National Marine Fisheries Service conducted a trawl survey of Norton Sound and the northeast Bering Sea. This report includes data on the abundance and distribution of red king crab (*Paralithodes camtschatica*), blue king crab (*P. platypus*), and Tanner crabs (*Chionoecetes bairdi* and *C. opilio*) in those regions. All four species occurred in Norton Sound, but only *C. opilio* was found in the northeast Bering Sea. An estimated 1.203 million legal size (>104 mm carapace length) male red king crabs occurred in the Norton Sound survey area; the majority of these were undergoing or had recently completed molting in September. The only other species reaching legal size in Norton Sound was *C. opilio*, but in very few numbers. Egg clutches were absent from female *C. opilio* in Norton Sound, but were present in the northeast Bering Sea in relatively low numbers. These data suggest that some factor prevented female *C. opilio* in those regions from maturing or spawning at the same size as in the more southerly eastern Bering Sea.

CONTENTS

INTRODUCTION

The National Marine Fisheries Service (NMFS) conducts an annual trawl survey of the eastern Bering Sea in order to assess the abundance of commercially important groundfish and shellfish resources (Fig. 1). The region surveyed includes the entire continental shelf from Unimak Pass north to Nunivak Island and St. Matthew Island and west to 178°W long. Data on the abundance and distribution of commercially important crab species are published after each survey (e.g. Stevens and MacIntosh 1985).

On a triennial basis, NMFS expands its survey to include the region between the latitudes of St. Matthew Island (60°30'N lat.) and St. Lawrence Island (63°30'N lat.), and from 168°W long. almost to the U.S.-U.S.S.R. convention line. This region is referred to as the northeast Bering Sea (Fig. 1). The expanded survey also includes portions of Norton Sound. This was done in 1976, 1979, 1982, and 1985. This document presents the results of the expanded survey for 1985.

SURVEY AREA AND METHODS

The standard eastern Bering Sea survey occurs at stations located 20 nautical miles (nmi) apart. However, due to logistic requirements and the relatively low importance of the northeast Bering Sea to commercial fisheries, in that region only alternate stations were fished (i.e. at intervals of 40 nmi). In contrast, the Norton Sound area was sampled at intervals of 10 nmi. Stations there were designated with a lowercase letter-number

combination, starting at the southeast corner and ascending alphabetically with increasing latitude and numerically with increasing longitude.

The survey was conducted aboard the chartered F/V Argosy from 16 September to 6 October 1985, and included 78 successful tows in Norton Sound, and 16 in the northeast Bering Sea. Methodology was identical to that of the standard survey (Stevens and MacIntosh 1985). An 83-112 eastern otter trawl was towed once at each station; tows lasted 30 minutes and averaged 1.5 nmi in length. All crabs were sorted by species and sex, and measured except where large catches of Chionoecetes opilio occurred; these were subsampled. The standard crab measurements were carapace length (cl) for red king crab (Paralithodes camtschatica) and blue king crab (Paralithodes platypus), and carapace width (cw) for Tanner crabs (Chionoecetes bairdi and C. opilio). Catches were standardized to crabs per square nautical mile.

Norton Sound red king crab population estimates were made by the area-swept method (Alverson and Pereyra 1969), for four geographic subareas. First, an estimate was made for the entire survey area. This area was subdivided into two subareas corresponding to open and closed areas in the 1985 commercial fishery (Alaska Dep. Fish and Game (ADFG) 1985; Fig. 2) and a population estimate made for each. The fourth estimate was made for an area which had been previously surveyed with crab pots by ADFG in July 1985 (Fig. 2).

For each species in a given subarea, the area of distribution was post-stratified into two strata (high and low density) by the method of cumulative square roots (Cochran 1977). This technique was accomplished by arranging the catch per unit effort (CPUE) data in a frequency distribution, and calculating the cumulative square root for each frequency. The sum of these was then divided into equal intervals according to the number of strata desired; the stations contributing to each interval then constituted a stratum, provided they were contiguous. A stratified estimate of the mean and variance was then calculated for each subarea. This technique produced estimates which were unbiased, with reduced variance; minor adjustments for contiguity were made without increasing the variance significantly.

All of the above estimates were made for two different sets of length frequency data. The first estimate was made using actual crab measurements. The second set of estimates was made using a length frequency distribution adjusted to compensate for growth that had occurred during the 2-month interval between the ADFG survey and the NMFS survey. To adjust for this, the estimated recent growth increment was subtracted from the length of each softshell crab. Twelve mm were subtracted from postmolt lengths greater than 98 mm (Powell et al. 1983), and 11% subtracted from lengths of 98 mm or less. Because softshell females were immature, the same increments were subtracted as for males. The purpose of this procedure was to make population estimates which could be compared to those made by ADFG in July.

Biomass estimates for red king crab were made using regression equations of weight on length derived from Norton Sound king crab collected during 1985 by NMFS (female crab) or ADFG (male crab). For other species, regression equations are based on data collected in the eastern Bering Sea. The equations used were of the form

$$W = aL^b,$$

and the parameters employed are given in Appendix A. All biomass estimates are given in lbs for consistency with ADFG harvest guidelines.

RESULTS

Norton Sound

Bottom water temperatures in Norton Sound (Fig. 3) were relatively warm, averaging 7.0 °C (s.d.=1.09).

Red king crab

Legal sized (≥ 100 mm cl) red king crab were fairly evenly distributed in a band parallel to the northern shoreline of Norton Sound (Fig. 4). Few were caught south of 64°00'N. lat. A few were caught at the farthest northwest stations sampled, but there was not time to sample farther in that direction; except for that corner, almost the entire range of red king crab in Norton Sound was covered. The largest catch of legal males occurred just south of Cape Nome.

The mean size of male crab was 93.7 mm cl (range 10-168) and that of female crab was 66.5 mm cl (range 16-103)(Table 1). Length frequencies of male and female crabs caught are shown in Figures 5A and 6A. A large group of both male and female crabs with a modal length of about 65-69 mm is evident. Examination of the male length frequency plot (Fig. 5A) indicates that we sampled this population in the middle of the molt (see Appendix B). Over 50% of males between 75 and 114 mm were premolt crab. Seventy (18%) males caught were softshell, indicating that they had molted within the preceding few days. Some of the 103 new, hardshell males caught were barely hard and had clearly molted within the previous few weeks. All these softshell crab and an unknown portion of the new, hardshell crab had molted since the ADFG pot survey was conducted in July. Among females, only 9% (all immature) were premolt or softshell (Fig. 6A). Figures 5B and 6B reflect more closely the population length frequency at the time of the ADFG survey in July. The incidence of molting activity (premolt or softshell crab) among all crab less than 65 mm was also very low. Therefore, the only high incidence was among mature males.

Mature females were exclusively new and hardshell, and all had full clutches of external embryos. A plot of the percent of females that were ovigerous (Fig. 7) indicates that 50% were mature at about 73 mm. Therefore, it appears that many of the females in this mode will molt to maturity in 1986.

It is difficult to estimate the timing of the 1985 mating season by looking at embryo development in September because estimates of the rate of embryonic development vary. Marukawa (1933) reported that red king crab embryos have complete compound eyes 100-110 days after fertilization while Matsuura and Takeshita (1985) reported that the compound eye appears at 170 days. We collected egg masses from Norton Sound red king crab females and preserved them in formalin for later examination in the laboratory. Newly eyed eggs, defined as having some dark pigment in the eye, but not necessarily a completely formed compound eye, constituted 39% of the clutches; the remainder were uneyed eggs (Fig. 8). Using the two estimates above, the spawning season could have started as early as February and ended as late as July.

Figure 8 shows that smaller females tended to have uneyed eggs and larger females eyed eggs. This appears to be opposite to the situation in Bristol Bay, where the smaller primiparous crab mate before larger multiparous crab and thus would have embryos at least as well developed as those of larger crab at any time of the year.

Estimates of abundance varied depending upon the area examined. For the entire trawl survey area, the estimated number of males ≥104 mm cl was 1.203 million crab, or 3.321 million lbs, with an approximate 95% confidence interval (equivalent to two standard errors) of ±32% (Table 2A). Approximately 64% of those (768,000 crab or 2.195 million lbs) were in the area open to commercial fishing (Table 2C). Downward adjustments of the length of recently molted crab reduced the number of recruit

crab to 1.129 million or 3.138 million lbs (Table 2B). Estimates of abundance for legal male red king crab in the pot-surveyed area were 0.955 and 0.904 million crab for actual and molt-adjusted crab >104 mm cl, respectively (Tables 2A, 2B, and 2C). The latter figure translates into 2.536 million lbs, compared to the ADFG estimate of 3.0 million lbs for the same area and size range of crabs (pers. commun., January 1986[1]).

Blue king crab

A total of only 13 blue king crab, including no legal size males, were found at five stations, all in the northwest corner of the trawl-survey area; these were not plotted. The two males measured 104 and 112 mm cl, and the 11 females averaged 94.6 mm cl (Table 1). Of the 10 mature females (≥85 mm cl) 8 carried egg clutches. The other two carried empty embryo cases attached to the pleopod setae, as is typical for blue king crab females between biennial spawning years (Somerton and MacIntosh 1985).

Population estimates were 16,000 (±100%) prerecruit males, and 74,000 (±90%) mature females (Table 3A). Confidence intervals are large because of the small sample.

Tanner crabs

Chionoecetes bairdi

No large (>134 mm cw) or prerecruit (110-134 mm cw) male C. bairdi were caught. Therefore, Figure 9 presents densities of small (<110 mm cw) male crab. Those were split into a large

[1]Charles Lean, ADFG, P.O. Box 1148, Nome, AK 99762.

central group and a smaller western group. Average sizes were 50.4 mm cw for males, and 49.2 mm for females (Table 1). None of the females carried eggs, and all were classified as immature.

Population estimates were 1.370 (±35%) million males, and 275,000 (±93%) females (Table 3B).

Chionoecetes opilio

C. opilio was the most abundant species of crab in Norton Sound, and was distributed throughout the survey area except at the most eastern and northern stations. Only sublegal male crab (<78 mm cw) were plotted (Fig. 10).

Average sizes were 34.4 mm for males and 33.2 mm for females (Table 1). Both males and females showed strong length frequency modes at about 25 and 34 mm (Fig. 11). Only 12 males larger than 63 mm were captured. Since the size at maturity for males in the eastern Bering Sea is 65 mm (Somerton 1981), there appeared to be very few mature males in Norton Sound.

Only one female with external embryos was caught, although there were 173 females >49 mm taken (Fig. 12). The size at 50% maturity is 50 mm cw in the eastern Bering Sea (Otto et al. 1980), and Jewett (1981) gave 50 mm as the size at maturity in the southern Chukchi Sea. Not only were there very few females of mature size in Norton Sound but very few of those were carrying embryos.

Population estimates (Table 3C) were 53.9 million males (±28%) and 33.5 million females (±25%), virtually all of which were immature.

Northeast Region

Bottom water temperatures (Fig. 13) in the northeast Bering Sea were relatively cold, averaging 0.1 °C (sd=1.23). C. opilio was the only crab species encountered in the northeast region, except for one hybrid Tanner crab. Very few large or prerecruit crab were caught. Figure 14 shows that small crab were distributed over the entire northeast region, with greatest densities in the farthest northwest and southeast corners of the area. Average sizes were 47.2 mm cw for males and 38.8 mm for females. The same two length frequency modes (25 and 34 mm) that were dominant in Norton Sound were present, but were dwarfed by a third mode at about 44 mm (Fig. 11).

In contrast to Norton Sound, 50% of northeast region females >49 mm carried external embryos. This is still far below the 74% figure for the standard eastern Bering Sea survey in 1985. Figure 12 suggests that, in the northeast Bering Sea, size at 50% maturity for females is the same as in the eastern Bering Sea but that other factors (that come into play at sizes >50 mm) may prevent some mature females from carrying embryos. One possible explanation is the scarcity of legal sized, hence mature, males in the area.

Population estimates (Table 3D) were 3,492 million males (±45%) of which only 9.7 million were large (>102 mm cw). There were an estimated 1654 million females (±30%).

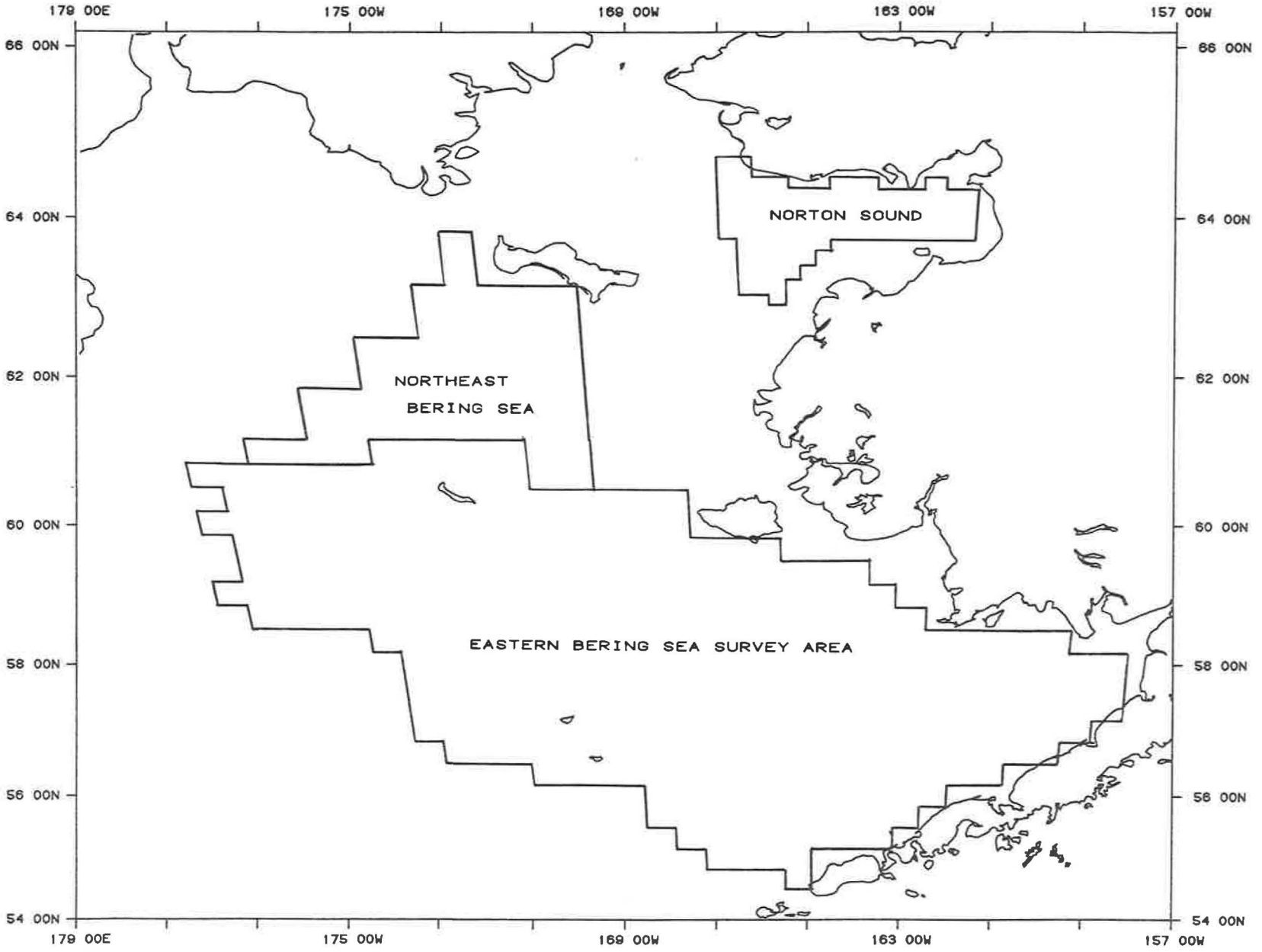

Figure 1.--Map showing regions surveyed in the eastern Bering Sea, northeast Bering Sea, and Norton Sound.

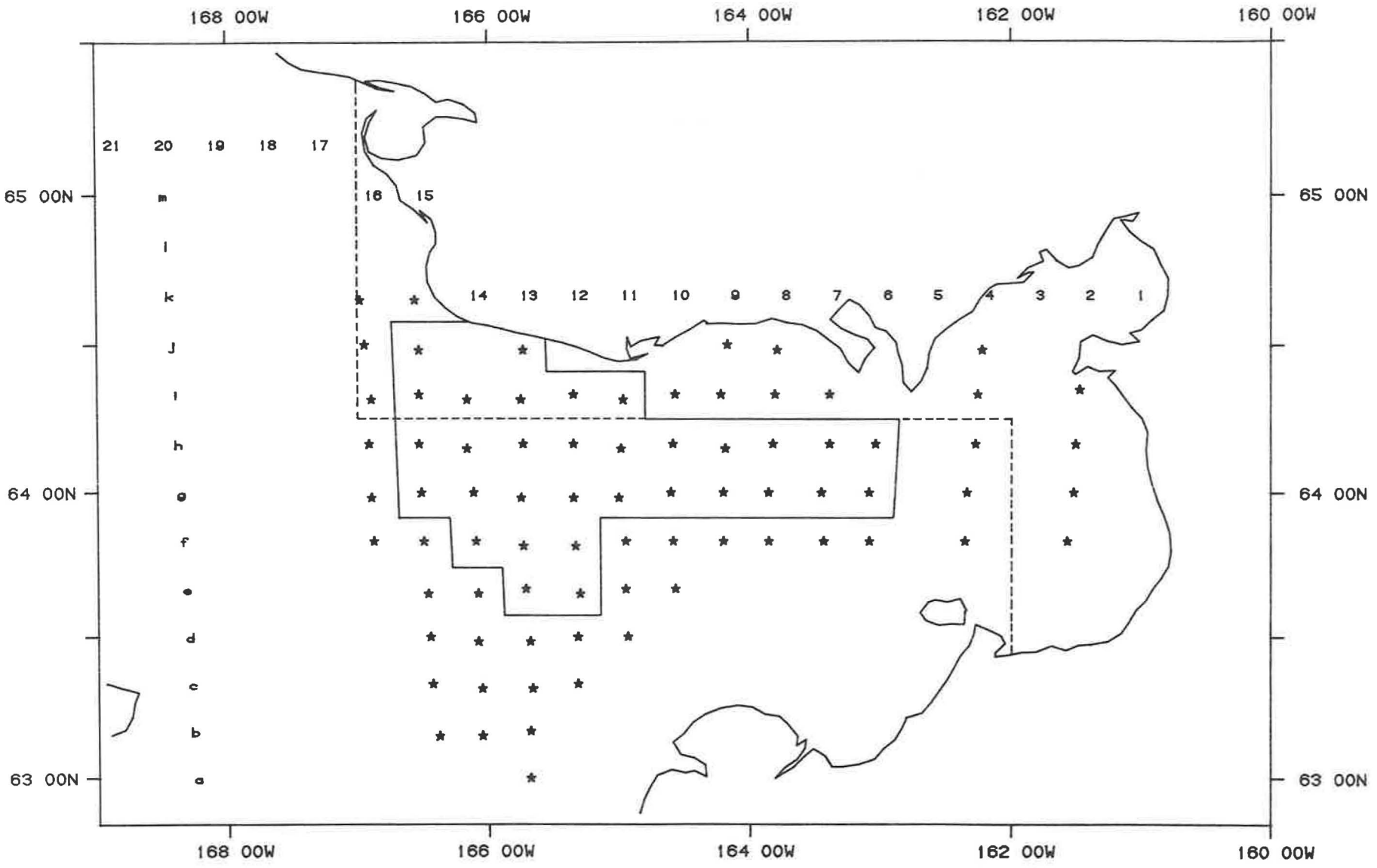

Figure 2.--Location of stations sampled by trawl in Norton Sound, 1985. Area enclosed by solid lines was surveyed with crab pots by the Alaska Department of Fish and Game in July, 1985. Dotted line separates areas open (offshore) and closed (inshore) to commercial fishing.

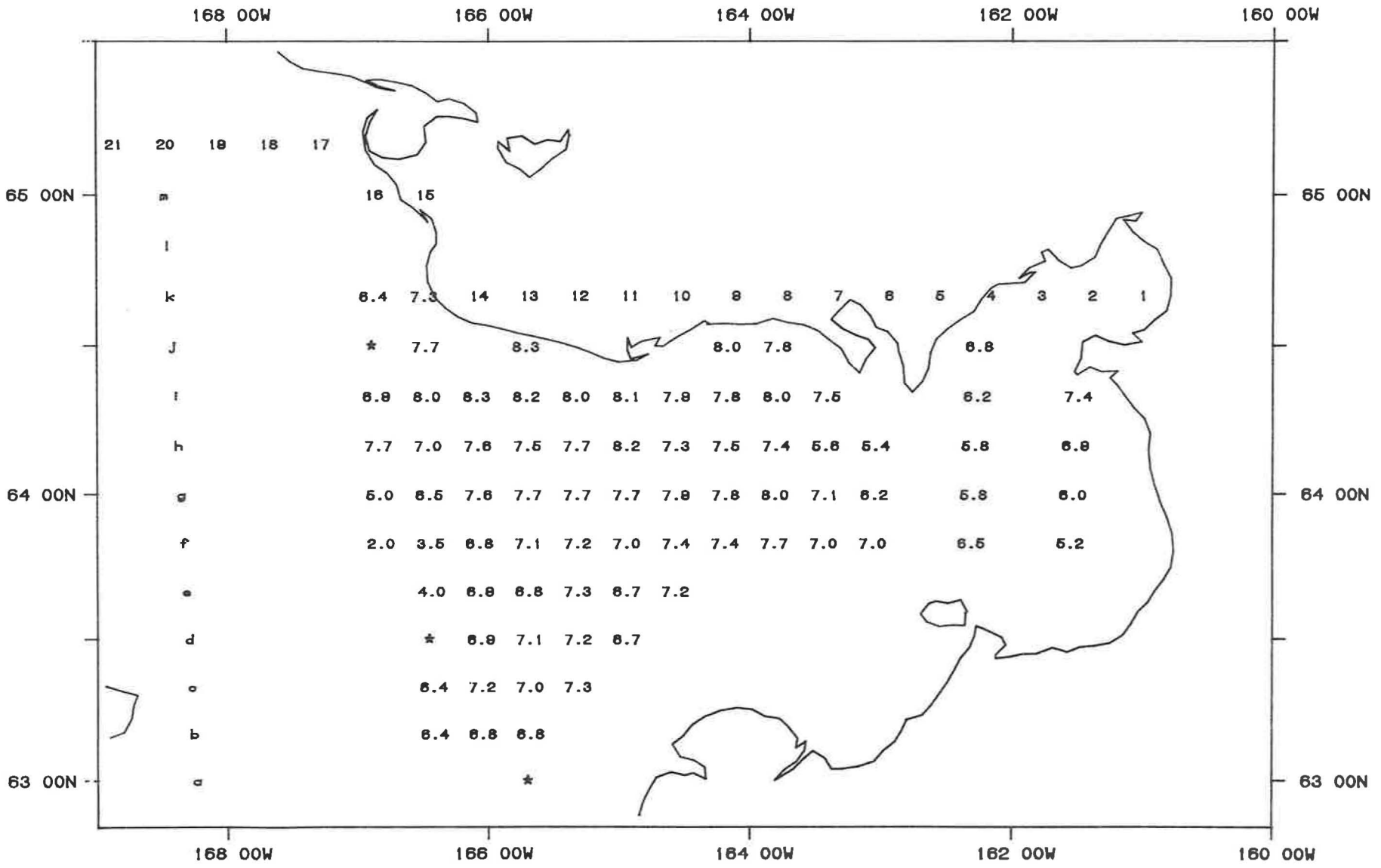

Figure 3.--Bottom water temperature (°C) at stations sampled in Norton Sound, 1985.

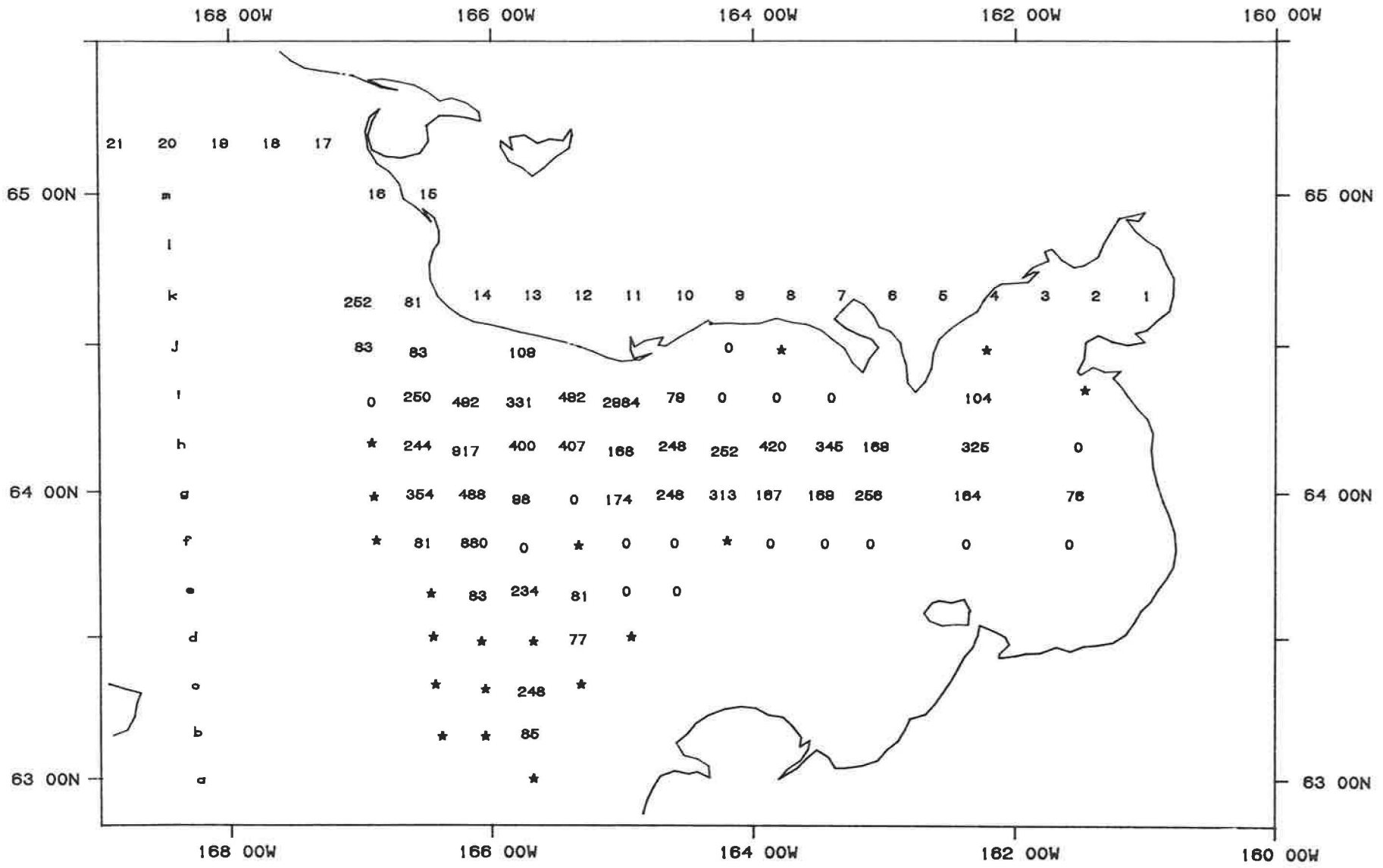

Figure 4.--Estimated number of crabs per square nautical mile for red king crab (Paralithodes camtschatica) legal (≥100 mm carapace length) males at stations sampled in Norton Sound, 1985.

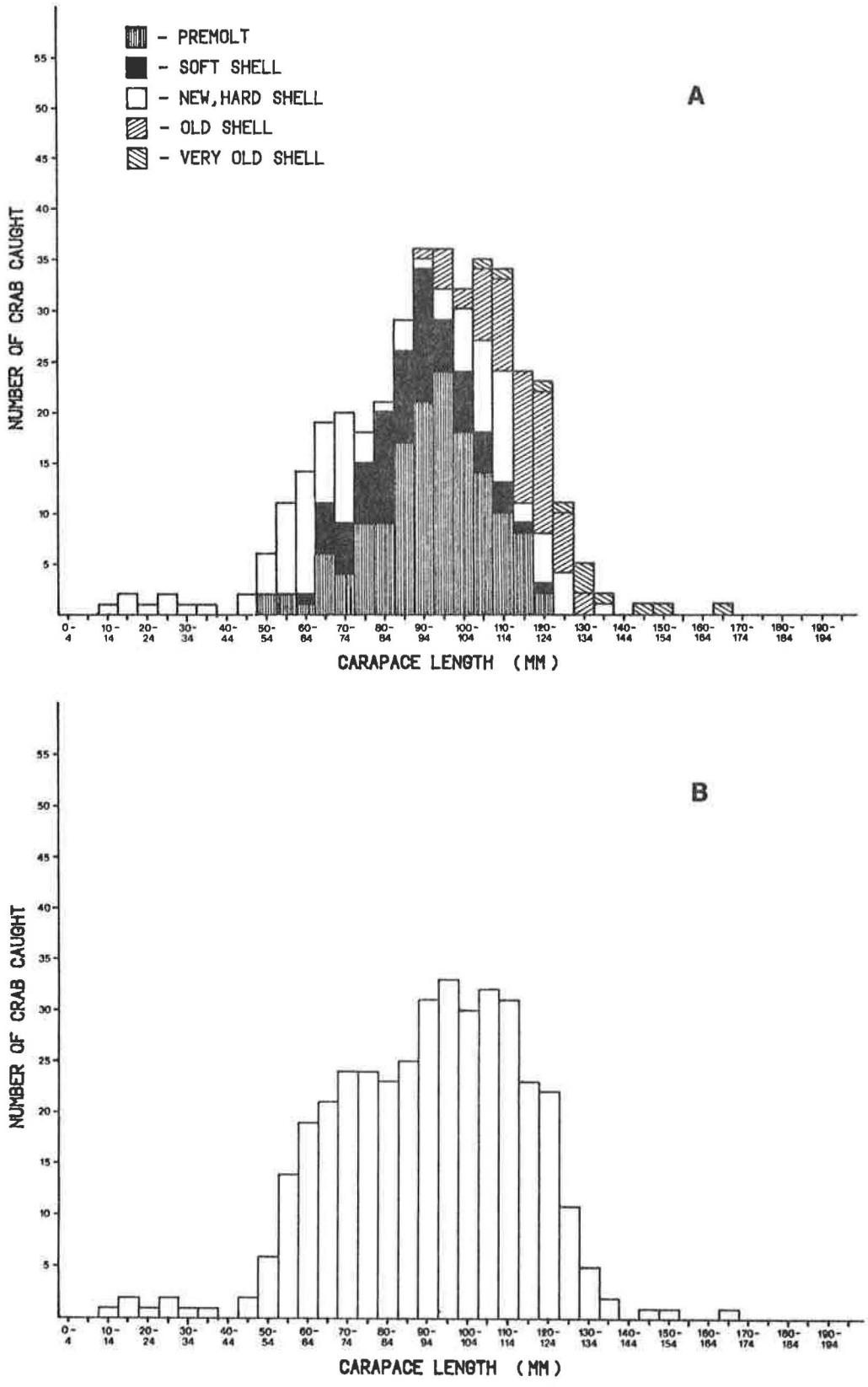

Figure 5.--Length frequency of male red king crabs (Paralithodes camtschatica) from Norton Sound: A) before adjustment (subtraction of increment) for recent growth; B) after adjustment.

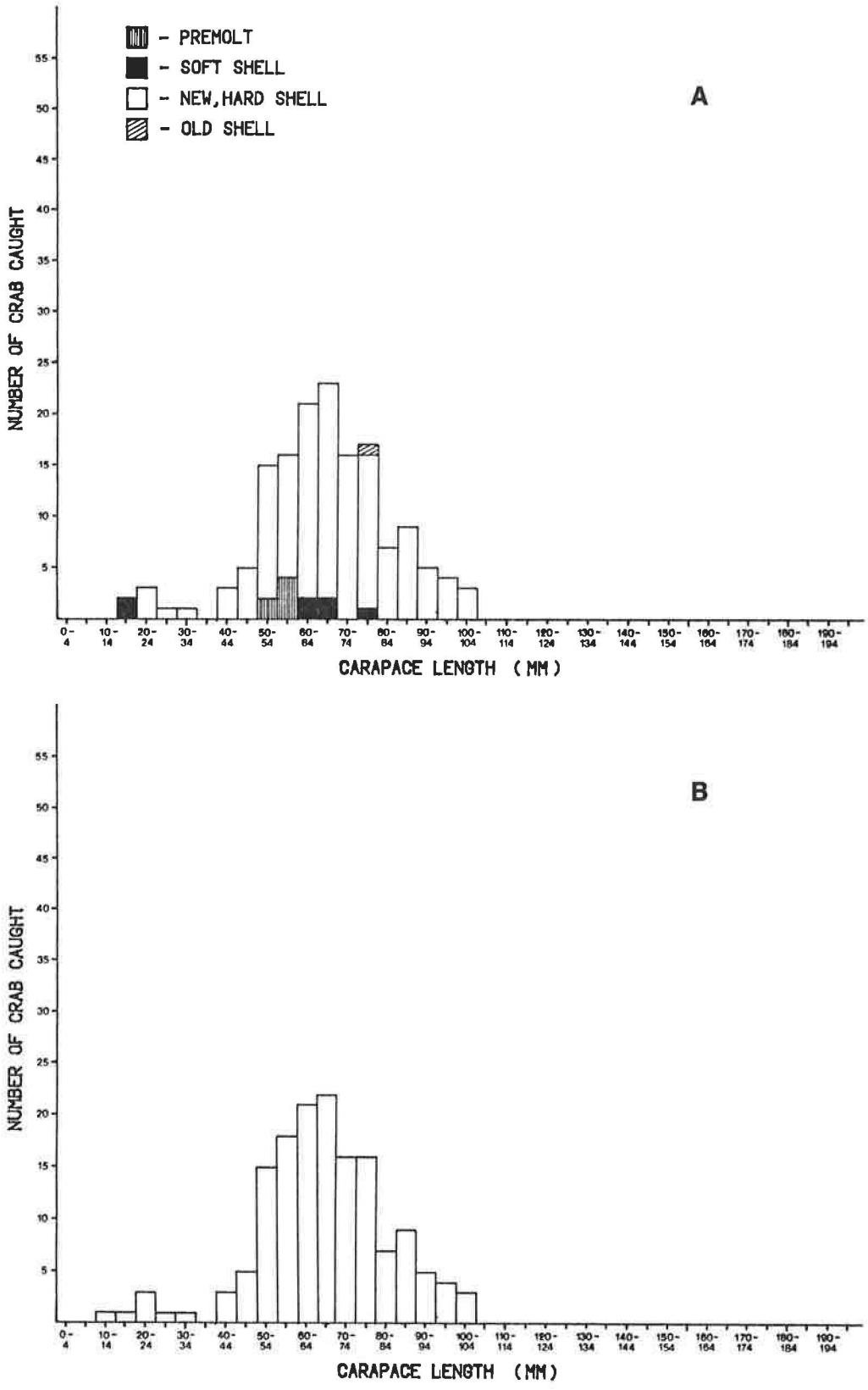

Figure 6.--Length frequency of female red king crabs (Paralithodes camtschatica) from Norton Sound: A) before adjustment (subtraction of increment) for recent growth; B) after adjustment.

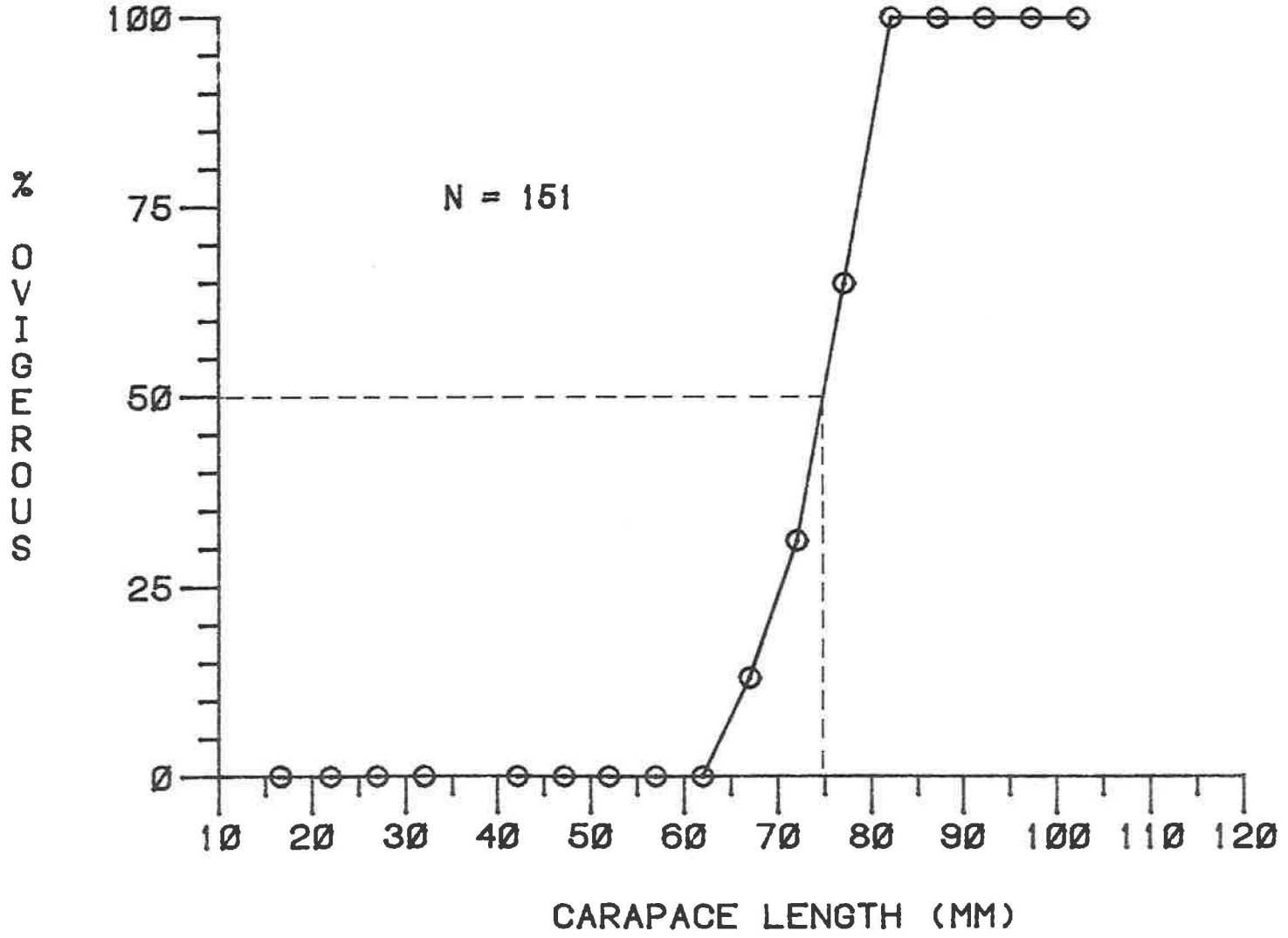

Figure 7.--Percent of female red king crabs (Paralithodes camtschatica) from Norton Sound carrying external embryos (ovigerous), by 5-mm carapace length groups. Dotted line indicates size at 50% maturity.

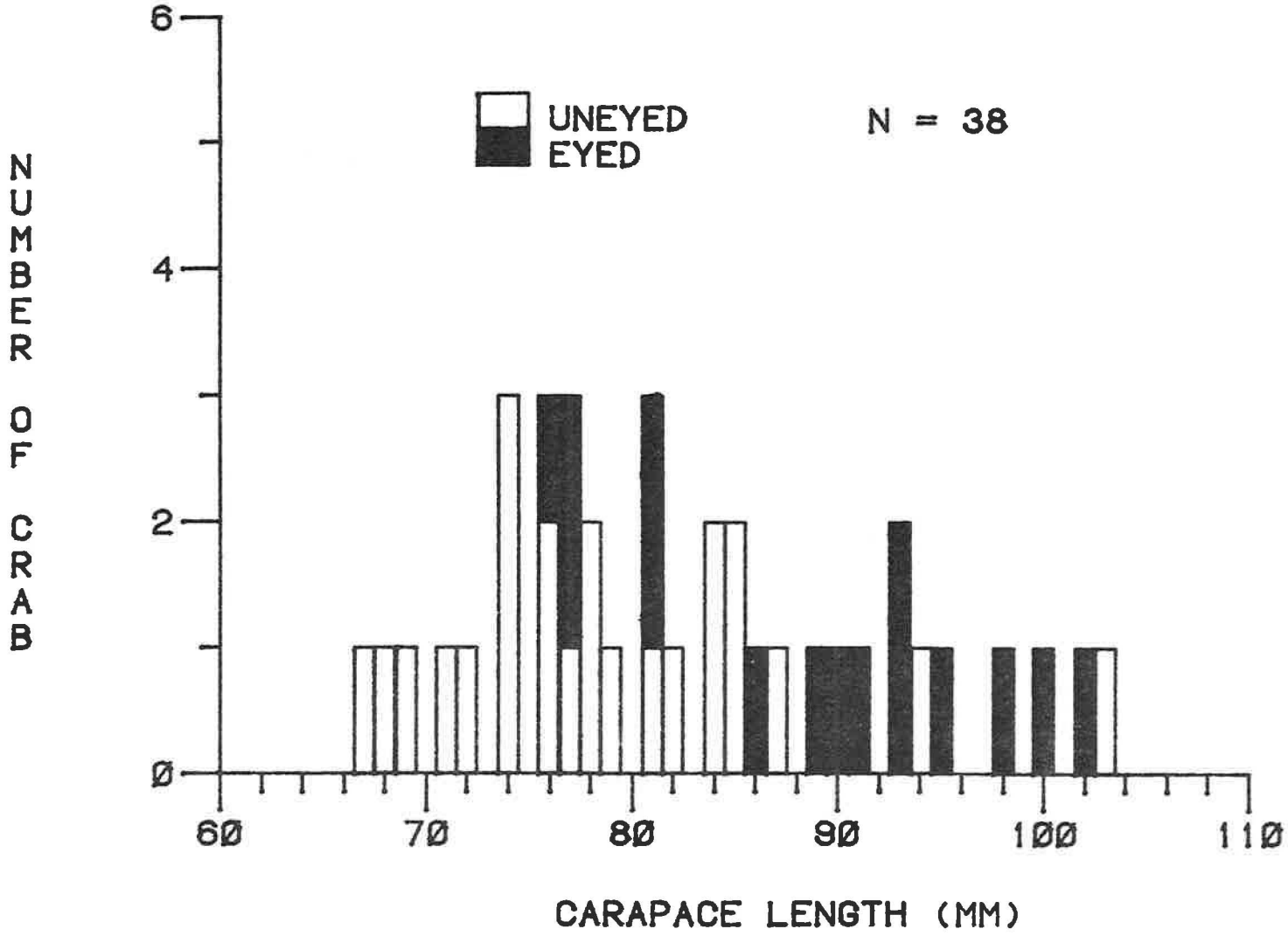

Figure 8.--Stage of embryo development versus carapace length of female Norton Sound red king crabs (Paralithodes camtschatica).

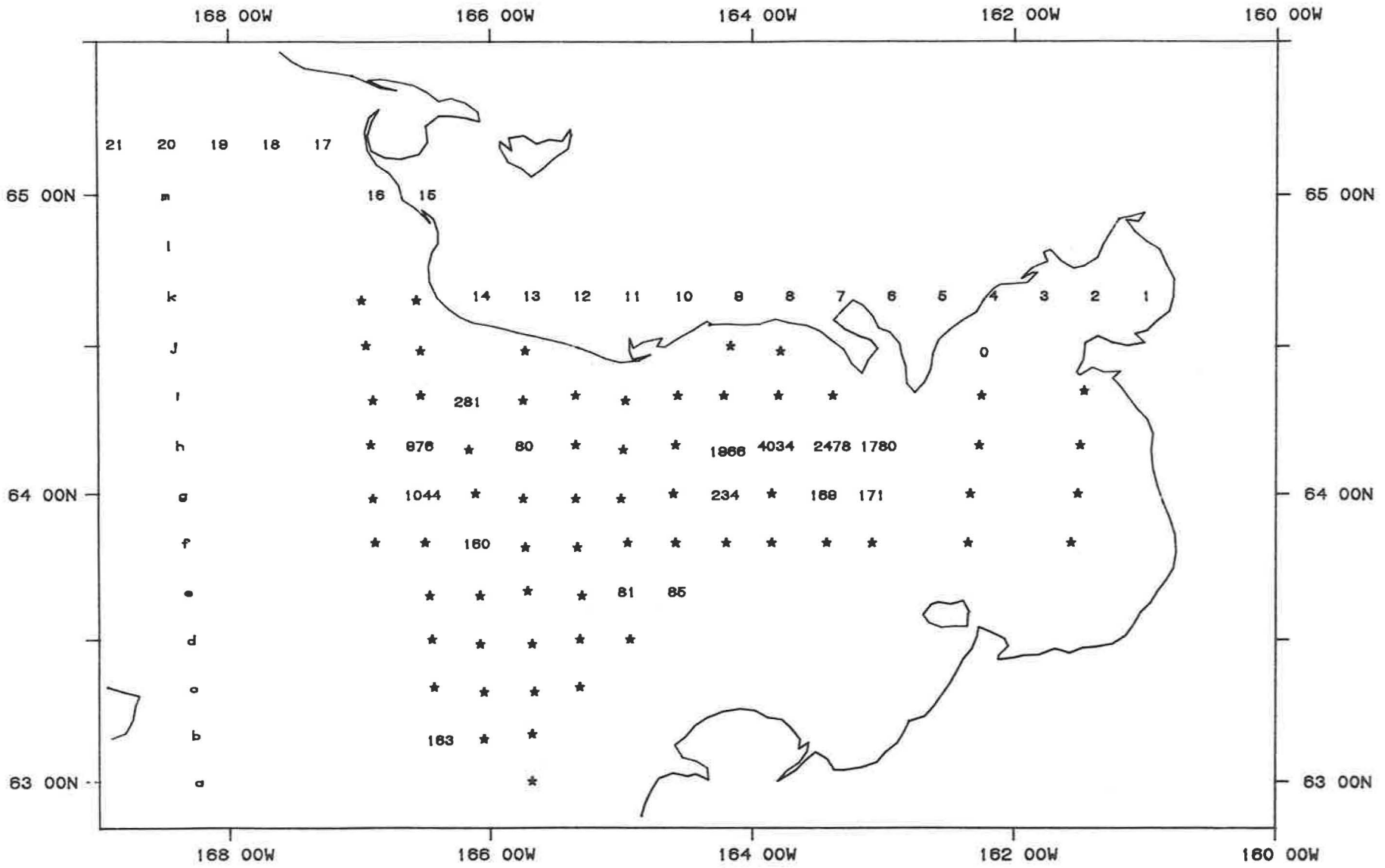

Figure 9.--Estimated number of crabs per square nautical mile for Tanner crab (Chionoecetes bairdi) immature (≤109 mm carapace length) males at stations sampled in Norton Sound, 1985.

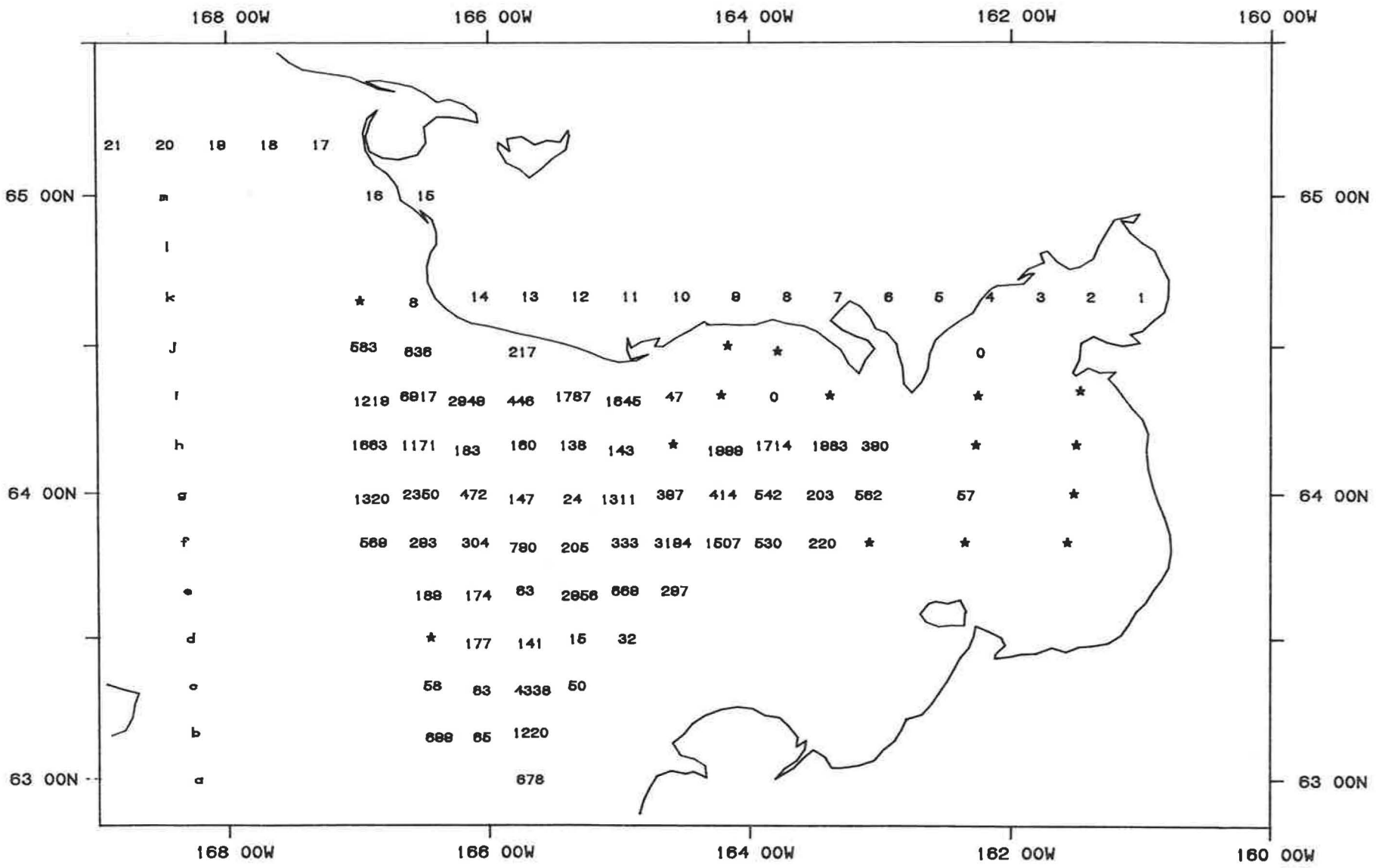

Figure 10.--Estimated number (10's) of crabs per square nautical mile for Tanner crab (Chionoecetes opilio) sublegal (≤77 mm carapace length) males at stations sampled in Norton Sound, 1985.

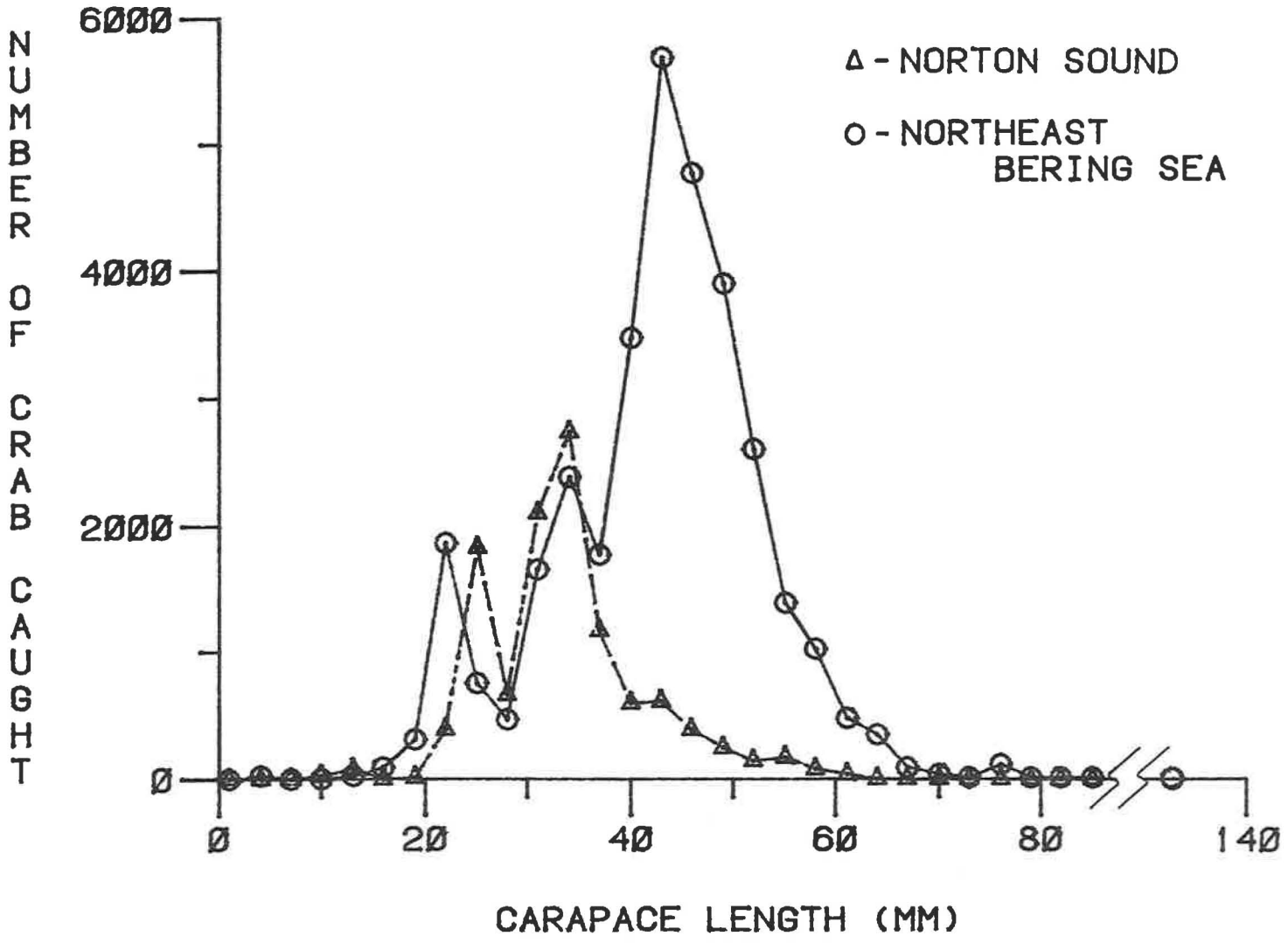

Figure 11.--Width frequencies of Tanner crabs, Chionoecetes opilio (sexes combined), from Norton Sound (triangles) and the northeast Bering Sea (circles).

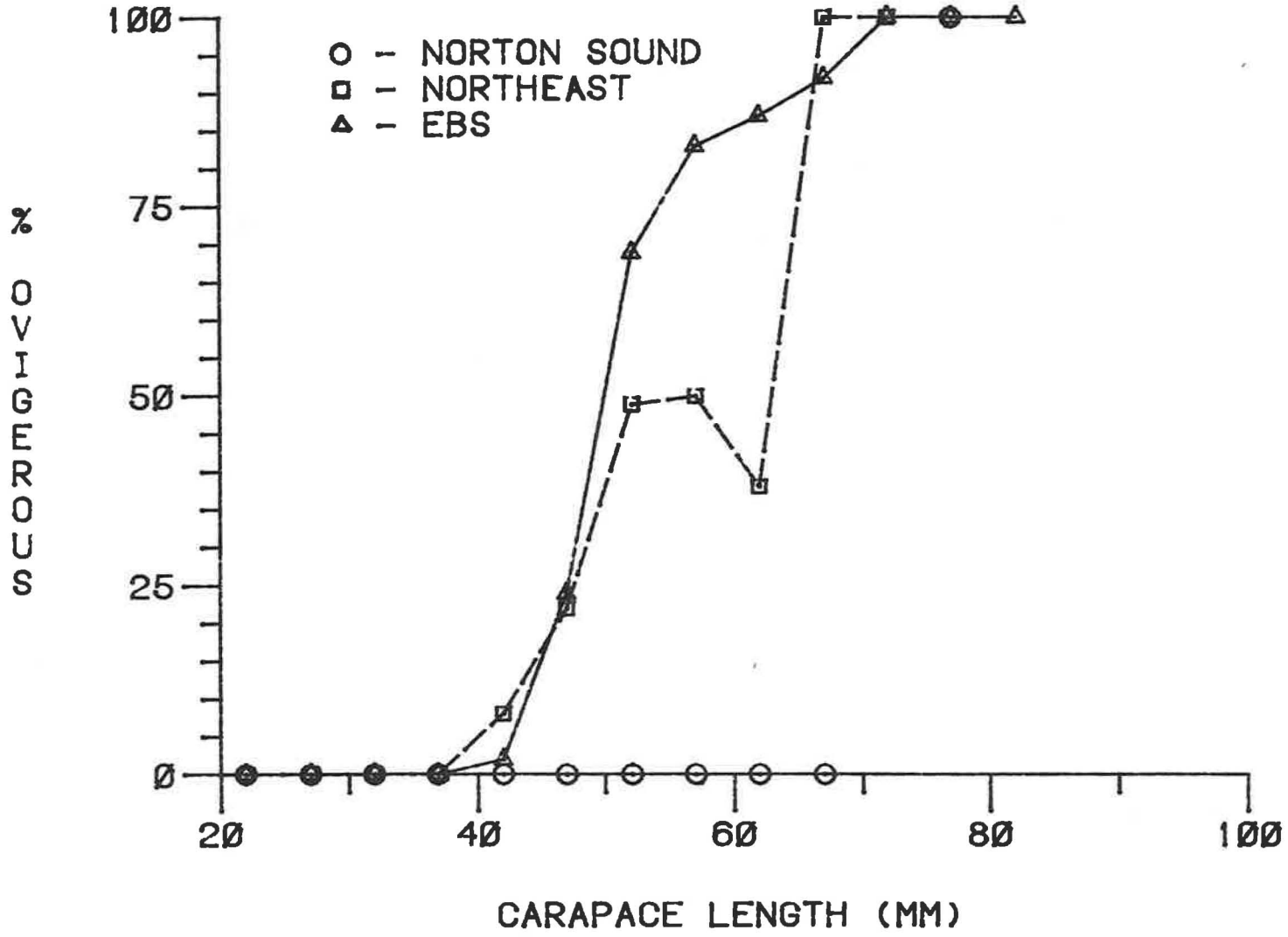

Figure 12.--Percent of female Tanner crabs, Chionoecetes opilio, ovigerous, by 3-mm carapace width groups, for Norton Sound, northeast Bering Sea, and eastern Bering Sea (EBS).

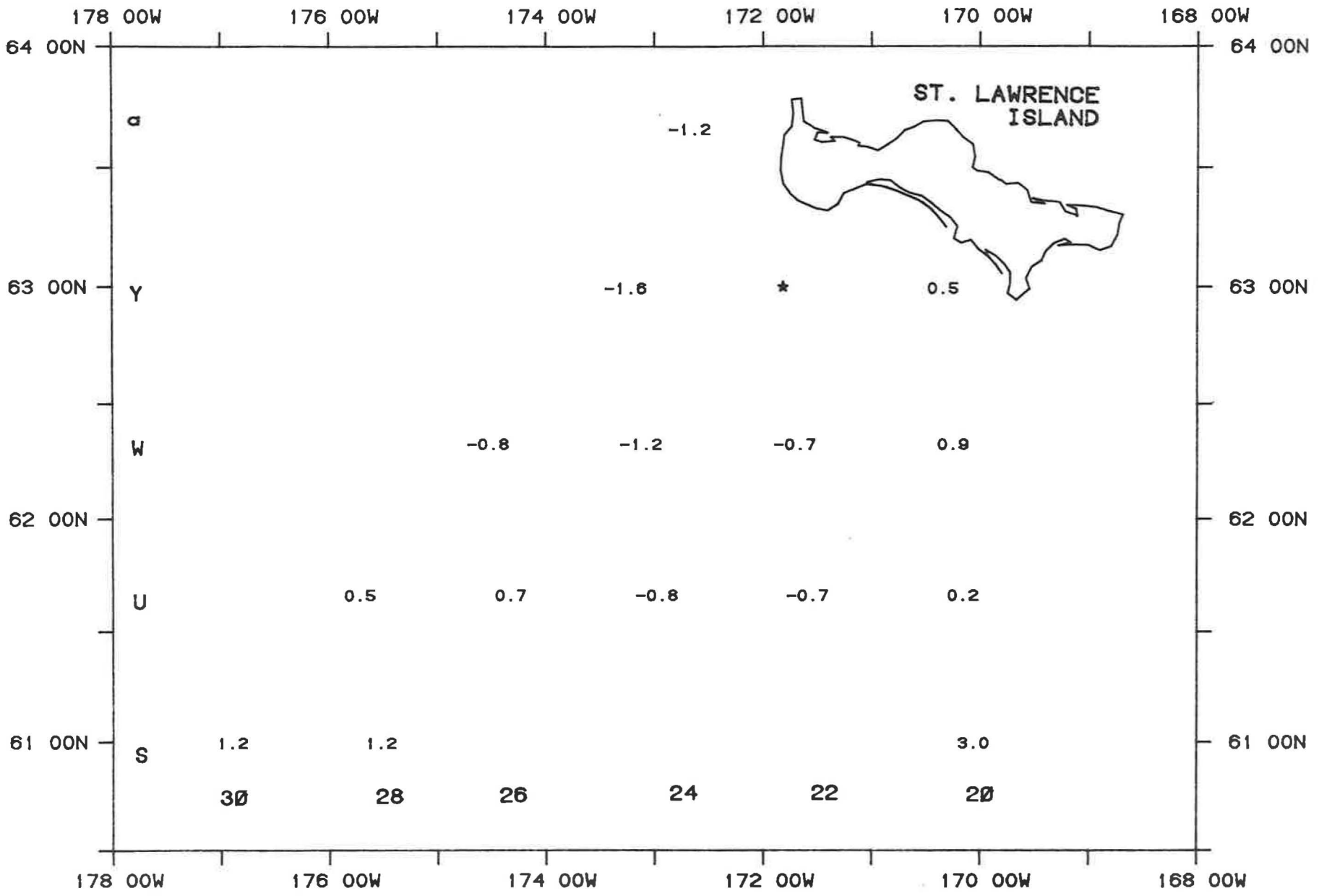

Figure 13.--Bottom water temperature (°C) at stations sampled in the northeast Bering Sea, 1985.

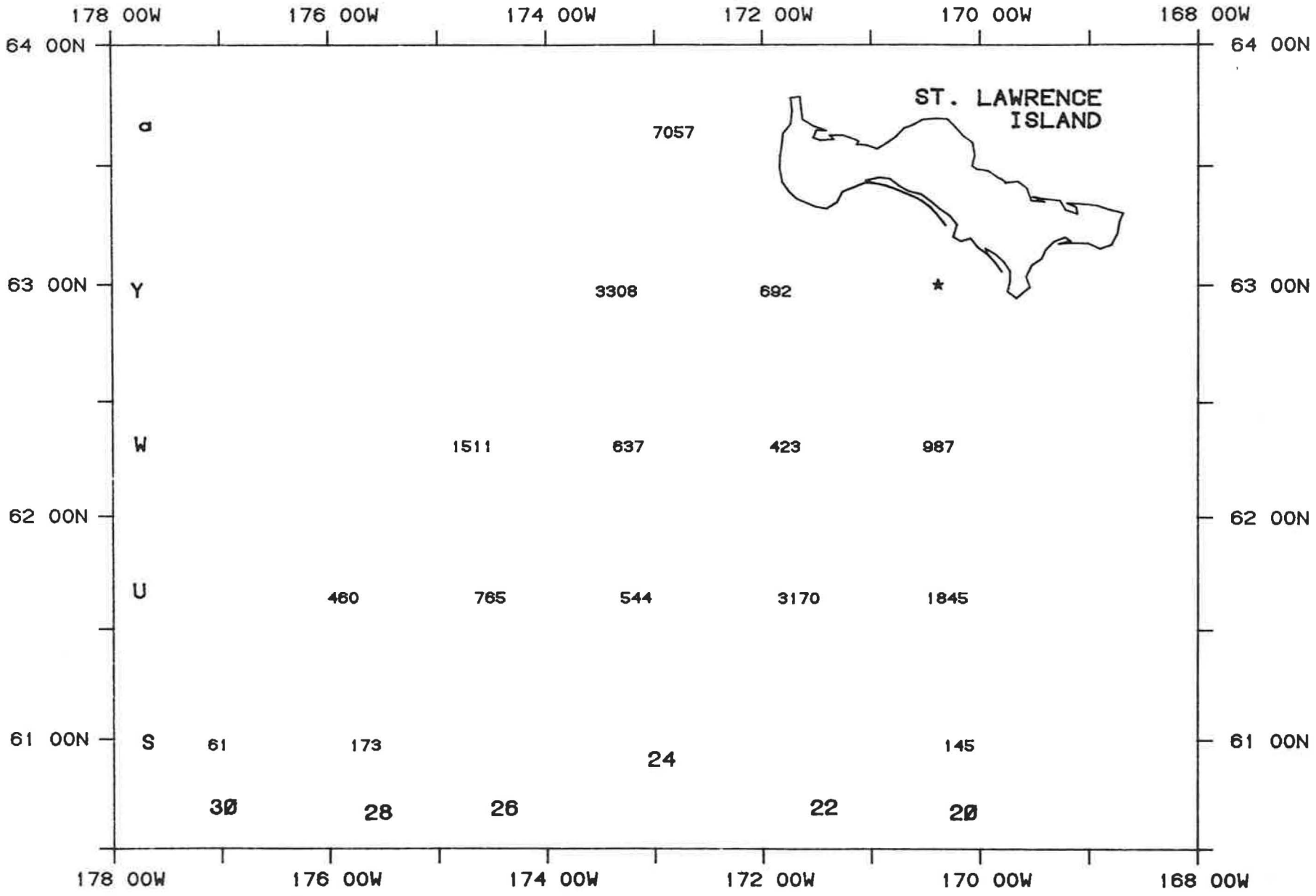

Figure 14.--Estimated number (100's) of crabs per square nautical mile for Tanner crab (Chionoecetes opilio) sublegal (≤77 mm carapace length) males at stations sampled in the northeast Bering Sea, 1985.

Table 1.--Mean size, depth, and temperature where captured for crab species in Norton Sound and northeast Bering Sea. Sizes are carapace length for red king crab (*Paralithodes camtschatica*) and blue king crab (*P. platypus*) and carapace width for Tanner crabs (*Chionoecetes bairdi* and *C. opilio*).

Species	Sex	No.	Depth (fm) mean	Depth (fm) range	Size (mm) mean	Size (mm) range	Temperature °C mean	Temperature °C range
NORTON SOUND								
Red King Crab	M	389	12.1	6-17	93.7	10-168	7.4	3.5-8.3
	F	151	10.2	5-15	66.5	16-103	7.2	5.2-8.3
Blue King Crab	M	2	13.5	12-15	108.0	104-112	6.6	6.3-6.9
	F	11	12.8	12-16	94.6	34-115	6.3	2.0-7.7
C. bairdi	M	84	10.6	5-15	50.4	35- 60	6.6	5.4-8.3
	F	13	9.5	5-15	49.2	37- 65	7.1	5.7-7.8
C. opilio	M	2726	11.2	3-17	34.4	7- 86	7.1	2.0-8.3
	F	1760	10.7	3-17	33.2	10- 77	7.1	2.0-8.3
NORTHEAST BERING SEA								
C. opilio	M	1742	37.5	20-66	47.2	10-134	0.3	-1.6-3.0
	F	751	34.9	20-66	38.8	3- 71	0.1	-1.6-3.0

Table 2.--Population estimates for Norton Sound red king crab (*Paralithodes camtschatica*) in four subareas. A) Actual sizes in trawl and pot surveyed areas; B) Adjusted sizes (after subtraction of recent growth increment) in trawl and pot surveyed areas; C) Actual sizes in areas open and closed to commercial fishing; D) Adjusted sizes in open and closed areas.

Sex	Length (mm)	Crab (x10⁶)	Lbs. (x10⁶)	CI[1] (± %)	Crab (x10⁶)	Lbs. (x10⁶)	CI[1] (±%)
A Standard Sizes		Trawl Survey Area			Pot Survey Area		
Males	0-89	1.354	1.075	69	0.811	0.699	56
	90-104	0.908	1.528	62	0.750	1.275	73
	>104	1.203	3.321	32	0.955	2.667	36
	All	3.465	5.924	45	2.517	4.641	48
Females	0-69	0.849	0.246	105	0.323	0.086	94
	>70	0.557	0.497	40	0.206	0.159	67
	All	1.406	0.744	70	0.528	0.245	70
B Adjusted lengths							
Males	0-89	1.523	1.180	65	0.906	0.753	55
	90-104	0.813	1.373	65	0.707	1.197	74
	>104	1.129	3.138	33	0.904	2.536	38
	All	3.465	5.691	45	2.517	4.486	48
Females	0-69	0.859	0.247	106	0.323	0.086	94
	>70	0.547	0.490	39	0.206	0.159	67
	All	1.406	1.183	76	0.528	0.245	70
C Standard Sizes		Open area			Closed Area		
Males	0-89	0.387	0.295	81	0.966	0.780	91
	90-104	0.373	0.633	44	0.535	0.895	100
	>104	0.768	2.195	25	0.436	1.126	77
	All	1.528	3.123	36	1.937	2.801	75
Females	0-69	0.240	0.055	132	0.609	0.191	136
	>70	0.261	0.236	41	0.296	0.261	65
	All	0.501	0.292	67	0.905	0.452	102
D Adjusted Lengths							
Males	0-89	0.454	0.349	79	1.070	0.831	86
	90-104	0.362	0.607	45	0.451	0.766	112
	>104	0.712	2.056	24	0.416	1.082	80
	All	1.528	3.012	36	1.937	2.679	75
Females	0-69	0.240	0.055	132	0.619	0.192	137
	>70	0.261	0.236	41	0.287	0.254	65
	All	0.501	0.292	67	0.905	0.446	102

[1]Confidence interval expressed as a percentage of the mean.

Table 3.--Population estimates for other crab species in Norton Sound and the northeast Bering Sea.

	Sex	Length (mm)	Crab (x10⁶)	Lbs. (x10⁶)	CI[1] (±%)
A	*Paralithodes platypus*				
	Males	100-119	0.016	0.033	100
	Females	0-89	0.017	0.011	200
		>89	0.074	0.136	90
		All	0.091	0.147	107
B	*Chionoecetes bairdi*				
	Males	0-109	1.370	0.118	35
	Females	0-84	0.275	0.046	93
C	*C. opilio* in Norton Sound				
	Males	0-77	53.863	2.171	28
		>77	0.025	0.015	200
		All	53.888	2.186	28
	Females	0-49	31.968	1.525	25
		>49	1.498	.317	108
		All	33.466	1.842	25
D	*C. opilio* in Northeast Bering Sea				
	Males	0-77	3469.3	294.1	45
		78-101	13.0	11.6	104
		>101	9.7	13.2	112
		All	3492.0	318.9	45
	Females	0-49	1315.4	98.6	39
		>49	338.3	64.3	33
		All	1653.7	162.9	30

[1]Confidence interval about numbers and biomass expressed as a percentage of the mean.

ACKNOWLEDGMENTS

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APPENDIX A

Parameters of Length-Weight Regressions

Species	Males		Females with eggs		Females without eggs	
	a	b	a	b	a	b
Paralithodes camtschatica	0.004808	2.615	0.001445	2.840	0.000794	2.950
Paralithodes platypus	0.000329	3.175	0.114389	1.919	0.035988	2.156
Chionoecetes bairdi	0.000190	3.099	0.003661	2.564	0.001823	2.705
Chionoecetes opilio	0.000230	3.129	0.000675	2.943	0.002527	2.564

APPENDIX B

Crab Shell Conditions

National Marine Fisheries Service biologists estimate the shell condition of crabs according to the following scale:

0= Crab preparing to molt or in process of molting.
1= Very new shell. Soft, flexible, watery. Indicates crab molted within hours or days.
2= New shell; hard and usually clean. Crab molted within previous year.
3= Oldshell, or skipmolt. Crab has not molted within year.
4= Very old shell. Crab may not have molted for 2 years.
5= Extremely old shell. Crab may not have molted for 3 or more years.