Preliminary Notes on the Reproductive Condition of Mature Female Snow Crabs (*Chionoecetes opilio*) from Disko Bay and Sisimiut, West Greenland

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Abstract

In the first week of June 1998-2000, female snow crabs were collected from exploited populations in Disko Bay and the area around Sisimiut, to study the reproductive condition of mature females. Analyses of ovaries and broods were performed on the females. Eggs hatched mainly in April and May and the fecundity was positively correlated with carapace width at both locations. Based on the development of ovaries and brood, females seem to have a 2-year reproductive cycle in the colder area around Sisimiut and a 1-year reproductive cycle in Disko Bay where bottom temperature is warmer.

Introduction

The snow crab, *Chionoecetes opilio*, has recently become commercially exploited in Greenland. The fishery developed in 1996 and landings reached 11,000 t in 2000. The fishery is distributed (Fig. 1) from Paamiut in the south (61°N) to Uummanaaq in the north (71°N). Until 1998, mainly an inshore fishery prosecuted snow crab, but in the past 2 years an offshore fishery has developed. Until 2000, the fishery was little regulated. Only males > 90 mm in carapace length are harvested, while females are protected.

Biological research and monitoring were started in 1996. Since 1997 an annual trap survey has been conducted in Disko Bay and inshore areas near Sisimiut, on the west coast of Greenland. Owing to the recent development of the fishery and lack of research on snow crab, knowledge of this stock and its biology are poor.

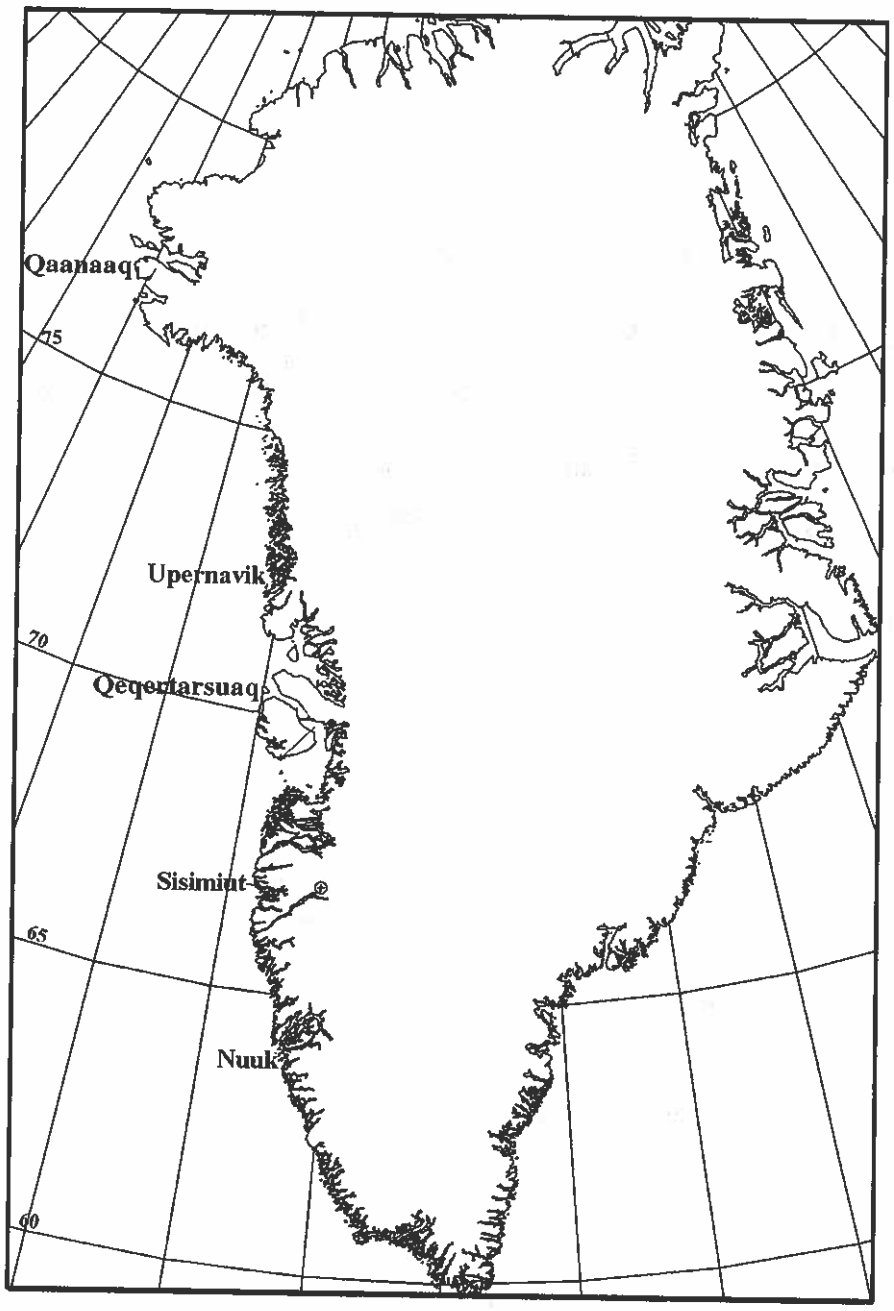

Figure 1. Greenland.

Based on the existing knowledge of snow crab biology in eastern Canada, it is clear that gaining a better understanding of the female reproductive cycle is very important for fishery management (Comeau et al. 1999). Both sexes are functionally mature after their terminal molt, which can occur over a wide range of sizes (e.g., Conan and Comeau 1986, Sainte-Marie and Hazel 1992, Sainte-Marie et al. 1995). Mature females include primipara, which are first-time spawners, and multipara which are repeat spawners (Sainte-Marie 1993). Multiparous females can be distinguished from primiparous females by their older carapace and the presence on their legs of scars inflicted by males during previous matings (Sainte-Marie and Carrière 1995).

In eastern Canada, Mallet et al. (1993) showed that eggs were brooded for 2 years in the Gulf of St. Lawrence. Sainte-Marie (1993) observed that maturation of the brood and ovaries took 24 or 27 months for multiparous and primiparous females, respectively, in Baie Sainte-Marguerite; Comeau et al. (1999) noted an egg incubation period of 2 years for multiparous females in Bonne Bay. The common conclusion was that the females from those areas have a 2-year reproductive cycle. Moriyasu and Lanteigne (1998) pointed out that females also have a 2-year reproductive cycle in the southern Gulf of St. Lawrence owing to the low temperature. In Japan, laboratory studies by Kon (1974) determined that the embryonic development lasted 1 year at temperatures greater than 4.5°C.

The main objective of this study was to obtain preliminary information on egg stage, brood and ovary development, and fecundity from mature females collected in Disko Bay and around Sisimiut. I sought possible evidence of differences in the reproductive cycle between the two areas, based on the assumption that their different temperature regimes would influence ovary development and egg incubation. This study will also provide knowledge on the period of hatching and spawning in the fishing areas in Greenland.

Materials and Methods

Study Area and Sampling Procedure

Female snow crabs were collected in Disko Bay (68°40′N to 69°25′N, 51°15′W to 53°W) (Fig. 2) and in three fjords: Itilleq, Qeqertalik, and Kangerluarssuk near Sisimiut (66°30′N, 53°30′W) (Fig. 3). Snow crabs were captured in traps with a mesh size of 21 mm from randomly selected locations in the study area, at depths of 200-400 m. Bottom temperature was recorded by a Seamon mini-recorder (made by Hugrún, Iceland), which was secured to the traps and programmed to record every 15 minutes. Samplings were conducted in the first week of June in 1998, 1999, and 2000. Primiparous and multiparous females were sorted onboard, carapace width (CW) was measured with a vernier caliper to the nearest 0.01 mm, and shell and brood condition were determined according to the criteria given by Sainte-

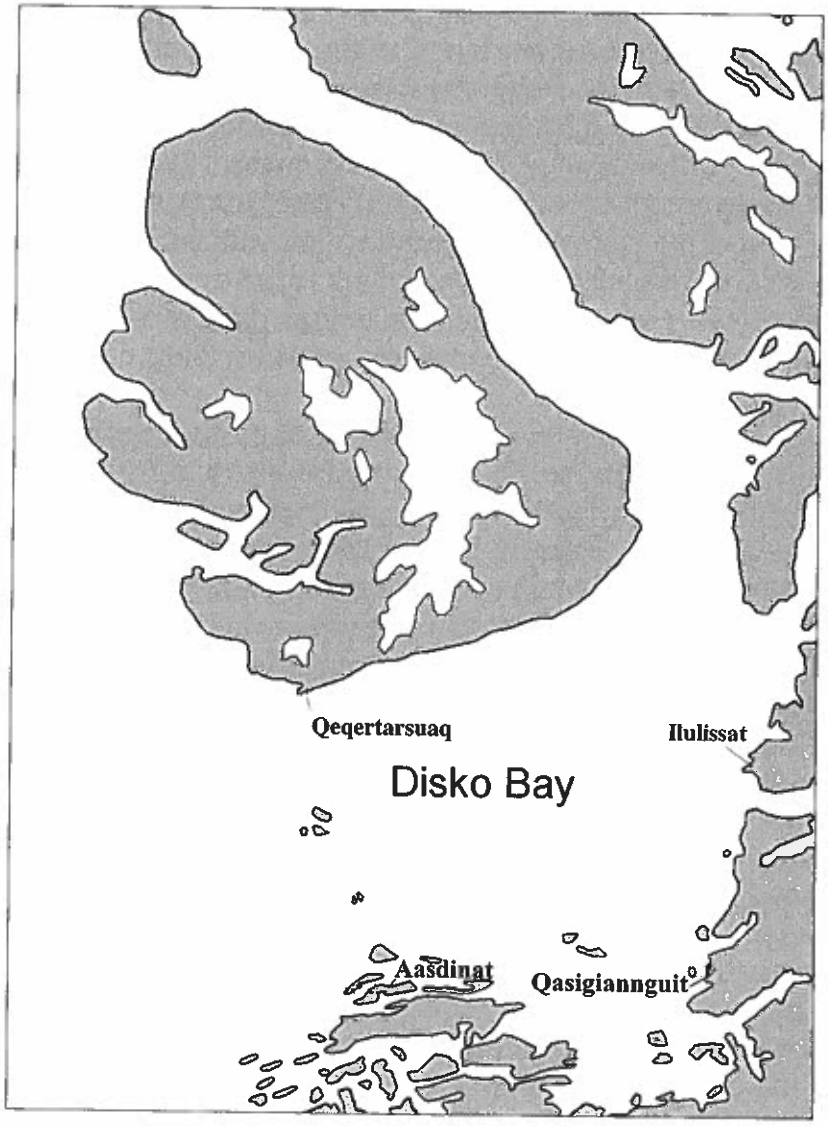

Figure 2. Study area in Disko Bay. Samples were taken during the trap survey in June from 1998 to 2000.

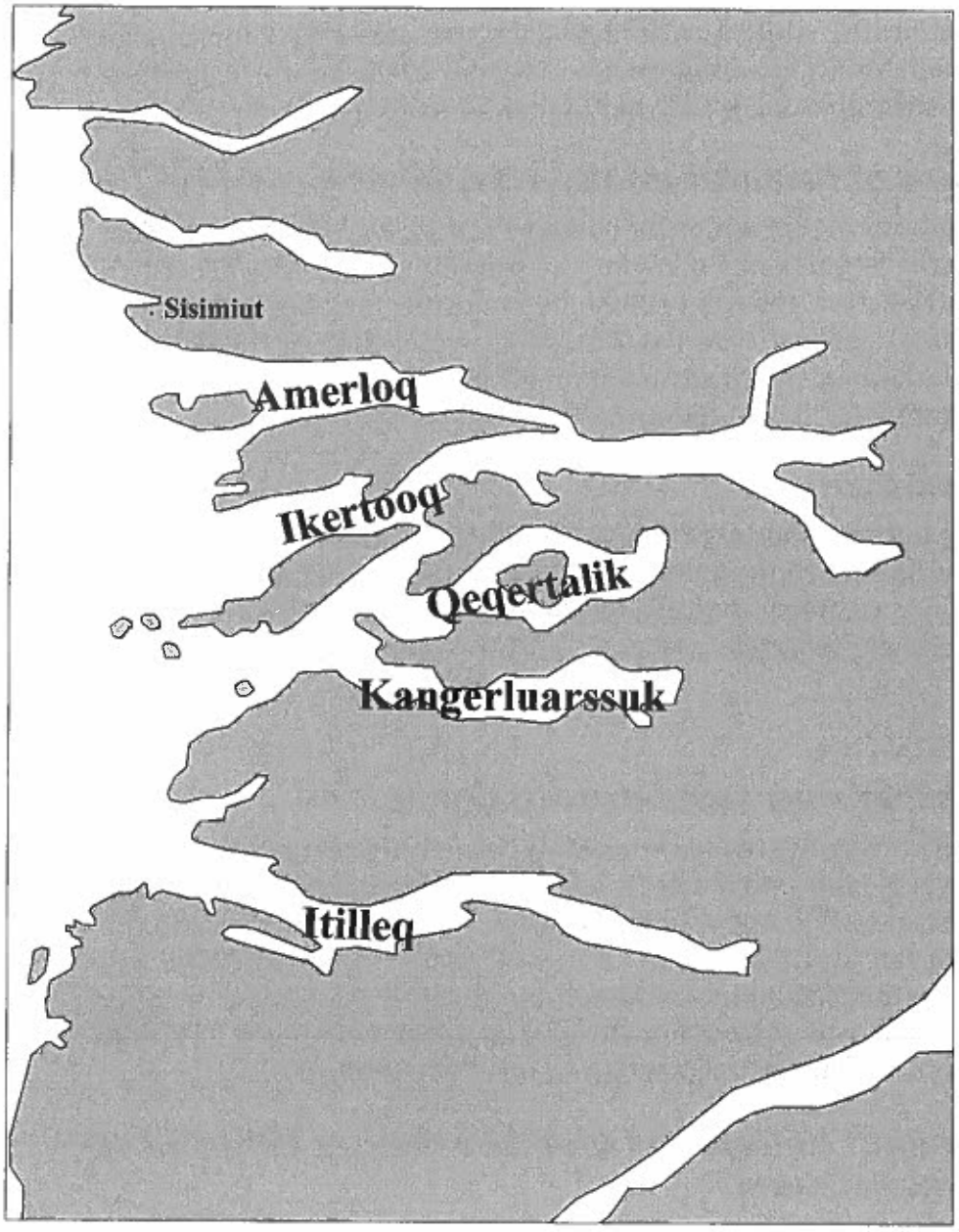

Figure 3. Study area of Sisimiut. Samples were taken in the fjords Itilleq, Kangerluarssuk, and Qeqertalik, during the trap survey conducted in June from 1998 to 2000.

Marie (1993). Unfortunately, analysis of data subsequently showed that primiparous and multiparous females were not all properly classified. Therefore the two types were not distinguished in analyses.

Subsampling of Females and Laboratory Processing

Subsamples of both primi- and multiparous females were taken each year for analysis in the laboratory. Following the sampling procedure described by Mallet et al. (1993), three to five females were selected in each available 5 mm size class. Females were fixed in 4% seawater-diluted formalin. In the laboratory, the egg clutch, ovaries, and a subsample of 30 eggs from each female were weighed to the nearest 10^{-5} g.

Data Analysis

Fecundity was determined by dividing the weight of the whole clutch by the weight of individual eggs for each female. Descriptive statistics, correlation, and linear regression (Sokal and Rohlf 1981, Fowler et al. 1998) were use to describe variables and relationships among them.

Results

Weather and Temperature Conditions

In 1998, ice covered both areas during winter and it broke up in the beginning of May in Disko Bay and in the fjords near Sisimiut. Owing to the mild winters in 1999 and 2000, the ice cover in Disko Bay was very thin and the ice broke up in late April. The temperature measurements in Disko Bay and in the fjords near Sisimiut are given in Table 1. The temperature in Disko Bay was higher than in the fjords near Sisimiut, where shallow sills prevent offshore, deep warm water from entering the fjords.

Annual Changes in Color of Brood in Mature Females of Disko Bay and Sisimiut

In Disko Bay, a total of 1,105 mature females, ranging from 49 to 89 mm CW, were sampled in the first week of June from 1998 to 2000. The proportion of mature females carrying bright orange eggs without eyespots was 98% in 1998-1999 and 96% in 2000. Less than 1% of mature females carried broods with dark orange eggs having eyespots and only 4 mature females were observed with dark brown eggs. No females with empty eggshells were observed.

Near Sisimiut, a total of 6,404 mature females, ranging from 46 to 95 mm CW, were sampled from 1998 to 2000. In 1998 and 1999, 99% of mature females carried bright orange eggs without eyespots while the remainder carried dark orange eggs with eyespots or dark brown eggs. In 2000, 79% of the mature females carried bright orange eggs without eyespots and 16% carried dark orange eggs with eyespots. Three percent of females carried dark brown eggs, 4% had empty eggshells, and 1% had no brood.

Table 1. Bottom temperature (°C) in Disko Bay and Sisimiut in June 1998-2000.

	1998			1999			2000		
Locality	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Disko Bay	3.1	2.6	4.1	3.3	2.5	3.9	2.7	1.9	3.7
Sisimiut	0.8	0.6	1.9	1.1	0.5	2.1	0.4	−0.8	1.7

Clutch and Ovary Weight in Subsamples

A subsample of 475 mature females from Disko Bay and Sisimiut was examined to determine the weight of the clutch and ovaries. All females were carrying bright orange eggs without eyespots, except three females collected from Disko Bay in 2000, which had dark brown eggs. Clutch weight was positively correlated with carapace width for the mature females in Disko Bay and Sisimiut (raw data in Fig. 4; data transformed to their natural logarithm in Fig. 5).

Considering females from the Sisimiut area, scatterplots of ovary weight on female carapace width showed two clouds of points, which were also evident in data from June 2000 (Fig. 5). The two clouds of points were quite parallel and differed only in elevation. The upper cloud represents females with orange ovaries while the lower cloud represents females with beige ovaries. Proportions of females with orange and beige ovaries were respectively 40% and 60% in 1998, 63% and 37% in 1999, and 33% and 67% in 2000. A one-tailed *t*-test revealed that orange ovaries were significantly heavier ($P < 0.05$) than beige ovaries for females collected in Sisimiut. The equation of the regression line for females with orange ovaries was:

$$\ln(\text{ovary weight}) = 3.9552 \ln(\text{CW}) - 15.3009$$
$$(r^2 = 0.679, F = 54.79, P < 0.05),$$

while for females with beige ovaries it was:

$$\ln(\text{ovary weight}) = 2.7932 \ln(\text{CW}) - 11.3454$$
$$(r^2 = 0.841, F = 164.26, P < 0.05).$$

Females in Disko Bay had beige ovaries, excepting the three females with dark brown eggs, which had orange ovaries. A one-tailed *t*-test showed that mean ovary weight for females with beige ovaries was the same in Disko Bay and in fiords near Sisimiut ($P > 0.05$).

Number of Eggs per Clutch in Mature Females

Females from Disko Bay that were examined for fecundity probably carried recently extruded eggs, because their ovaries were very small. Three females

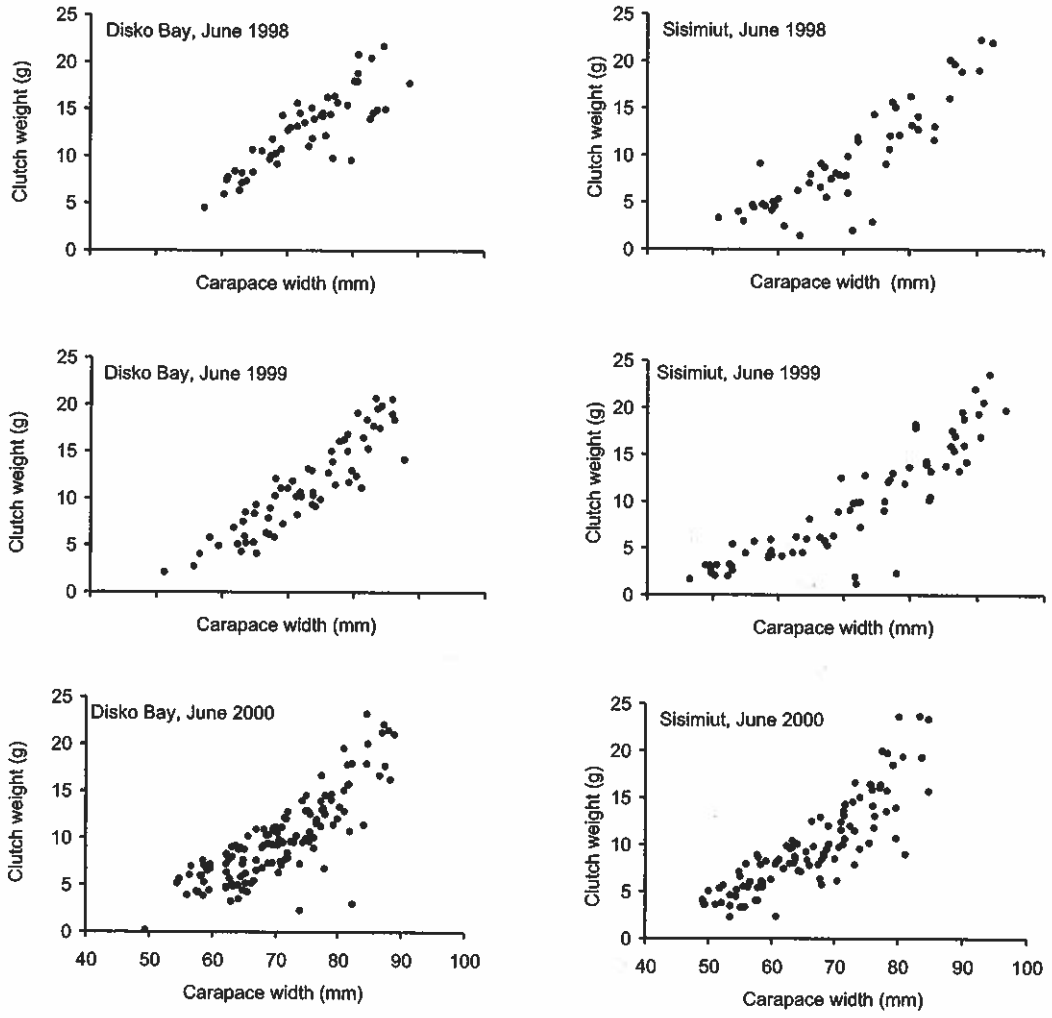

Figure 4. Clutch weight vs. carapace width for mature females collected in Disko Bay and Sisimiut in June 1998-2000.

with dark brown eggs were excluded from the analyses of fecundity. However, females from Sisimiut probably carried either recently extruded or older eggs, based on the difference in ovary development. Fecundity was positively correlated with carapace width (Fig. 6) and the equations

$$y = 0.7244\ CW^{2.6712}\ (r^2 = 0.619) \text{ and } y = 0.5395\ CW^{2.7295}\ (r^2 = 0.678)$$

described the relationships between number of eggs and carapace width for Disko Bay and Sisimiut, respectively. From Table 2 it appears that the average number of eggs carried by the females was different between Disko Bay and Sisimiut in 1998 and 1999. In general, the mean number of eggs, for females of similar mean carapace width, was greater for females in Disko Bay than in Sisimiut.

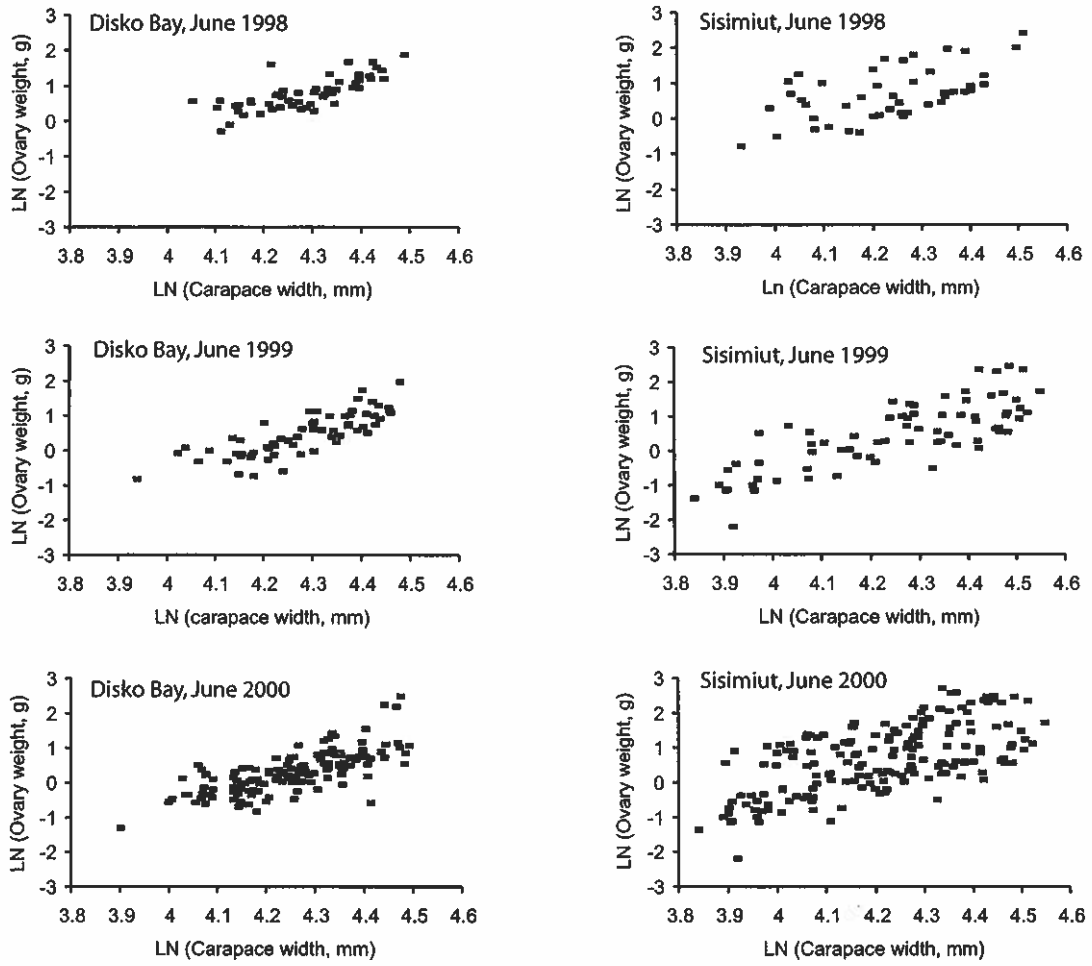

Figure 5. Weights of ovaries vs. carapace width for mature females from Disko Bay and Sisimiut, June 1998-2000.

Discussion

Egg stages

Since clutches with bright orange eggs predominated in Disko Bay and in Sisimiut in June, and only a small number of clutches had dark brown eggs, it is likely that females may hatch their eggs in early June or before. Observations from the fjord Eqaluit Paarliit in Greenland showed the same composition of brood stages in June and the hatching period was determined to occur between April and May 2000 (Burmeister, unpubl. data). Therefore it is reasonable to assume that mature females from Disko Bay and Sisimiut might hatch their eggs in the same period. Mallet et al. (1993) showed that egg hatching for multiparous females occurs in June in the southern Gulf of St. Lawrence, while Sainte-Marie (1993) showed it occurred from April to June in the northern Gulf of St. Lawrence. However, the time of hatching may vary inter-annually. Unpublished data from

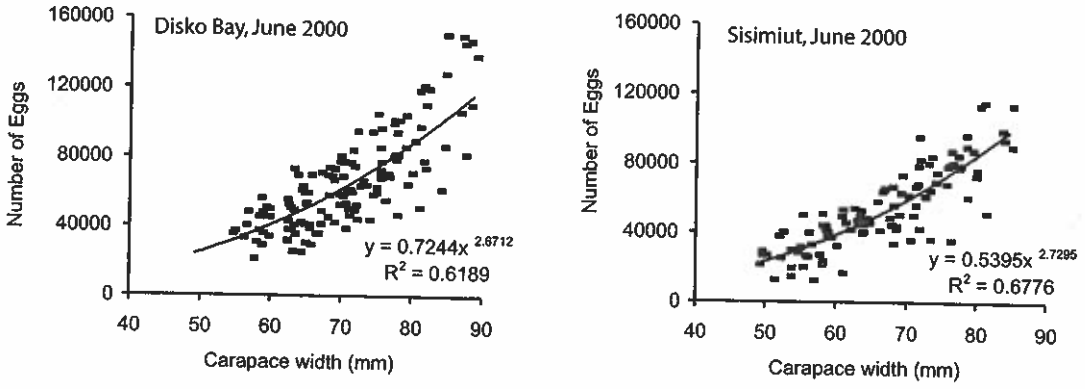

Figure 6. Number of eggs in clutches plotted against carapace width for mature females collected in Disko Bay and Sisimiut, June 2000. The equation describes the relationship between carapace width (x) and number of eggs (y) for both locations.

Greenland show that females with dark brown eggs (i.e., soon to hatch) were dominant in Kangaatsiaq (68°N) in June 1996.

Ovaries and Clutch

The development of ovaries based on color and weight was different between Disko Bay and Sisimiut. In Disko Bay, females with beige ovaries and bright orange eggs predominated. Based on the stage and color of the ovaries and eggs during the period 1998-2000, I infer that: (1) mature females in Disko Bay spawn during May and June, and (2) maturation of ovaries lasts approximately 12 months. Therefore snow crab females from Disko Bay seem to have a 1-year reproductive cycle.

In Sisimiut, females could be separated into two groups based on ovary weight and color. Two clouds of points in scatterplots of weight of ovaries against carapace width were apparent in 1998 and were even more evident in 2000. The upper cloud represents females with orange eggs without eyespots and orange ovaries and the lower cloud represents females with beige ovaries and bright orange eggs without eyespots. On the assumption that females hatch their eggs from April to May, females represented in the upper cloud probably spawned their eggs about 1 year before the time of sampling, while females in the lower cloud probably spawned their eggs only a few weeks before I collected my samples. If this interpretation is correct, then maturation of ovaries and brood of mature females might take at least 2 years. This conclusion is consistent with more detailed studies from Canada. In Baie Sainte-Marguerite, it was estimated that maturation of brood and ovaries lasted 27 months in primiparous females and 24 months in multiparous females (Sainte-Marie 1993). Comeau et al. (1999) demonstrated a 2-year incubation period for eggs of multiparous females. Mallet et al. (1993) suggested that maturation lasts 2 years

Table 2. Average number of eggs in subsampled mature females collected in Disko Bay and Sisimiut in June 1998-2000.

	Disko Bay				Sisimiut			
Year	*N*	Mean	Mean CW	S.D.	*N*	Mean	Mean CW	S.D.
1998	51	66,689	72 mm	22,833	54	45,089	72 mm	34,047
1999	63	73,203	72 mm	31,772	71	50,429	71 mm	34,012
2000	135	65,725	70 mm	28,344	101	53,936	66 mm	24,007

based on histology of female gonads in habitats with temperature from –1 to 1°C. Moriyasu and Lanteigne (1998) also showed that the duration of embryo development is 2 years at low temperature and suggested that the reproductive cycle could be annual if females remained in deep warmer waters with temperature ranging from 1.3 to 6.3°C.

In 1999, there was no distinct separation in development stages of ovaries for mature females from Sisimiut. Bottom temperature was also warmer than average that year (Table 1). Perhaps females are able to shift between a 2- and 1-year cycle when the bottom temperature increases. If this is the case, then differences in temperature between my study sites may provide some indication of the temperature threshold at which the shift occurs. Females in Disko Bay seem to have a 1-year reproductive cycle at 1.9 to 4.1°C, while females from Sisimiut seem to have a 2-year reproductive cycle at temperatures ranging between –0.8 and 2.1°C

Females from Disko Bay carried more eggs than similarly sized females from Sisimiut. In Disko Bay, the number of eggs ranged from 25,000 to 120,000, as seen also in females from Bonne Bay, Canada (Comeau et al. 1999). In Sisimiut, the number of eggs was generally lower than those from Disko Bay. The difference in fecundity could be due, for example, to differential egg mortality resulting from the difference in the rate of egg development between the two study sites, or to different mixtures of primiparous and multiparous females.

Conclusion

The results of this preliminary study cannot provide a definitive interpretation of the reproductive biology of snow crab in Disko Bay and Sisimiut. However, they do give a preliminary idea of some biological parameters and therefore contribute to a better understanding of the population of snow crab in Greenland waters. Further work will be conducted to address the issue of primiparous and multiparous females carefully, to gain a better understanding of the fecundity variations among sites. Furthermore, studies with different focuses, such as an estimate of the abundance of females with a 1-year or 2-year reproductive cycle, seasonal movement of

ovigerous females in relation to depth and water temperature, and the effect of male exploitation on mating and egg production will be conducted to develop a better understanding of the reproductive strategies of the snow crab and the impact of harvesting in Greenland.

Acknowledgments

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