BIOLOGICAL ASPECTS OF THE SPRING BREEDING MIGRATION OF SNOW CRABS, *CHIONOECETES OPILIO*, IN BONNE BAY, NEWFOUNDLAND (CANADA)

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, has been documented by Hooper (in press). 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 morphometric sampling data are included in Hooper's general description of the breeding migration. The purpose of this paper is to provide a more 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

Three hundred and three sexually paired snow crabs were collected during three field trips to Bonne Bay from 24 April to 29 May 1984 by scuba diving (10-30 m depth). Each pair was kept in a separate mesh bag. At the surface, each crab was measured to the nearest millimeter (maximum carapace width (CW)) and its shell condition (soft, new/hard, or old/hard) determined. The eggs of females were examined to determine their stage of development. Following this, males were tagged with Floy vinyl "T-bar" tags (Taylor 1982) and released, and females were either tagged and released, or retained for later examination of their ovaries and spermathecae 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). Other than the fact that males were invariably larger than females, there was no discernible relationship between size of the male and size of the female with which it was paired (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
121-120 (large)	59-84	70.9	108
		Total	303

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. Only 3 males in 303 pairs were smaller than 95 mm, the legal size limit.

Female Reproductive Condition

During the 24-27 April 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 7-11 May, 59% had empty brood pouches indicating that hatching was well advanced. However, during 22-25 May, 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. Dead eggs were carried by 1.4% of females examined. All females dissected (77) had ripe (extrusion imminent) ovaries (Table 2); however, only two with partially extruded clutches

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

Sampling period	Eyed (%)	Larvae liberating (%)	Larvae liberated (%)	*N*
24-27 April	92	0	8	128
7-11 May	9	32	59	81
22-25 May	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	
24-27 April	100	45.7	48.6	5.7	35
22-25 May	100	7.1	92.9	0	42

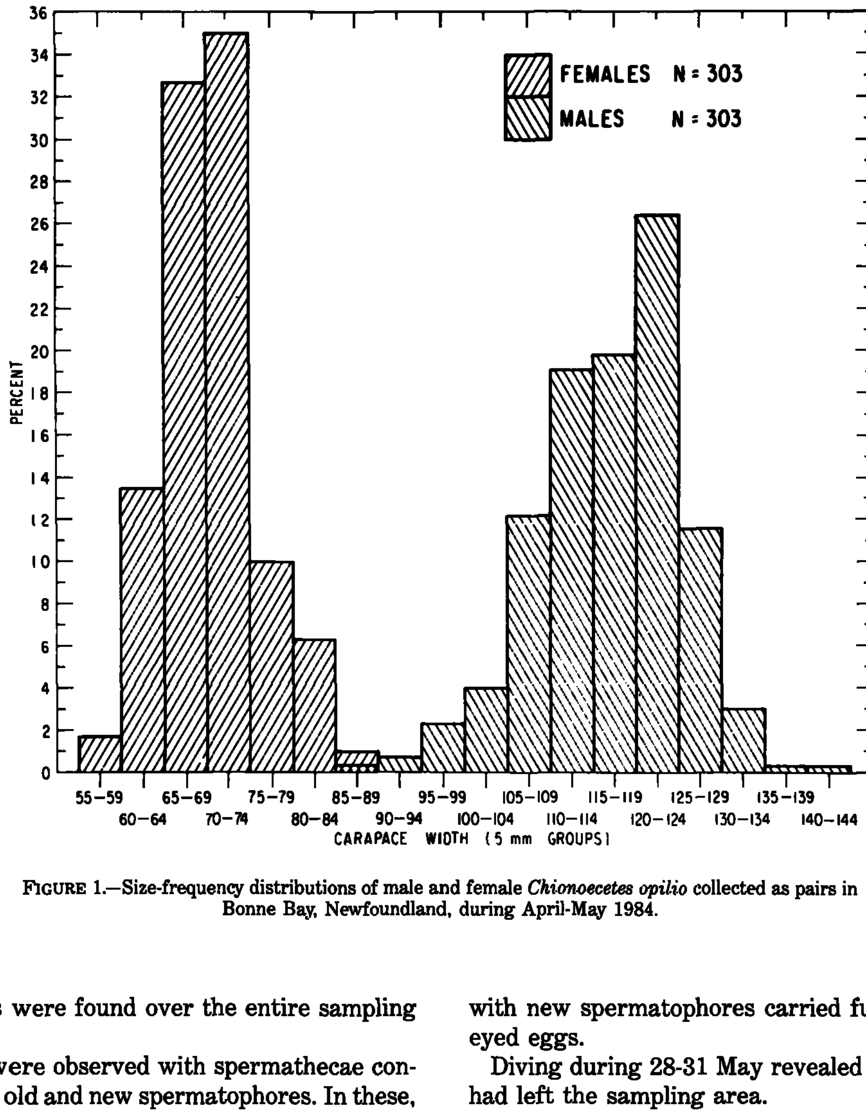

FIGURE 1.—Size-frequency distributions of male and female *Chionoecetes opilio* collected as pairs in Bonne Bay, Newfoundland, during April-May 1984.

of new eggs were found 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 glutinous material containing new spermatophores for three-fourths of their length, while the remaining one-fourth at the dorsal end of the organ was shrunken and contained a yellowish brown substance of a "waxy" consistency. Females which did not have new spermatophores had very small spermathecae which were entirely yellowish brown in color. This is very similar to that described for *Chionoecetes bairdi* by Paul (1982). While 97% of all females examined contained old spermatophores, those containing new spermatophores as well increased to 92.9% from 48.6% between 24 April and 25 May (Table 2). Two specimens contained new spermatophores only and all had old epizooite-encrusted shells. Thirty-six percent of the females with new spermatophores carried full clutches of eyed eggs.

Diving during 28-31 May 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 (Unpubl. data) found five pairs and Hooper (Unpubl. data) found 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 with 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]. Release of larvae in shallow, warmer water (temperature was 3°C at 30 m during 7-11 May) 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 *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 prefishery 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 yr of 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 be less likely to mate successfully in competition with large males.

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, Hooper (in press) suggested that males leave the deeper water area after selecting a mature female which is carried to the shallow water breeding area. Males retain possession of individual females for extended periods (Hooper in

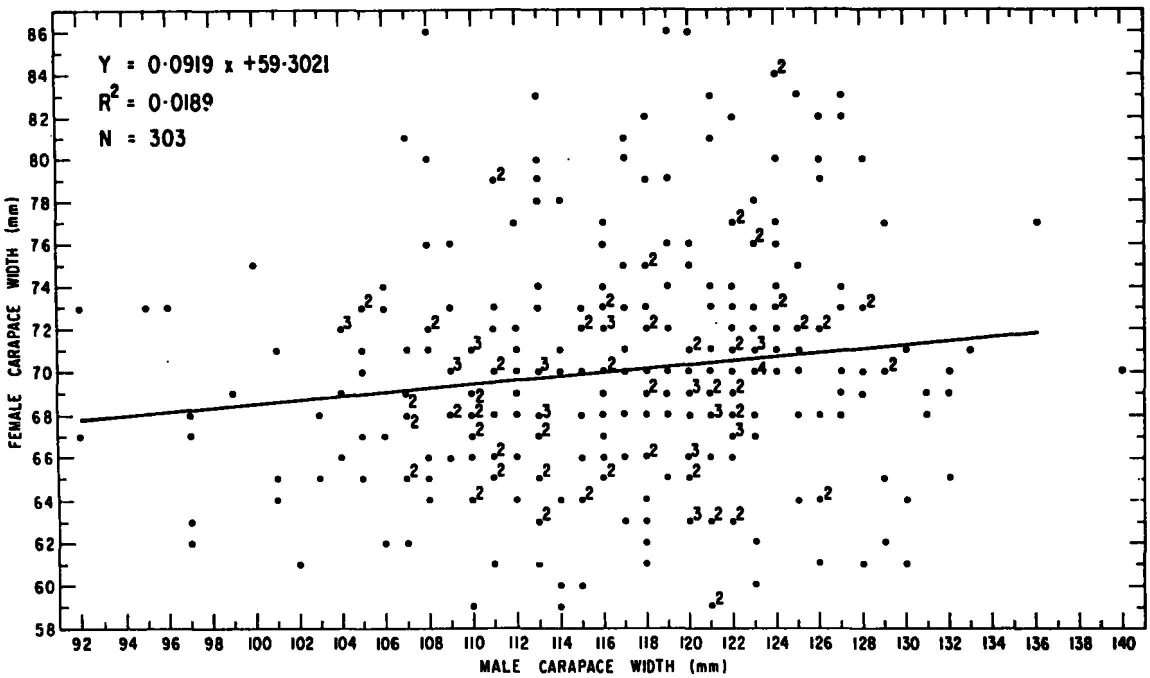

FIGURE 2.—Regression of female carapace width on male carapace width for pairs of *Chionoecetes opilio* collected in Bonne Bay, Newfoundland, during April-May 1984. Numbers adjacent to points indicate more than one observation. Slope of the regression is not significant (P = 0.017).

press) (possibly up to 2 mo) 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 d after all their eggs have hatched. In fact, they reported that only one ovigerous female mated successfully during their study.

In the Gulf of St. Lawrence, male snow crabs mature within the 50-65 mm CW size range (Powles 1968; Watson 1970); however, in the sampling reported here, only 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. This snow crab population appears to be small and is isolated from populations elsewhere in the Gulf of St Lawrence by the 35 m deep sill at the mouth of Bonne Bay. This area has not been fished commercially and at present the population is considered to be in the virgin state. Hooper's (in press) observations indicated there is keen competition between single males and males already paired with a female for possession of the female. Under prefishery 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 sublegal (<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 with multiparous females in the absence of competition from large males and, if they are not, whether there are sufficient numbers of large sublegal males to maintain full reproductive potential in a heavily fished population.

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FEEDING, DIET, AND REPEAT SPAWNING OF BLUEBACK HERRING, *ALOSA AESTIVALIS*, FROM THE CHOWAN RIVER, NORTH CAROLINA

Current knowledge of the frequency of feeding among spawning blueback herring, *Alosa aestivalis* Mitchill, is limited. Other aspects of the blueback herring's life history have been more extensively studied: feeding of juveniles (Davis and Cheek 1966; Nichols 1966; Burbidge 1974; Domermuth and Reed 1980; Crecco and Blake 1983), distribution at sea (Hildebrand 1963; Holland and Yelverton 1973[1]; Neves 1981), and spawning range (Bigelow and Schroeder 1953; Hildebrand 1963; Scott and Crossman 1973). However, determination of the occurrence of feeding by adults in freshwater has received little attention despite the fact that spawning bluebacks are common in rivers from southern New England (Bigelow and Schroeder 1953) to the St. Johns River, FL (Hildebrand 1963). Throughout this extensive range only Frankensteen (1976) has studied feeding among adult bluebacks in freshwater. Furthermore, no attempt has been made to correlate feeding with length, weight, and sex of individual fish, distance upstream, or the number of seasons a blueback has spawned.

The objective of this study is to enhance our knowledge of the freshwater feeding of blueback herring. In this paper I describe the occurrence of feeding, diet, and percentage of repeat spawning among adults collected in the Chowan River, NC. I also examined, by multiple regression analysis, the relation between feeding activity in freshwater and length, weight, sex, the number of repeat spawnings, and the distance travelled upstream.

Materials and Methods

Collection of Data

Bluebacks were collected at two sites in the lower Chowan River system during April 1980 and 1981. Williams' Fishery, where five collections were made in 1980, is located on the lower Meherrin River near its junction with the Chowan River, 90 km upstream from the Chowan River's mouth. Rocky Hock Creek, where bluebacks were sampled twice in 1980 and once in 1981, is roughly 20 km from the mouth of the Chowan River. Bluebacks at Williams' Fishery were still migrating upstream while those at Rocky Hock Creek, a known spawning ground,[2] were preparing to spawn.

Bluebacks were caught in chicken-wire dip nets and fixed gill nets with 58 mm stretched mesh at Rocky Hock Creek. A drift gill net of similar mesh size and a haul seine were used at Williams' Fishery. None of the fish collected had spawned yet.

Bluebacks were measured, weighed, and sexed, and scales were removed for aging. The foregut and midgut regions of the stomach anterior to the pyloric caeca were removed and placed in 15% Formalin[3] within 10-15 min of capture.

Stomach contents were examined in the laboratory under a dissecting scope. First, fullness of the foregut and midgut, which are separate sections, was estimated visually following Hynes (1950) and Yoshiyama (1980). Five levels of fullness were used: half full (1/2), full (1), and distended with food (2) (as in Yoshiyama 1980), plus one quarter full (1/4), and empty or with traces of food (0). Contents of each section were then placed in a petri dish, identified, and counted. Also, the presence or absence of prey items was noted.

Scales were viewed at 50× through an EPO LP-2 Profile Projector and marks were interpreted following Marcy (1969).

[1]Holland, B. F., Jr., and G. F. Yelverton. 1973. Offshore anadromous fish exploratory fishing program. Completion report, Project AFC-5, 123 p. North Carolina Department of Natural and Economic Resources, Division of Commercial and Sports Fisheries, Raleigh, NC 27611.

[2]S. Winslow, North Carolina Division of Marine Fisheries, Elizabeth City, NC 27909, pers. commun. February 1980. S. Winslow had determined the previous year (1979) that blueback herring collected at this site on Rocky Hock Creek were spawning. Also, a dam upstream prevented blueback herring from moving any further than 150 m above my collection site.

[3]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.