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Biological Aspects of the Spring Breeding Migration of Snow Crabs (*Chionoecetes opilio*) in Bonne Bay, Newfoundland (Canada)

by

D. M. Taylor, R. G. Hooper[2] and G. P. Ennis
Fisheries Research Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland A1C 5X1

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[2] NICOS/Biology Department
Memorial University of Newfoundland
St. John's, Newfoundland A1B 3X9

Abstract

Detailed biological sampling was carried out during the 1984 spring breeding migration of snow crabs *Chionoecetes opilio* in Bonne Bay, Newfoundland. In male/female pairs, males ranged from 89 to 140 mm ($\bar{X}$ = 116.4) carapace width (CW) and females from 55 to 86 mm ($\bar{X}$ = 67.8). The difference in size between the male and female of a pair ranged from 19 to 72 mm and averaged 47 mm. This difference is an important element in behavioral ecology associated with reproduction in this species. During the last week of April, 92% of the females sampled were carrying old eggs in various stages of development while 8% had released all larvae. Gonads were ripe and spermathecae invariably contained old spermatophores but in 48.6% of the females, spermathecae contained new spermatophores as well. Four weeks later, 47% of the females sampled had released most or some portion of their larvae, 93% had new spermatophores in the spermathecae but only one was extruding new eggs. The observations demonstrate that female snow crabs can successfully mate in hard shell condition and while carrying a full clutch of old eggs.

Résumé

Un échantillonnage biologique détaillé du crabe des neiges (*Chionoecetes opilio*) a été effectué en 1984 lors de sa migration reproductrice printannière dans la baie Bonne, à Terre-Neuve. Chez des paires de mâles et de femelles, la largeur de carapace (LC) des premiers variait de 89 à 140 mm ($\bar{X}$ = 116,4); celle des secondes, de 55 à 86 mm ($\bar{X}$ = 67,8). La différence de taille entre mâle et femelle d'une paire allait de 19 à 72 mm, avec moyenne de 47 mm. Cette différence est un élément important dans l'écologie du comportement associée à la reproduction chez cette espèce. Dans la dernière semaine d'avril, 92 % des femelles échantillonnées portaient des oeufs âgés, à divers stades de développement, alors que 8 % avaient libéré toutes leurs larves, Les gonades étaient mûres et, invariablement, les spermathèques contenaient des vieux spermatophores. Cependant, les spermathèques de 48,6 % des femelles contenaient également des spermatophores. Quatre semaines plus tard, 47 % des femelles échantillonnées avaient libéré la majorité ou une portion de leurs larves, 93 % possédaient des spermatophores nouveaux dans leurs spermathèques, mais seulement une femelle était en voie d'expulser des oeufs nouveaux. Ces observations indiquent que les femelles peuvent s'accoupler avec succès alors que leur carapace est dure et qu'elles portent un plein complément de vieux oeufs.

Introduction

Hooper (in press) has documented the occurrence of an annual (April-May) deep-to-shallow-water breeding migration of snow crabs (Chionoecetes opilio) in Bonne Bay, on the west coast of Newfoundland. In addition to being the first record of this phenomenon in this species, his observations contradict some generally accepted conclusions regarding the species' reproductive biology. The most significant of these are that females undergo a terminal molt to maturity and do not mate in the hard shell condition (Ito 1967; Watson 1972; Takeshita and Matsuura 1980).

Little biological sampling data are included in Hooper's general description of the breeding migration. The purpose of this paper is to provide a detailed description of various biological aspects of the phenomenon such as size difference between paired males and females, and condition of the external egg masses, ovaries and spermathecae during the breeding period.

Materials and Methods

A total of 303 male/female pairs of snow crab was collected during three field trips to Bonne Bay from April 24 to May 29, 1984 by SCUBA diving (10-30 m depth). Each pair was kept separate. At the surface, each crab was measured to the nearest mm (maximum carapace width - CW) and its shell condition determined. The brood pouch of females was examined to determine stage of egg development. Following this, males were tagged with Floy vinyl "T-bar" tags (Taylor 1982) and released and females were either tagged or retained and their ovaries and spermathecae later examined in the laboratory.

Results

Size Distribution

Size distributions were unimodal for each sex but with no overlap in their carapace widths (Fig. 1). Males ranged from 89 to 140 mm ($\bar{X}$ = 116.4 mm) CW and females from 55 to 86 mm ($\bar{X}$ = 67.8 mm). There was no discernable relationship between size of male and size of the female with which it was paired (r^2 = 0.019, Fig. 2). Mean sizes of females paired with small, medium and large size males were the same ($P < 0.005$, Bartlett's test of homogeneity of variance).

Male CW (mm)	Female CW (mm)		
Range	Range	Mean	N
89-109 (small)	55-86	69.2	59
110-120 (medium)	59-86	69.6	136
121-140 (large)	59-84	70.9	108

The mean difference in carapace width between paired males and females increased from 21 mm at 89 mm male CW to 70 mm at 140 mm (Fig. 3).

Female Reproductive Condition

During the April 24-27 sampling period, 92% of the females carried full clutches of eyed eggs and the remainder had liberated all or most of the larvae (Table 1). By May 7-11, 59% had empty brood pouches indicating that a considerable amount of hatching had taken place. However, during May 22-25, 53% of the females were carrying full clutches of eyed eggs and only 39% had empty brood pouches. This increase in relative abundance of females with eyed eggs could have resulted from a return to deeper water of females that had liberated larvae or an influx of new animals from deeper water. Small numbers (1.4% overall) of females carried clutches of dead eggs. All females dissected (77) had ripe ovaries (Table 2), however, only two with partially extruded clutches of new eggs were observed over the entire sampling period.

Females were observed with spermathecae containing both old and new spermatophores. In these, spermathecae were engorged with a very white gelatinous material for 3/4 of their length while the remaining 1/4 at the dorsal end of the organ was shrunken and contained a yellowish-brown substance of a "waxy" consistancy. Females which did not have new spermatophores had very small spermathecae which were entirely yellowish-brown in colour. This is very similar to that described for *Chionoecetes bairdi* by Paul (1982). While 97% of the females examined contained old spermatophores, those containing new spermatophores as well increased to 92.9% from 48.6 to between April 24 and May 25 (Table 2). Two specimens contained new spermatophores only and all were old-shelled. Many of the females with new spermatophores carried full clutches of eyed eggs.

Diving during May 28-31 revealed that all crabs had left the sampling area.

Discussion

Small numbers of grasping, male/female pairs of *C. opilio* and *C. bairdi* have been observed in shallow water elsewhere. Ennis (unpublished) found four pairs and Hooper (unpublished) three pairs of *C. opilio* in Bonavista Bay and Placentia Bay, Newfoundland, respectively. Donaldson (1975) reported two pairs of *C. bairdi* in Alaska. However, nothing comparable to the magnitude of the breeding migration of *C. opilio* observed in Bonne Bay, Newfoundland has been reported for other areas. There is considerable scope for speculation on the ecological significance of this migration. Although about half the females examined just prior to their departure from the shallow (<35 m) sampling depths in 1984 still had full clutches of eyed eggs, liberation of a large proportion of larvae in shallow water may enhance chances for larval survival overall. At the time of the migration, bottom temperatures in Bonne Bay at depths beyond 35 m are probably 0°C or lower (deep water temperatures are not available for Bonne Bay but Squires et al. (1971) reported temperatures <0°C at depths beyond 30 m in early June in North Arm, Bay of Islands about 40 km to the south).

Releasing larvae in shallow, warmer water (temperature was 3°C at 30 m during May 7-11) would considerably reduce the degree of thermal shock associated with larvae swimming to the surface. The rate of embryonic development would likely be increased also, resulting in earlier larval release.

In the development of a management strategy for snow crab (*C. opilio*) stocks on the Atlantic coast of Canada, a key assumption has been that, despite high levels of exploitation, reproductive potential in a stock remains at pre-fishery levels. The basis for the assumption is that females are protected from exploitation by the 95 mm CW minimum legal size because they do not grow to that size and also that males mature at sizes much smaller than 95 mm CW. In a recent review, following more than 15 years heavy fishing in some areas, there was no evidence to indicate that the assumption was invalid (Elner and Robichaud 1983). However, the observations presented here suggest that a large size differential between the male and female of a pair is an important element of behavioral interactions during breeding activity. It is possible that males smaller than 89 mm CW (the smallest male observed paired with a female), even though physiologically mature, may not be capable of mating successfully.

Males and females appear to be segregated over most of the year (Hooper in press). Observations on the east coast of Newfoundland indicate that large males occur mainly on muddy bottom in deep water whereas females and small males occur on sand-gravel or rocky bottom somewhat shallower (Miller and O'Keefe 1981). In the breeding migration which occurs in Bonne Bay, it is suggested that males leave the deeper water area and each selects a mature female which is carried to the shallow water breeding area. Males appear to retain possession of individual females for extended periods (possibly up to 2 months) during which time the female is held by and dependent on the male. In laboratory studies on *C. bairdi*, Paul and Adams (1984) demonstrated that multiparous females are receptive to mating for periods ranging from <1 to 7 days. If this occurs in *C. opilio* as well, a lengthy courtship would enhance successful mating.

In the Gulf of St. Lawrence, male snow crabs mature over the 50-65 mm CW size range (Watson 1970; Powles 1968), however, in the sampling reported here, only three 3 males from the 303 pairs examined were smaller than the 95 mm CW minimum legal size, the smallest being 89 mm. Except for these, even solitary males of this size and smaller were absent from the area indicating that competition for females had occurred in deeper water. The snow crab population in Bonne Bay appears to be small and isolated from populations elsewhere in the Gulf of St. Lawrence by the 125 m sill at the mouth of the bay. It has not been fished commercially and at present the population is considered to be in the virgin state. Hooper's (in press) observations indicate keen competition between single males and males already paired with a female for possession of the female. Under pre-fishery conditions this competition can be expected to eliminate small males from participating in breeding activity. Adams (1982) demonstrated that multiparous female *C. bairdi* resisted mating attempts by small males and when males of significantly different sizes competed for the same female the larger male was invariably successful. Small numbers of the largest of the sub-legal (<95 mm CW) male *C. opilio* appear to be capable of competing and mating successfully. However, it is presently unknown whether males smaller than those observed are capable of successful mating in the absence of competition from large males and, if they are not, whether there are sufficient numbers of large sub-legal males to maintain full reproductive potential in a heavily fished population.

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Table 1. Summary of observations on external egg masses of female *Chionoecetes opilio* collected in Bonne Bay, Newfoundland, April - May 1984.

Sampling period	Percent			N
	Eyed	Larvae liberating	Larvae liberated	
April 24-27	92	0	8	128
May 7-11	9	32	59	81
May 22-25	53	8	39	87

Table 2. Summary of internal observations on female *Chionoecetes opilio* collected in Bonne Bay, Newfoundland, April - May 1984.

Sampling period	Ripe ovaries (%)	Spermatophores (%)			N
		old only	old and new	new only	
April 24-27	100	45.7	48.6	5.7	35
May 22-25	100	7.1	92.9	0	42

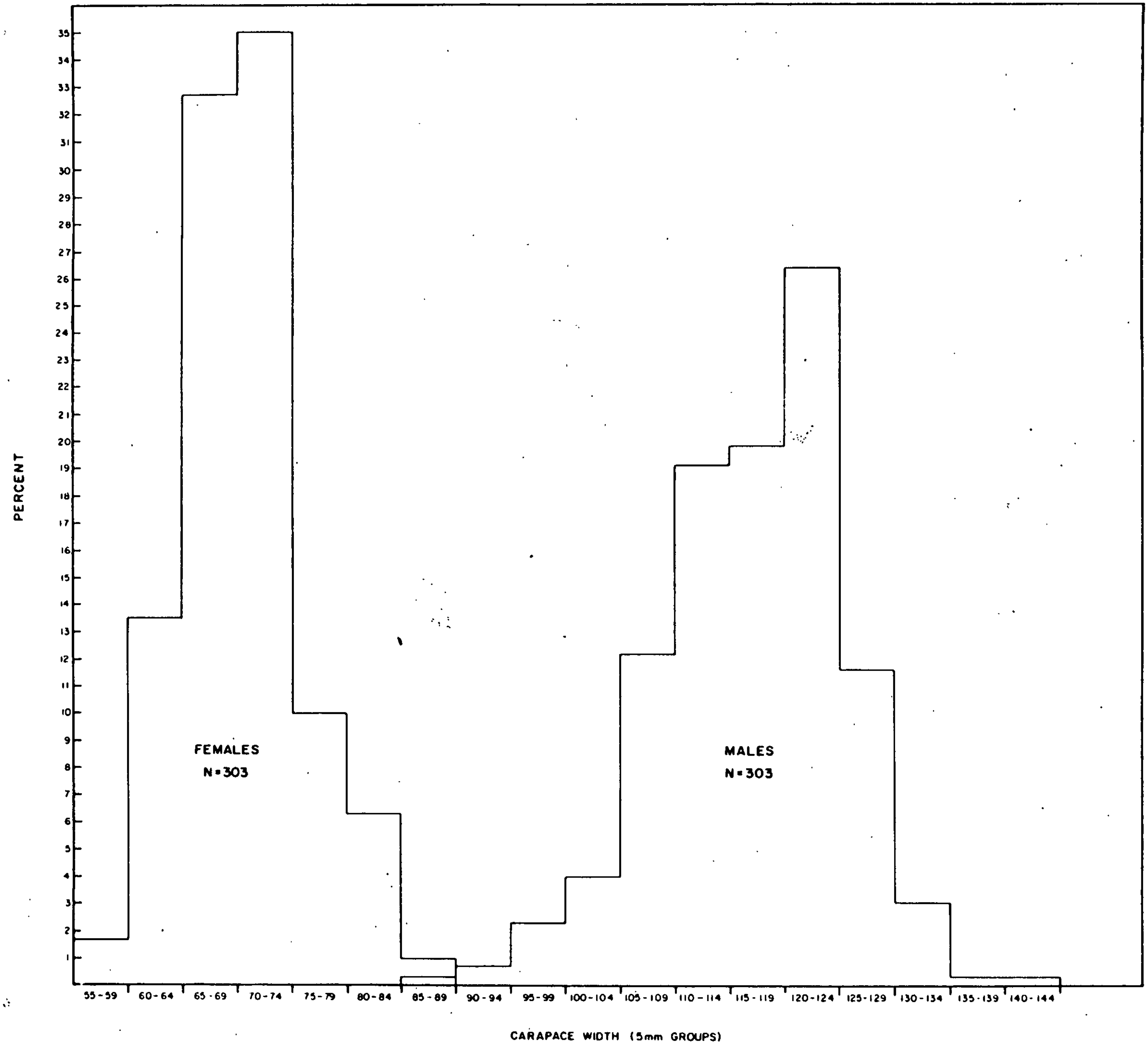

Figure 1. Size frequency distributions of male and female <u>Chionoecetes opilio</u> collected as pairs in Bonne Bay, Newfoundland during April-May 1984.

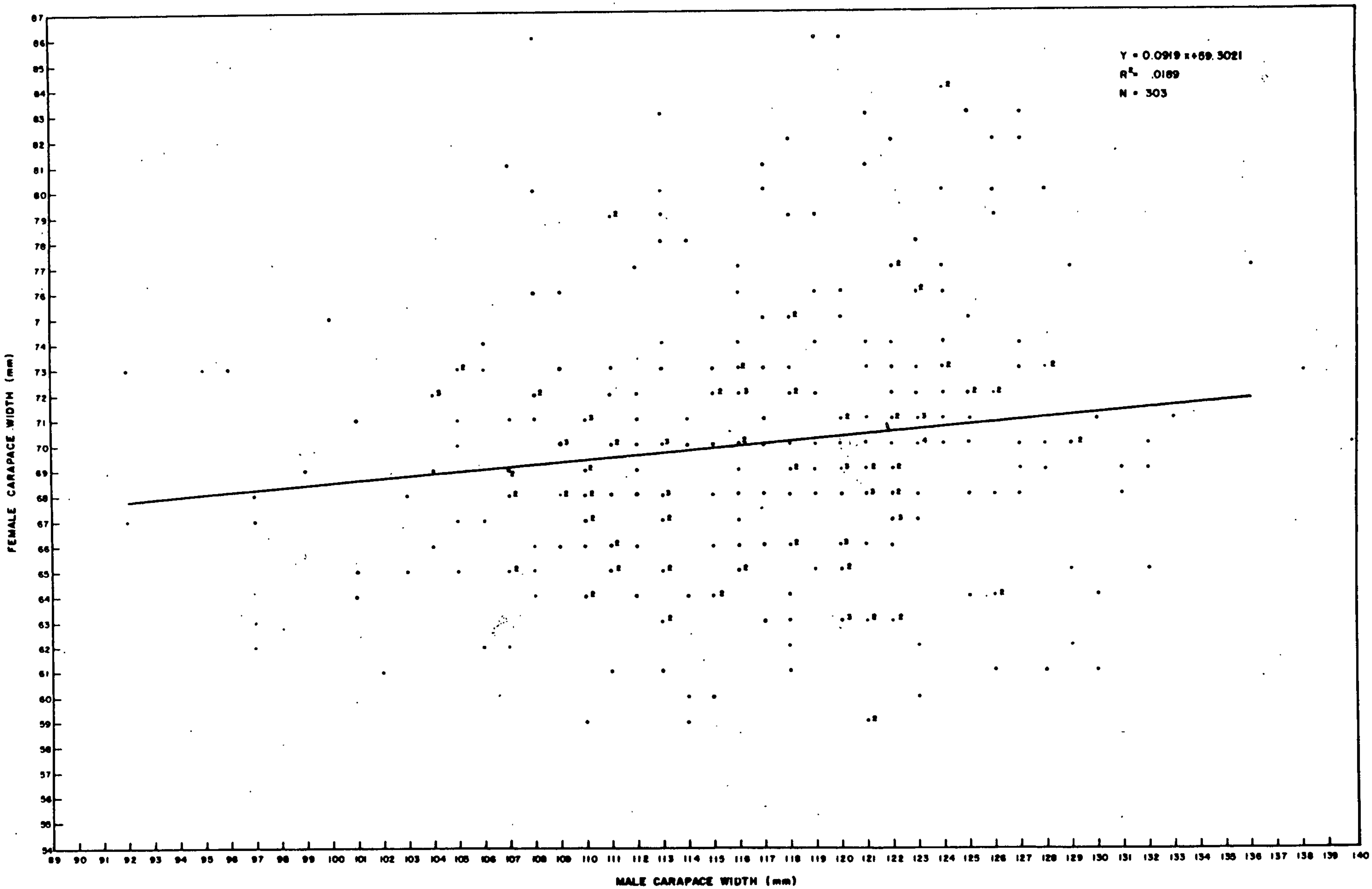

Figure 2. Regression of female carapace width on male carapace width for pairs of <u>Chionoecetes opilio</u> collected in Bonne Bay, Newfoundland during April-May 1984. Numbers adjacent to points indicate more than one observation. Slope of the regression is not significant (P = 0.017).

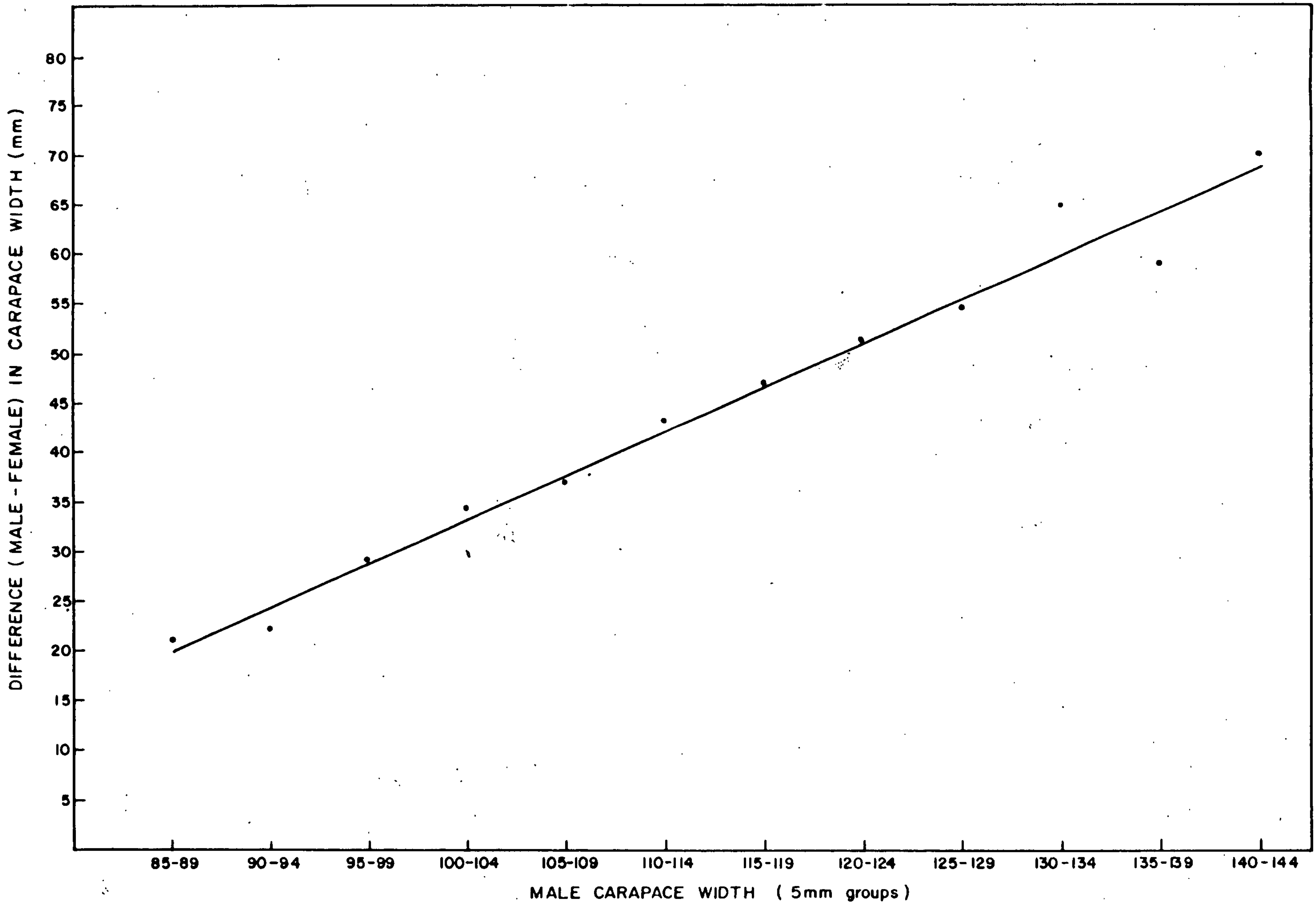

Figure 3. Mean difference in male and female carapace widths plotted against male carapace width for pairs of Chionoecetes opilio collected in Bonne Bay, Newfoundland during April-May 1984. The line was fitted by eye.