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Changes in the Composition of Snow crab (Chionoecetes opilio) Participating in the 1988 Breeding Migration in Bonne Bay

by

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Abstract

The mean size of male snow crabs (Chionoecetes opilio) in sexual pairs during the 1988 annual spring breeding migration to shallow water in Bonne Bay, Newfoundland was 82.7 mm carapace width (CW), a significant decrease from 100.3 mm in 1987. Males <95 mm participating in the migration increased significantly from 32.3% in 1987 to 87.5% in 1988. The mean size of females also decreased significantly from 69.9 mm CW in 1987 to 63.8 mm in 1988. New-shell animals increased from 12.9% to 80.0% for males and from 0% to 79.3% for females between 1987 and 1988. Evidence from research fishing indicates that these changes are related to a rapid decline in the virgin population after 1984 and a coincident strong pulse of recruitment.

Résumé

Dans les couples de crabes des neiges (Chionoecetes opilio) ayant pris part à la migration d'accouplement du printemps de 1988 dans les eaux peu profondes de la baie Bonne (Terre-Neuve), les mâles avaient en moyenne une largeur de carapace (LC) de 82,7 mm, ce qui représentait une diminution importante par rapport à 1987 (LC de 100,3 mm). Le nombre de mâles <95 mm participant à la migration a considérablement augmenté, passant de 32,3 % en 1987 à 87,5 % en 1988. Chez les femelles, la taille moyenne a elle aussi notablement diminué : la LC, qui était de 69,9 mm en 1987 est tombée à 63,8 mm en 1988. La proportion de crabes à nouvelle carapace est passée de 12,9 % à 80,0 % chez les mâles et de 0 % à 79,3 % chez les femelles, de 1987 à 1988. D'après les observations résultant de la pêche de recherche, les changements précités sont reliés à une diminution rapide de la population vierge après 1984 et au niveau élevé de recrutement survenu en même temps.

Introduction

During April-May each year, sexually paired snow crabs, Chionoecetes opilio, migrate into shallow water (10-30 m) in Bonne Bay, Newfoundland from depths possibly as great as 150 m. Various behavioral, ecological and biological aspects of this breeding migration were described by Taylor et al. (1985) and Hooper (1986) based on SCUBA diver observations and sampling in 1982, 1983, and 1984. There has been no commercial snow crab fishery in the Bay and the population was considered to be virgin in 1984 (Taylor et al. 1985). Typically, pairs included a relatively large, old-shell male and a much smaller, old-shell female. Although males reach sexual maturity over the 51 to 72 mm carapace width (CW) size range (Watson 1970), 304 paired males collected during the breeding migration in 1984 ranged from 89 to 140 mm CW. Keen competition between single and paired males for possession of females (Hooper 1986) probably eliminates small, mature males from participating in breeding activity in an unexploited population. All paired females collected in 1984 were multiparous (females that have produced more than one egg clutch), each had recently hatched a clutch of eggs or was carrying or in the process of hatching well-developed eggs, each also had a ripe ovary indicating extrusion of a new clutch of eggs to be imminent, and these females ranged in size from 55 to 86 mm CW (Taylor et al. 1985).

After 1984, an illegal fishery on the Bonne Bay snow crab population developed rapidly and apparently reduced the abundance of commercial size (≥95 mm CW) males (Ennis et al. 1988a). In 1986 and particularly in 1987 there were substantial increases in the percentage of males <95 mm CW (32.3% in 1987 cf. 1.0% in 1984) participating in pairing presumably because of reduced competition for possession of females (Ennis et al. 1988b). Females do not reach the 95 mm CW minimum legal size and probably were not targetted by the illegal fishery because of their relatively small size. Among paired females collected from 1983 to 1987, there were no changes in size composition, reproductive status or shell condition (Ennis et al. 1988b and unpublished data).

Sampling during the breeding migration in 1988 revealed further substantive changes in the composition of paired males and also the females. Our purpose is to describe these changes and consider their significance with respect to maintaining reproductive potential in a heavily fished snow crab population.

Materials and Methods

Sexually paired snow crabs were collected by SCUBA diving at depths from 10 to 30 m during the annual (April-May) breeding migration to shallow water in Bonne Bay each year from 1984 to 1988. In most cases, each pair was kept in a separate mesh bag. While mating crabs were present in shallow water, samples were also obtained from depths >90 m using small-mesh traps from 1985 to 1988. Maximum CW of each crab was measured to the nearest 1.0 mm and shell condition was determined according to criteria described by Miller and O'Keefe (1981). Chelae height was measured to the nearest 0.1 mm for diver-caught, paired males in 1986, 1987, and 1988 and for trap-caught males in 1988. The egg masses of females were examined and categorized as new (orange with no eye spots) or old (well developed with conspicious eye spots). The extent of hatching was approximated and for those in which hatching had been completed, the presence of newly-extruded (bright orange) eggs was noted.

Chela height and carapace width for the 1988 trap-caught sample of males were plotted on a natural log-log scale and each specimen initially assigned to morphometrically mature and immature groups. A SAS package discriminant analysis of the data resulted in 100% accurate classification in the initial group assignments. This calibration set was used to classify males from the 1986, 1987, and 1988 diver-caught pairs. The equation

$$l_n \text{ CH} = 1.330 \; l_n \text{ CW} - 3.1281$$

was derived to distinguish between morphometrically mature and immature specimens.

Results

Composition of Sexually Paired Males and Females

The mean size of males in sexual pairs collected during the breeding migration in Bonne Bay decreased significantly from 116.6 mm CW in 1984 to 100.3 mm in 1987 (Tukey test, $P < 0.001$) and to 82.7 mm in 1988 ($P < 0.001$) (Table 1). In these pairs the percentage of males <95 mm CW increased significantly from 1% in 1984 to 32.3% in 1987 ($P < 0.001$) and to 87.5% in 1988 ($P < 0.001$). For females, there was no change ($P = 0.88$) in the mean size from 1984 to 1987 (70.0 and 69.9 mm CW, respectively) but it decreased significantly ($P = 0.0001$) to 63.8 mm CW in 1988.

From 1984 to 1987, 12.4% and 2.2% of the paired males and females respectively, were new-shell (i.e. had molted within the preceding two years) but in 1988 80.0% of the males and 79.3% of the females were new-shell (Table 1). In 69.2% of the 208 pairs collected in 1988 both the male and female were new-shell and in 10.1% both were old-shell.

Comparison of 1988 Diver- and Trap-caught Samples

The mean size of males in trap-caught samples from depths >90 m during May-June, 1988 was 86.4 mm CW, slightly larger than the 82.7 mm $\overline{CW}$ of the diver-caught males. Among trap-caught males the percentage <95 mm CW was lower (71.7% cf. 87.5%) and the percentage new-shell was also lower (72.6% cf. 80%) compared to the diver-caught males. Considering the uncertainties generally associated with obtaining representative samples using baited traps, these observations indicate little difference in the composition of males in deep water and those participating in the breeding migration at around the same time.

There were substantial differences, however, in the composition of females in these diver-caught and trap-caught samples. All of the diver-caught females (both old- and new-shell) were carrying old, eyed eggs or were in the process of hatching or had very recently completed hatching their eggs. However, most of the trap-caught females (98.3% of the old-shell and 33.3% of the new-shell) were carrying new (orange) eggs, which likely had been extruded sometime within the preceding 2-3 months, the remainder were carrying old eggs similar to those of the diver-caught females (Table 2). The diver-caught females were smaller ($\overline{CW}$ = 63.8 mm cf. 70.3 mm; t-test, P = 0.0001) and mostly new-shell (79.3% cf. 20.3%) (Tables 1 and 3).

Changes in Relative Abundance, 1985-88

Although research fishing in deep water at the same time that paired crabs were present in shallow water was not extensive, the summarized catches provide a qualitative indication of changes that occurred in the Bonne Bay population from 1985 to 1988. Catch rates of male crabs $\geq$95 mm CW in May-June research fishing dropped from 23.6 per trap haul in 1985 to 3.8 in 1987, a substantial decline (t-test, P = 0.01) especially considering that the percentage new-shell increased from 8.1% to 31.6% (Table 3). The catch rate in 1988 was up to 8.6 per trap haul, indicating an increase in abundance of commercial males. Between 1985 and 1987, catch rates of males <95 mm increased from 1.7 to 29.0 per trap haul (t-test, P = 0.11; a Mann-Whitney test gave P < 0.01) and the percentage new-shell increased from 15.8% to 94.5% (Table 3). There was also a substantial decline (t-test, P < 0.01) in the catch rate of females from 38.7 per trap haul, all of which were old-shell, in 1985 to 7.0 per trap haul, of which 51.4% were new-shell, in 1987 (Table 3). The catch rate of females in 1988 was up to 21.1 per trap haul (Table 3) indicating that their abundance increased as well. The incidence of new-shell females dropped to 20.3% in 1988, presumably due to the new-shell females which first showed up in research fishing in 1986 (Table 3) becoming old-shell by 1988.

Morphometric Maturity

A carapace width-chela height equation derived from discriminant analysis of data from the 1988 trap-caught sample of males was superimposed on carapace-width/chela-height plots of 1986, 1987, and 1988 diver-caught paired males and those from the 1988 trap-caught sample (Fig. 1). At sizes <89 mm CW, only males that are categorized as morphometrically mature participated in the breeding migration to shallow water. At sizes ≥89 mm, 5 of 68 (7.4%) of the paired males are categorized as morphometrically immature. The morphometrically mature males in the diver-caught samples ranged from 61 to 124 mm CW and those in the trap-caught sample from 58 to 136 mm. In the trap-caught sample, the morphometrically immature males ranged from 62 to 90 mm and in the diver-caught samples from 89 to 114 mm.

Discussion

Our observations indicate that from 1984 to 1988 the Bonne Bay snow crab population shifted from one dominated by large, old-shell individuals to one dominated by smaller, new-shell animals. The shift apparently was initiated by reduced abundance of the virgin population caused by a rapid development of an illegal fishery after 1984 (Ennis et al. 1988a).

Very few female snow crab reach sizes >85 mm CW and in regulated trap fisheries in Atlantic Canada are protected from exploitation by the 95 mm CW minimum legal size. Because of their small size and negligible meat yield, females are unattractive for harvest. However, they are caught in gillnets which anecdotal information suggests were used extensively in illegal fishing in Bonne Bay. Females caught in gillnets would likely be destroyed because of the difficulty of removing them intact for release.

Although illegal fishing seems to be the most plausible explanation, natural mortality due to senility may also have contributed to the decline of the virgin population.

The substantial increase in the incidence of small and new-shell crab in Bonne Bay indicates a strong recruitment pulse which has largely replaced the virgin population. This is likely related to substantially improved conditions for growth and survival of juveniles that undoubtedly occurred as the virgin population declined. It has been hypothesized that such a mechanism contributed to increased recruitment in the southwest Gulf of St. Lawrence snow crab population during the early 1980s (Elner and Bailey 1986). In a review of the available evidence, Ennis (1988) suggested that density-dependent processes operating subsequent to larval settlement likely affect recruitment to the snow crab fishery.

Comparison of females participating in the 1988 breeding migration with those caught in traps in deep water at the same time indicates that the breeding migration is only part of the overall breeding activity in the Bonne Bay population. At the same time that both old- and new-shell females were mating and hatching old eggs in shallow water, almost all (98.3%) of the old-shell females in deep water were carrying new eggs. Some (33.3%) of the new-shell females in deep water were carrying new eggs, the others carried old eggs which were soon to be hatched (Table 2). Only one female taken in deep water had hatched some of its eggs. Among those taken in shallow water, however, 65% had hatched some eggs and 9% had completed hatching and begun to extrude new eggs. These observations indicate that in the Bonne Bay population much breeding activity occurs in deep water. Spawning and hatching the following year occurs over a more protracted period than indicated by the breeding migration to shallow water.

Males categorized as morphometrically immature as small as 62 mm CW have been observed to mate in laboratory tanks (Ennis et al. 1988a). Our observations on diver-caught, paired males in Bonne Bay, however, indicate that morphometrically immature males smaller than 89 mm do not participate in the breeding migration. At larger sizes, their participation in the breeding migration appears to be limited by their relative scarcity in the population (Fig. 1).

Our results document very significant changes which have take place in the Bonne Bay snow crab population in recent years. The changes represent classic population responses to declining abundance of a virgin population, i.e. increased growth and survival of young animals and reduced size at maturity.

Our earlier conclusion that reproductive potential in a snow crab population will be maintained at a high level despite removal by fishing of a large proportion of commercial-size males each year (Ennis et al. 1988b) is further supported by these results. They also indicate a high capacity for increased productivity (i.e. annual recruitment to the standing stock) within a snow crab population associated with density-dependent, dynamic responses to exploitation.

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Table 1. Carapace width and shell condition of sexually paired male and female *Chionoecetes opilio* collected by SCUBA divers in Bonne Bay, Newfoundland, 1984-88.

		Males				Females		
Year	N	$\overline{CW}$ (mm)	Range	% <95 mm	% new-shell	$\overline{CW}$ (mm)	Range	% new-shell
1984	304	116.6	89-140	1.0	16.4	70.0	55-86	3.3
1985	199	113.8	76-132	2.0	7.0	69.9	60-90	1.0
1986	15	111.1	94-123	6.7	0.0	69.1	64-82	0.0
1987	31	100.3	62-126	32.3	12.9	69.9	58-82	0.0
1988	208	82.7	61-133	87.5	80.0	63.8	49-78	79.3

Table 2. Comparison of shell condition and egg development of diver-caught and trap-caught female *Chionoecetes opilio* in Bonne Bay, Newfoundland, May-June 1988.

	Old-shell			New-shell		
	N	New eggs	Old/hatching eggs	N	New eggs	Old/hatching eggs
Diver-caught	43	0	43	165	0	165
Trap-caught	118	116	2	30	10	20

Table 3. Summary of snow crab, *Chionoecetes opilio*, catches in research fishing with small-mesh traps at depths >90 m in Bonne Bay, Newfoundland during May-June, 1985-88.

	Males ≥95 mm CW			Males <95 mm CW			Females[2]		
Year	N	CPUE[1]	% new-shell	N	CPUE[1]	% new-shell	N	CPUE[1]	% new-shell
1985	260	23.6	8.1	19	1.7	15.8	464	38.7	0.0
1986	401	10.8	5.5	129	3.5	68.2	609	16.5	1.3
1987	19	3.8	31.6	145	29.0	94.5	35	7.0	51.4
1988	60	8.6	15.0	161	23.0	95.0	148	21.1	20.3

[1] Number per trap haul

[2] Immature females are excluded

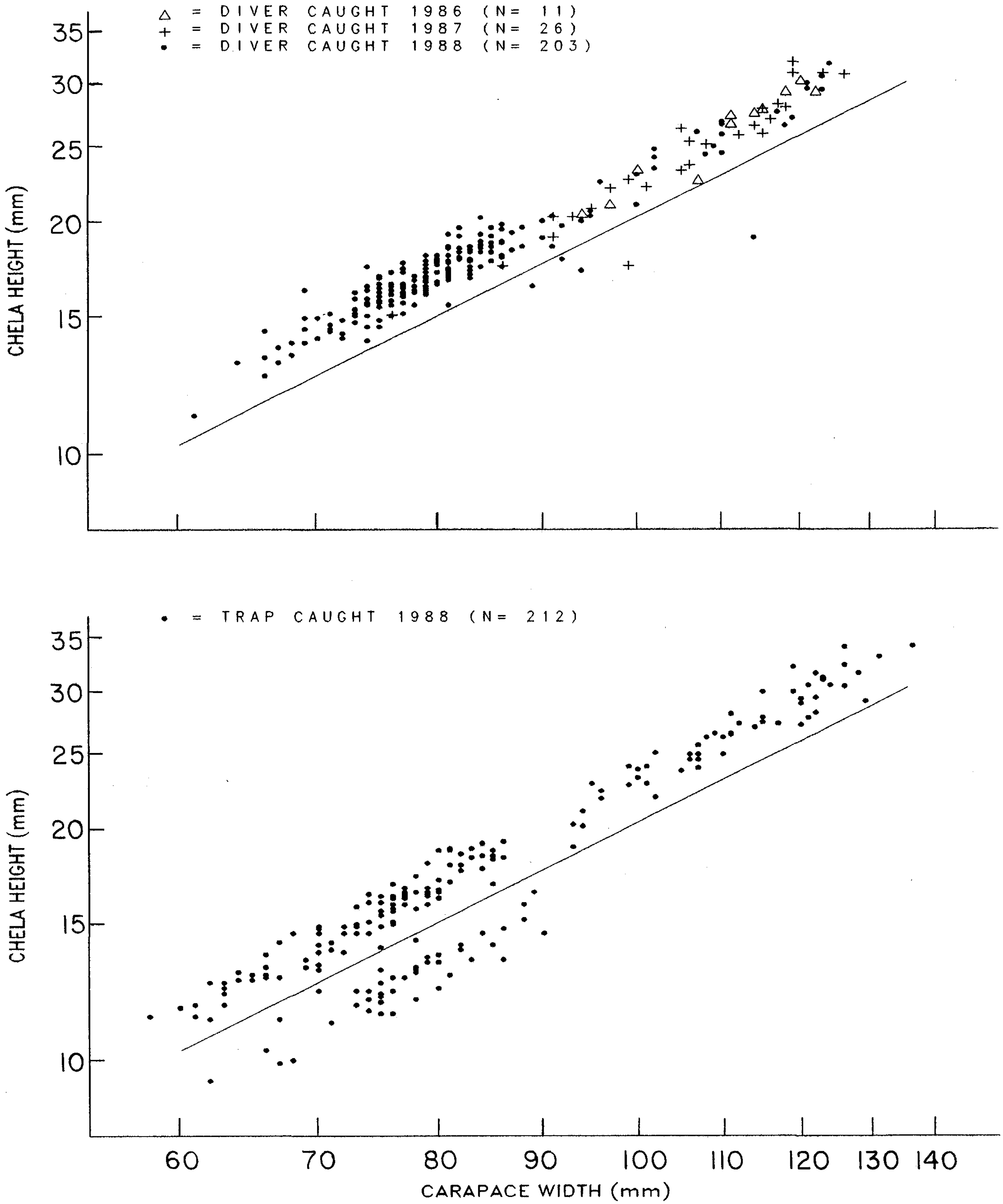

Fig. 1. Natural log-log plots of carapace width versus chela height for the 1986, 1987, and 1988 diver-caught and the May-June 1988 trap-caught male *Chionoecetes opilio* in Bonne Bay, Newfoundland. The cutting line (l_n CH = 1.3330 l_n CW - 3.1281) is from discriminant analysis of the 1988 trap-caught sample.