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Reproductive Biology and Distribution of the Snow Crab from the Northeastern Chukchi Sea

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Abstract.—We determined size at maturity, fecundity, distribution, and abundance of the snow crab *Chionoecetes opilio* during 1990 and 1991 in the northeastern Chukchi Sea, Alaska. Snow crab abundance and biomass varied extensively between stations but tended to be greatest in the southern part of the study area and offshore rather than inshore. Biomass estimates varied extensively, ranging from 1.2 to 4,000 kg/km^2. At all latitudes most females with mature-shaped abdominal flaps were gravid. The smallest ovigerous snow crab was 34-mm carapace width (CW). Average CW of ovigerous females was 46 mm (SD = 4) and carried 19,900 (SD = 6,500) eggs. The equation describing the relationship between CW and the number of eggs (Y) per clutch was $Y = 0.672\ (\mathrm{CW})^{2.668}$; $r^2 = 0.54$. The vasa deferentia of males were examined for the presence of spermatophores. All males 35-mm CW and greater had spermatophores; only 19% with CW of 25- to 29-mm were so classified. Spermatophore diameters increased from about 44 μm in 25- to 29-mm CW males to about 64 μm in males 35- to 44-mm CW. Spermatophore diameters for crabs between 45- and 70-mm CW were similar, generally between 75 and 80 μm.

The snow crab *Chionoecetes opilio* is a circumpolar species for which there are substantial fisheries in the Atlantic and the Pacific oceans. In the northwest Pacific Ocean, snow crabs occur in the northern Sea of Japan, the Bering and Chukchi seas from Wrangel Island to Point Barrow, and the Beaufort Sea at the mouth of the Mackenzie River (Slizkin 1989). Most of the existing information on the biology of this species has been developed for the northwestern Atlantic Ocean or the Sea of Japan stocks (Bowerman and Melteff 1984).

In the northeastern Chukchi Sea, snow crabs are a dominant benthic species, but because they are not harvested their basic biology is poorly described. This preliminary survey provides new information on distribution trends and reproduction for a seldom-sampled population.

Methods

The sampling sites were dictated by oil lease sales in the area north and east of Point Hope (north of approximately 68°20′), east of the international boundary (168°58′), and limited in the north by sea ice. Before sampling, 11 transects and 56 stations were located perpendicular to the coast on a nautical chart. Stations were positioned approximately 55–110 km apart depending on transect length. Nearshore stations were established closer to one another so that within a transect there were at least two stations bounded by the coastal current. In 1990 there were 48 stations sampled and in 1991 there were 8 additional stations sampled to examine snow crab abundance and biomass (Figure 1). Sea ice or bad weather precluded actual collection at some of the predetermined station positions, so samples were taken as close as possible to the desired site.

During 1990 the bottom temperature averaged 3.8°C (SD = 3.3°C) and ranged from −1.0 to 12°C; salinity was 29–33 ppt. Contour maps of bottom temperature and salinity for 1990 occur in Weingartner (1997, this volume). During 1991 the bottom temperature averaged 0.1°C (SD = 2.0°C), and ranged from −1.0 to 7°C; salinity was 29–33 ppt.

A chartered 34-m commercial trawler, *Ocean Hope III*, was used during 16 August to 17 September 1990 and 10–23 September 1991 to collect snow crab abundance and distribution data. Otter trawling from this vessel was conducted with the National Marine Fisheries Service's standard 83-112 survey trawl, which was fished directly on the bottom. The trawl had a 34.1-m footrope set back 7 cm from a tickler chain and a 25.2-m headrope. The mesh of the cod end was 90 mm and contained a 32-mm stretched mesh liner. The effective opening of the net was monitored by a Scanmar electronic mensuration unit hung from one wing; the net fished as expected. At most stations there were two 30-min tows in sequence along the same tract.

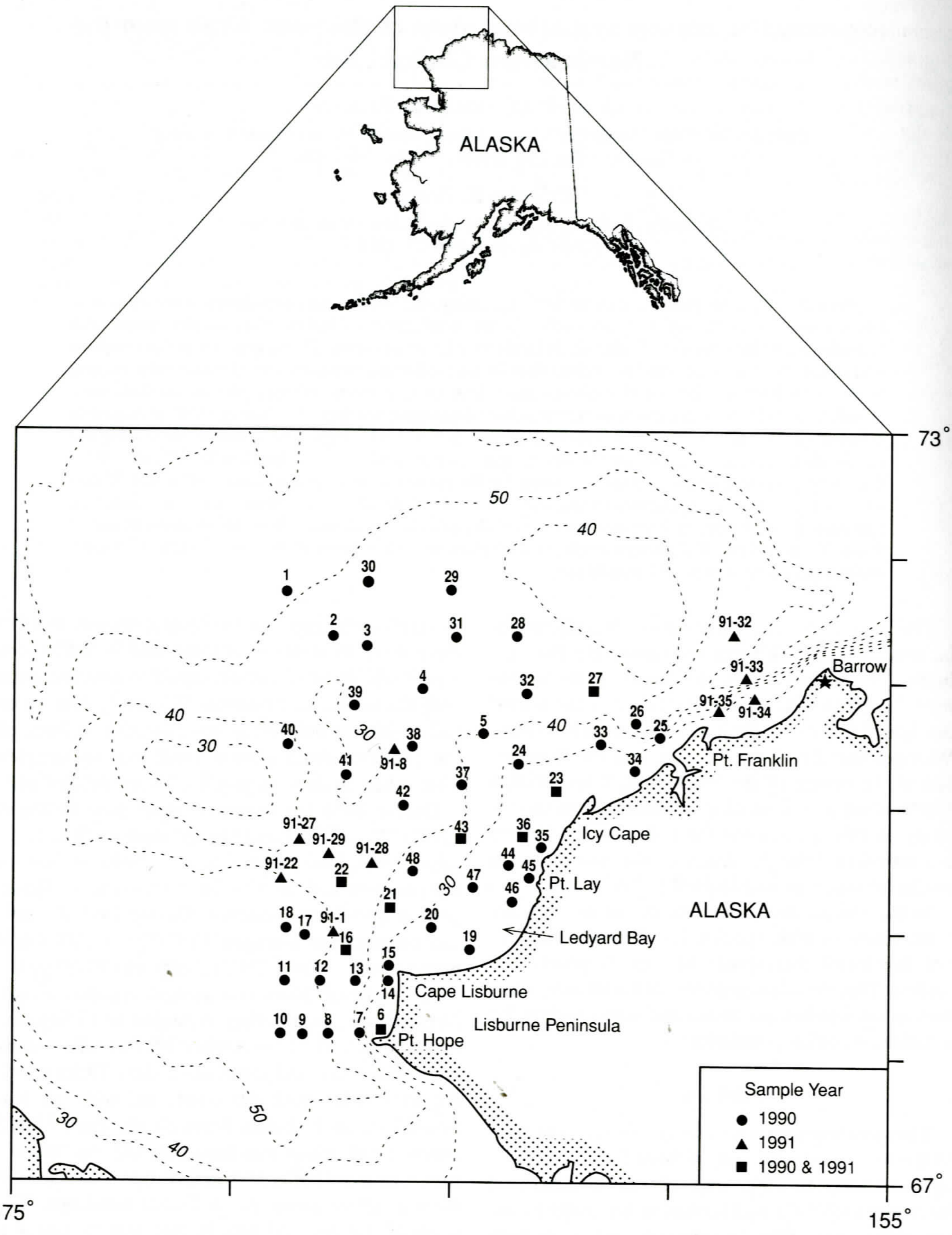

FIGURE 1.—Stations sampled for distribution and abundance of the snow crab *Chionoecetes opilio* in the northeastern Chukchi Sea during 1990 and 1991. Dotted lines indicate depth contours.

At most stations a gross weight of all snow crabs combined was measured; then all snow crabs were counted. Periodically, catches had more crabs or other species than could be processed before the next trawl sample. In those cases, all the snow crabs in the catch were put into baskets. Baskets were filled one at a time as the crew cleared the sorting area and no bias such as size selection was apparent. All baskets were then weighed and some were randomly selected to obtain the number and weight of snow crabs. The average weight of snow crabs at a station was estimated by dividing the total weight of all individuals in the sample by the number of crabs. Weighing individuals separately was not feasible aboard ship.

Abundance (number/km^2) and biomass (kg/km^2) estimates were based on trawl-opening width, the distance trawled, and the numbers and biomass of the catch. The distance trawled was determined from the ship's location at the beginning and end of each set by a Global Positioning System. The data from both tows at a station were averaged to estimate the abundance and biomass at each station.

The 73-m *Oshoro Maru* was used in July 1991 to collect snow crabs for additional reproductive observations; its otter trawl net had a 43.3-m headrope, a 48.6-m footrope with roller gear, and 90-mm stretched mesh with a 32-mm stretched mesh liner. These samples were not used to estimate abundance or biomass.

To examine the relationship between crab size and latitude, the carapace width (CW) of all the females collected at station 21 ($N = 25$) in July 1991 and at stations 23 ($N = 51$) and 91–32 ($N = 88$) in September 1991 (Figure 1) were measured to the nearest 1 mm. The CW of all males from stations 91-1 ($N = 125$) and 91–8 ($N = 131$) collected in July 1991 were also measured to the nearest 1 mm. Station locations are shown in Figure 1.

To determine if mature female snow crabs occurred throughout the sampling area, 503 females from 20- to 64-mm CW (Table 1) were collected at 14 sites (Table 2) in July and September 1991. They were examined for the presence of a mature-shaped abdominal flap and eggs.

In the August and September collections, eggs were too developed for fecundity estimates, but 93 females collected at station 1 in July had clutches of bright orange eggs that appeared to be recently extruded. Two females with new eggs had damaged abdominal flaps, so the eggs from only 91 clutches were counted. The dry weight of 100 eggs subsampled from each of the 91 clutches was measured. Eggs were dried at 60°C in a convection oven until a constant weight was reached. The remaining eggs on the pleopods of each female were removed and dried as previously stated. Fecundity estimates were determined by dividing the dry weight of the total egg mass by the average dry weight of eggs in the subsample. The number of eggs (Y) was related to carapace width with a power curve: $Y = a(CW)^b$, where $a > 0$).

Males ($N = 318$) used for maturity studies were all captured in September 1991 at stations 16, 21, 22, 27, 91-29, and 91-32 (Figure 1). Males over 20-mm CW were divided into groups based on 5-mm increments and had to be taken from several stations to get a minimum of 25 males of the desired

TABLE 1.—Number of snow crabs *Chionoecetes opilio* from the northeastern Chukchi Sea examined for the presence of eggs (in July and September) and spermatophores (in September), 1991.

Carapace width (mm)	Females		Males	
	Total number	Percent with eggs	Total number	Percent with spermatophores
15–19	0	0	1	0
20–24	17	0	36	0
25–29	27	0	37	19
30–34	54	2	49	49
35–39	29	52	25	100
40–44	156	73	25	100
45–49	169	86	26	100
50–54	41	93	29	100
55–59	9	75	25	100
60–64	1	100	25	100
65–69	0		26	100
70–74	0		14	100
Total	503		318	

TABLE 2.—Number of northeastern Chukchi Sea female snow crabs *Chionoecetes opilio* with mature-shaped abdominal flaps carrying eggs, July and September 1991.

Station location		Females		
Latitude N	Longitude W	Total number	Number with mature-shaped abdominal flaps	Percent with eggs
69°02′	167°38′	100	97	98
69°03′	166°43′	12	2	100
69°23′	166°28′	22	16	100
69°32′	165°59′	8	7	100
69°38′	167°41′	50	48	98
69°40′	168°31′	50	44	100
69°54′	168°42′	35	34	100
70°00′	165°03′	4	2	100
70°13′	167°05′	27	24	96
70°21′	162°53′	51	0	0
70°31′	166°08′	50	42	98
70°33′	162°20′	4	0	0
70°58′	163°39′	2	1	100
71°37′	159°02′	88	7	100

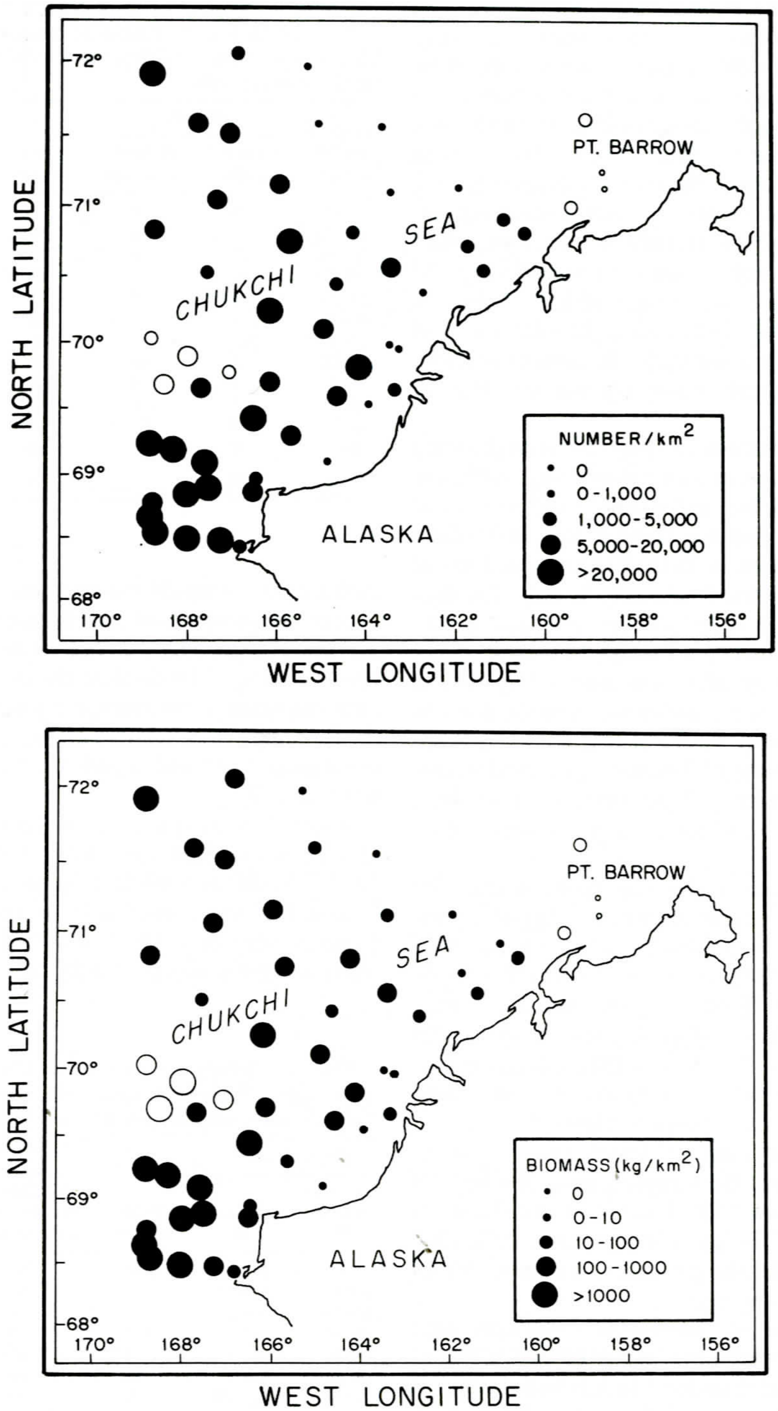

FIGURE 2.—Abundance (upper panel) and biomass (lower panel) of the snow crab *Chionoecetes opilio* captured by otter trawl at stations occupied in the northeastern Chukchi Sea during 1990 (closed circles) and 1991 (open circles).

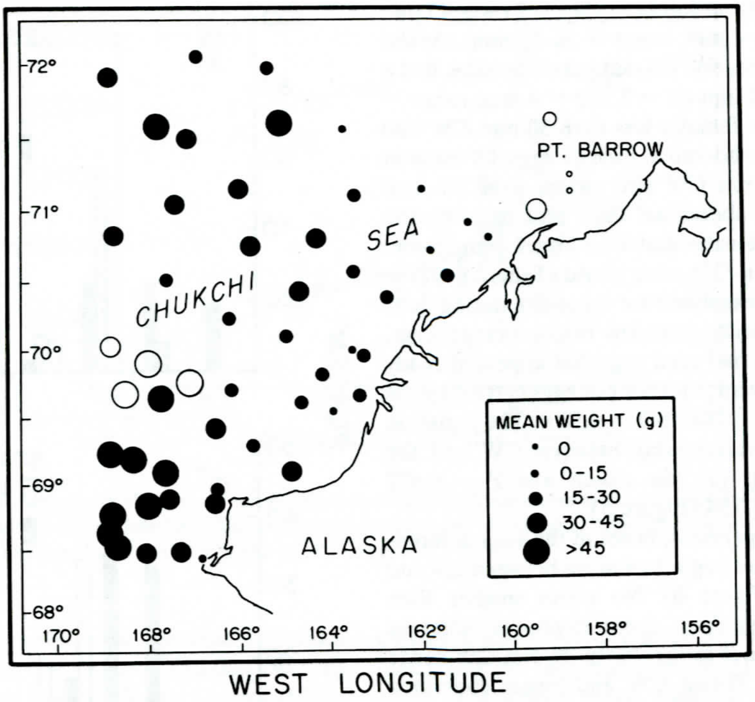

FIGURE 3.—Mean weight of the snow crab *Chionoecetes opilio* captured by otter trawl at stations occupied in the northeastern Chukchi Sea during 1990 (closed circles) and 1991 (open circles).

sizes (Table 1). In the group with the largest males (70- to 74-mm CW) only 14 individuals were captured. Size at the onset of physiological maturity was determined by histological examination of the vas deferens for spermatophores. The vasa deferentia were fixed in Bouin's solution, embedded, sectioned to 10–12 μm thick, and mounted following the techniques of Paul and Paul (1989). Standard Ehrlich's hematoxylin and eosin-y staining sequence (Clarke 1973) was used to enhance morphological identification of spermatophores.

Results

Snow crabs were present at all stations, with the largest abundance and biomass tending to be in the southern part of the study area, but varying extensively between stations (Figure 2). Abundance and biomass estimates also varied considerably between trawls at most stations. The highest estimated mean abundance was at station 1 (100,000/km^2). The largest mean biomass (4,000 kg/km^2) was at station 8, although station 1 biomass was nearly equivalent (3,100 kg/km^2). Lowest mean abundance was at station 28 (190/km^2), whereas the lowest biomass estimate occurred at station 35 (1.2 kg/km^2). Average crab weight (total weight of catch/number of crabs) was generally greater in the southern area than in the northern area and lower inshore than offshore (Figure 3). Individuals from stations south of about 70°N generally had greater average weight, but there was extensive variation. This trend was also reflected in carapace width. The smallest female crabs occurred at the northern sample sites (Figure 4). At the most northern station at which they were captured (91-32), the average size of all females (N = 88) was 33-mm CW (SD = 9 mm, range = 20–54 mm). At the more southern stations 23 (N = 51) and 21 (N = 22), female CW averaged 35 mm (SD = 5 mm, range = 28–44 mm) and 45 mm (SD = 4 mm, range = 36–50 mm), respectively. Male size at the north (91-8) and south (91-1) stations follow this same pattern (Figure 4). Gravid females were found at all latitudes sampled and 99% of those with mature-shaped abdominal flaps carried eggs (Table 2). Egg-bearing females ranged from 34- to 60-mm CW and averaged 46 mm (SD = 4 mm). Most females greater than 35-mm CW were carrying eggs (Table 1). The average size of the gravid females from southern station 21 was 45 mm (N = 16, SD = 4 mm, range = 36–50 mm). At the more northern station (91-32) gravid females had a mean CW of 50 mm (N = 7, SD = 4 mm, range = 44–54 mm). No females less than 30-mm CW had mature-shaped abdominal flaps or eggs. Of those in the 30- to 34-mm CW size group, only 2% had mature-shaped abdominal flaps and eggs. In the size groups of females that were larger than 35-mm CW, no less than 52% were gravid (Table 1). Of the gravid females examined for fecundity during July, 93 carried recently extruded bright orange eggs, while 4 females had eyed eggs that appeared ready to hatch. The average number of eggs carried by the 91 females was 19,900 (SD = 6,500). The equation describing the relationship between CW and the number of eggs (Y) per clutch was $Y = 0.672\,(\mathrm{CW})^{2.668}$; $r^2 = 0.54$ (Figure 5).

Presence of spermatophores in the vasa deferentia suggests males begin to mature between 25- and 29-mm CW (Figure 6). No males smaller than 25-mm CW contained spermatophores, whereas only 19% of males in the 25- to 29-mm CW range did. All males 35-mm CW and larger contained spermatophores (Table 1). Spermatophore diameters increased from about 44 μm in the 25- to 29-mm CW size group to 64 μm in males greater than 35-mm CW. In males between 45- and 70-mm CW, spermatophore diameters were approximately 75–80 μm (Figure 6).

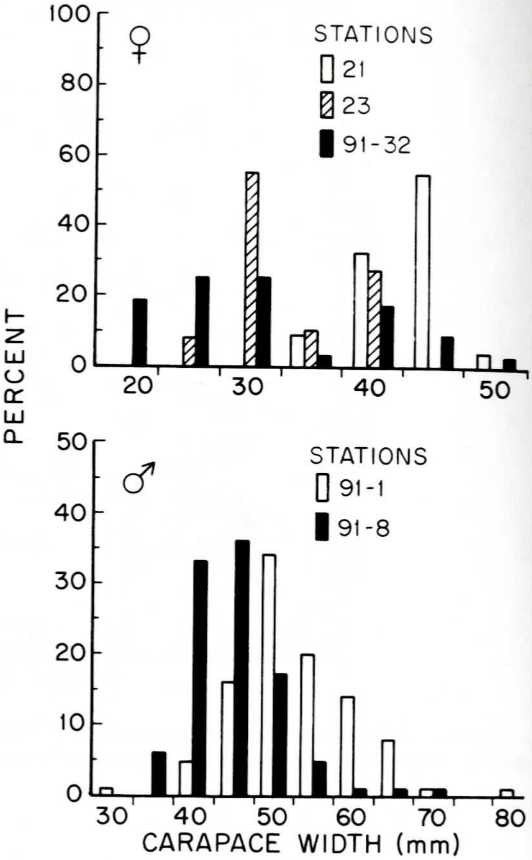

FIGURE 4.—Carapace widths of northeastern Chukchi Sea female snow crabs *Chionoecetes opilio* (upper panel) from stations 21 (69°26′N, 166°31′W), 23 (70°22′N, 162°43′W), and 91-32 (71°37′N, 159°02′W), and from male snow crabs (lower panel) from stations 91-1 (69°02′N, 167°38′W) and 91-8 (70°31′N, 166°08′W).

Discussion

Although snow crabs are widely distributed throughout the northwestern Atlantic Ocean (Elner 1982), Bering Sea (Otto 1982; Slizkin 1989), and northeastern Chukchi Sea (this study) little is known about the factors influencing their distribution and abundance. These factors must include larval recruitment dynamics, benthic habitat requirements, thermal tolerance, water depth preferences, predation, competition, and cannibalism, but the relative importance of each of these factors is unknown.

Prey preference for specific sediment types or depths may explain some of the distribution pattern observed for the snow crab. In the northwestern Gulf of St. Lawrence, where depths exceeded 135 m, Derosiers et al. (1982) found increases in snow crab size with increasing depth. The northeastern Chukchi Sea stations sampled (Figure 1), with one exception (91-33), had depths with a range of only 14–52 m, and snow crabs were found at every station. In the northeastern Chukchi Sea, the benthic sediments (Sharma 1979) form a general pattern of long, narrow gravel belts along the shore and in a few isolated patches in offshore regions. Sand predominates in nearshore areas, and silts and clays predominate offshore. Within this broad pattern, however, there is a mosaic of sediment types (Naidu 1988). Thus, during sampling we probably trawled across several bottom types, each with its own prey community. To better identify sediment habitats preferred by snow crabs, smaller areas must be sampled.

Chukchi Sea snow crabs tend to be smaller than those from the Bering Sea or the northern Atlantic Ocean. Chukchi Sea females averaged 46-mm (this study) to 50-mm CW (Jewett 1981) versus 63- to 72-mm CW in the Bering Sea (Somerton 1981). In

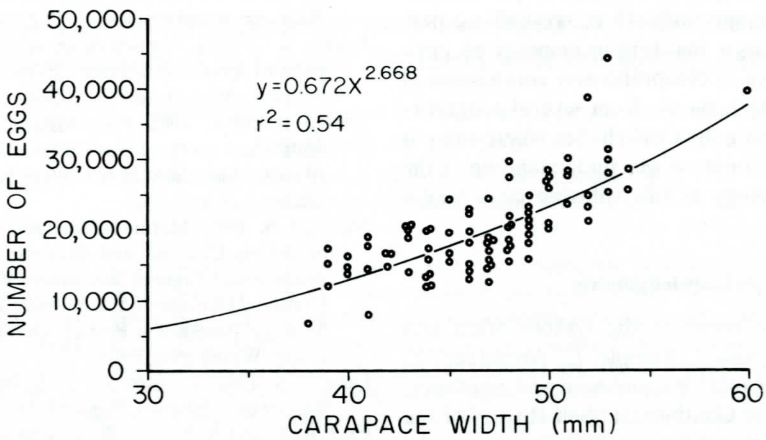

FIGURE 5.—Number of eggs in clutches of various-sized snow crabs *Chionoecetes opilio* captured by otter trawl in the northeastern Chukchi Sea during July 1991. The equation describing the relationship between carapace width (CW) and the number of eggs (Y) per clutch was $Y = 0.672\ (X)^{2.668}$ where X = CW.

commercial fisheries the legal size limit for males ranges from 78-mm CW in Japan (Sinoda 1982) to greater than 94-mm CW in Atlantic Canada (Elner 1982). Chukchi Sea males seldom reach 78-mm CW.

Fecundity estimates for snow crabs from this study are similar to other estimates (Jewett 1981). Fecundity of snow crabs is positively correlated with body size (Haynes et al. 1976; Paul and Fuji 1989). In the southeastern Bering Sea, a 55-mm CW female would have about 24,500 eggs (Haynes et al. 1976) versus 29,000 (Figure 6) for Chukchi Sea specimens 55-mm CW. In Atlantic Canada multiparous females typically carry 52,000–80,000 eggs, depending on geographic region (Davidson et al. 1985). There they reach maturity around 50-mm CW (Watson 1970) and a 55-mm female would carry about 26,600 eggs (Haynes et al. 1976).

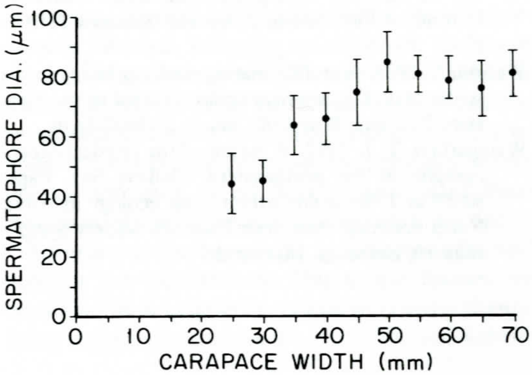

FIGURE 6.—Diameter of spermatophores in relation to size of male snow crabs *Chionoecetes opilio* captured by otter trawl in the northeastern Chukchi Sea during September 1991. Vertical bar represents ± 1 SD.

In 1976 Jewett (1981) found that only 3.3% of mature Chukchi Sea females were ovigerous versus 99% in this study. He collected in September and October with a benthic trawl, so the sampling period and collection gear were similar. He reported that 93% (N = 63) of mature females without external eggs had developing orange ova, so it is possible that they had not yet ovulated. In 1991 snow crabs had extruded eggs before 25 July. These contrasting observations suggest that the dates of snow crab ovulation vary interannually.

Based on claw morphometrics, Somerton (1981) estimated that 50% of male snow crabs in the Bering Sea that reached 65-mm CW were mature. In the northeastern Chukchi Sea, males greater than 65 mm are rare and all those greater than 35 mm have sperm. However, Hartnoll (1965) emphasized that spermatophore presence in small males is only circumstantial evidence of maturity. Laboratory studies and in situ observations are needed to identify the size at which male Chukchi Sea snow crabs mate with primiparous and multiparous mates.

Recently there has been considerable speculation on the reproductive habits of the snow crab, especially the importance of carapace and claw sizes of males (Conan and Comeau 1986). Comparison of size at maturity of female snow crabs from the

Chukchi Sea, Bering Sea, and the north Atlantic suggests that this species has a considerable capacity to modify size at maturity in response to environmental factors. A comprehensive comparison of snow crab mating behavior from several geographical areas, including the Chukchi Sea where there is no fishery, could improve our understanding of the reproductive biology of this valuable circumpolar species.

Acknowledgments

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