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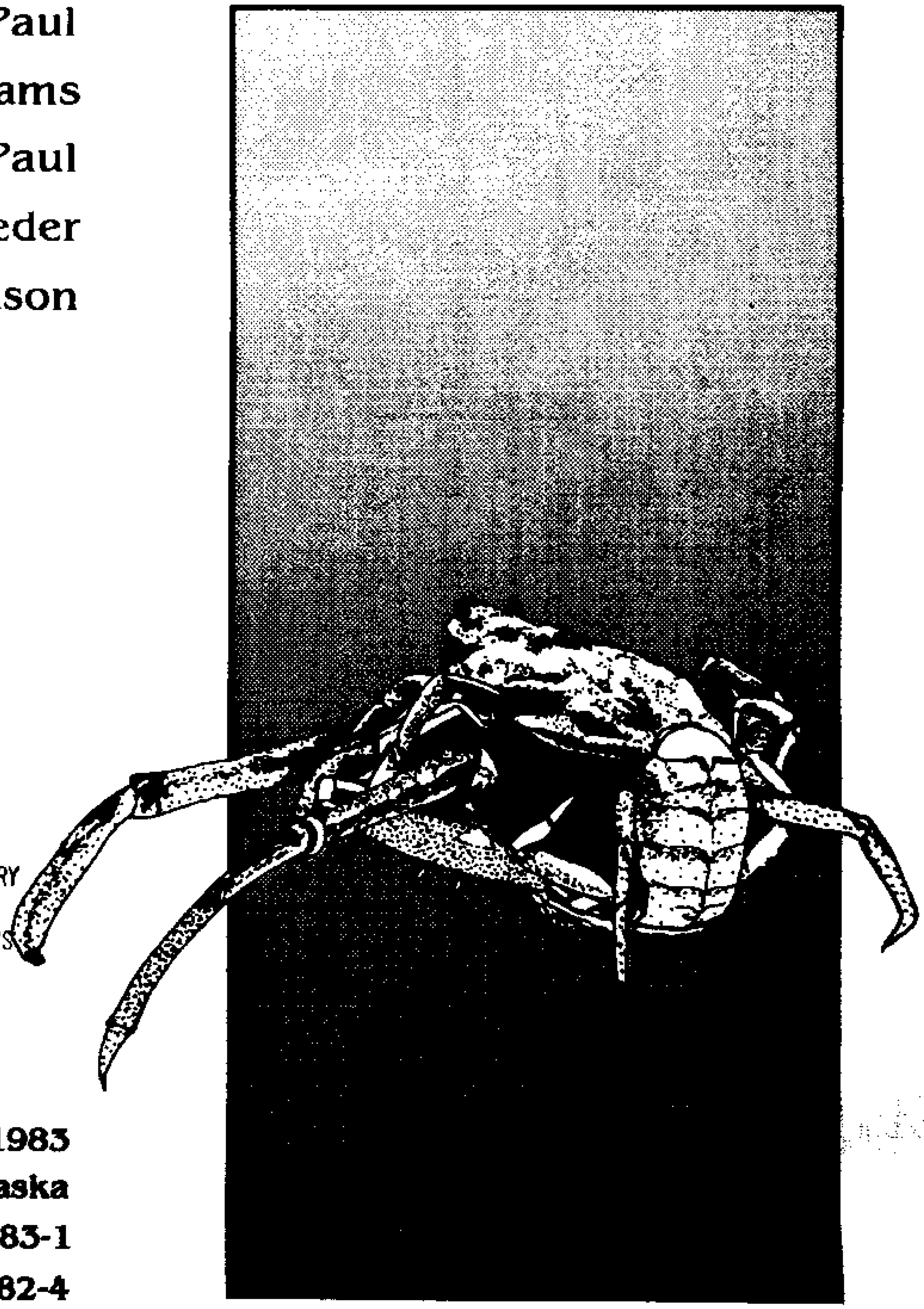

February 1983
University of Alaska
Alaska Sea Grant Report 83-1
IMS Report 82-4

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Sea Grant Report Number 83-1
IMS Report Number 82-4
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ACKNOWLEDGMENTS

This publication results from work sponsored in part by the Alaska Sea Grant College Program, cooperatively supported by the University of Alaska with state funds, and by NOAA, Department of Commerce, under grant number NA82AA-D-00044, project number R/06-11; and in part by the Alaska Department of Fish and Game with funds appropriated under the Commercial Fisheries Research and Development Act (P.L. 88-309, as amended), project number 5-47-R. Facilities were provided by the University of Alaska Institute of Marine Science Seward Marine Center. The tanner crab were collected by William Colgate and D. Hicks.

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ABSTRACT

Primiparous *Chionoecetes bairdi* attracted their mates prior to molting to maturity and for several weeks after molting. However, if they were not bred on the day of their maturity molt, they, with approximately equal probability, either extruded non-fertilized eggs or did not extrude any eggs. Non-mated females that curtailed egg extrusion, and were subsequently bred as hard shell individuals, within four weeks after molting produced viable eggs .

In the Kodiak area, scuba divers observed males, 70 to 160 mm, average 112 mm carapace width, grasping pubescent females. Males were always larger than females they grasped. In the laboratory, full clutches of viable eggs were produced by primiparous females whose mates were 65 to 140 mm carapace width, and over 90 percent had sufficient numbers of stored sperm to fertilize subsequent egg clutches. In the laboratory, females were mated to males smaller and larger than themselves. However, no obvious relationship of male size or carapace condition and the number of sperm cells in the spermatheca of their primiparous mates was observed.

If males were present in sufficient numbers, typically more than 90 percent of old shell *C. bairdi* were re-bred before they extruded eggs. This high rate of breeding activity in the laboratory was observed at sex ratios of one male to eight or fewer females. The smallest male mating with an old shell female was 110 mm and the average size of breeding males was 133 mm.

Old shell *C. bairdi* can produce normal sized clutches of viable eggs utilizing sperm stored for at least two years. After being isolated from males for one and two years, 3 percent and 28 percent respectively, of the multiparous females with reproductively active-appearing gonads were barren.

Grasping marks, resulting from the mating embrace, were not obvious on the legs of any primiparous female mated in the laboratory. In contrast, old shell females typically exhibited obvious grasping marks after mating.

In the laboratory, approximately 3 percent of the captive old shell females failed to produce eggs due to atrophied gonads. These were typically very old shell individuals. In the Kodiak area, 2 percent and 4 percent of the new shell and old shell crab were barren, while more than 10 percent of the very old shell females did not carry eggs.

Males can mate twice on the same day or several times within a week. Each time, they typically deposit enough sperm to fertilize several egg clutches.

INTRODUCTION

The snow or tanner crab, Chionoecetes bairdi, has recently become one of the most important commercial species in Alaskan waters. Because of the economic value and increased harvest pressure on this species, the Alaska Department of Fish and Game (ADF&G) and North Pacific Fishery Management Council seek to sustain this renewable resource through effective management. However, many biological questions necessary for proper management of the species remain unanswered. This study of C. bairdi breeding habits and reproductive capabilities was initiated to provide information for improved management of the species, supported jointly by the University of Alaska's Sea Grant College Program and Institute of Marine Science, and the Alaska Department of Fish and Game.

The C. bairdi fishery is restricted to males, and a decrease in the size of males in the population is to be expected. The effect of removing a large number of legal sized, 135 or 140 mm, males on the population's reproductive potential is undescribed. The objective of this report is to provide information on the reproductive biology of C. bairdi to assist both the Alaska Department of Fish and Game and the North Pacific Fishery Management Council in the management of C. bairdi crab stocks. Specifically, the following aspects of the reproductive biology of C. bairdi were investigated:

Objective One: The length of time prior to and following molting that a female will attract breeding males.

Objective Two: The relationships between male parent size, the amount of sperm in the female's spermatheca after egg extrusion, and number of eggs produced, and female parent size.

Objective Three: The frequency of mating and male mate size for old shell females.

Objective Four: The number of eggs and viable egg clutches extruded by a female relying on stored sperm as compared with recently mated females.

Objective Five: The percentage of barren females that occur in a random sample of old shell females.

Objective Six: Whether males can mate more than once in the breeding season.

METHODS

Crab were captured by trawl in Womans and Kalsin Bays, Kodiak, Alaska, by ADF&G investigators. They were transported to Seward either in the live well of an ADF&G vessel or air freighted to Seward Marine Center. For air shipment, crab were put in containers and covered with wet burlap. Crab survival rate for both techniques was approximately 80 to 85 percent.

The methods used to examine each of the six objectives outlined in the introduction are identified by the objective number before the methodological description.

OBJECTIVE ONE

Immature female crab were held in seawater tanks at 30 to 33 ppt, 4° to 6°C, at the Institute of Marine Science Seward Marine Center laboratory. Females were held segregated from males, except for a few females held with males to determine the amount of time prior to a molt to maturity a male was attracted to a pubescent female. Selected males were placed with females at the desired time for mating. Mating pairs were observed on a 24 hour basis. The Appendix provides growth data for crab molting in the laboratory.

OBJECTIVE TWO

Females were killed between one and five months after mating with a selected male, and their egg clutch and spermatheca removed for egg and sperm counts. Eggs were removed from pleopods, examined under a microscope for cleavage, then dried to constant weights at 80°C. The number of eggs present in each egg clutch, for all crab discussed in this report, was estimated by dividing total egg mass dry weight by the average dry weight of one egg. The dry weight of one egg was calculated by weighing 70 samples, from separate females, containing 200 eggs.

For comparison of male parent size and female fecundity, females were assigned to three carapace width groups: 80 to 89, 90 to 99, and 100 to 110 mm. Shell condition of male parents was classified as follows: new shell, carapace judged to be less than 1 year old; old shell, 1 to 2 years old; and very old shell, carapace 3 or more years old. These same carapace age categories also apply to female crab that have reached their terminal molt.

A spermatheca from each female was removed, dissected longitudinally, and sperm flushed from it with 4°C filtered seawater. The soft material containing sperm was macerated and its settled volume determined in a graduated centrifuge tube. Next, the material was diluted by a factor of 10^3:1 or 10^4:1 with cold filtered seawater. Immediately after stirring, two subsamples were placed in a hemacytometer and sperm cells allowed to settle for five minutes. Counts of intact sperm with brightly transmissive acrosomal vesicles were made at 250x under a light microscope. A quantitative estimate of the number of sperm in one spermatheca was calculated as follows: original homogenate volume x dilution factor x mean sperm count in the two hemacytometer chambers = total number of sperm.

Males grasping pubescent females were collected near Kodiak, Alaska by ADF&G biologists using scuba equipment. Carapace width of grasping individuals was measured to the nearest millimeter at the widest point of the dorsal exoskeleton excluding spines. Egg and sperm counts are not available for these observations.

OBJECTIVES THREE AND FOUR

To determine the frequency of mating for old shell _C. bairdi_, males over 110 mm carapace width were placed in three indoor tanks with females and when matings were observed, both male and female crab were marked with leg tags. Four additional groups of old shell females were placed in outdoor 10^6 liter 6°C saltwater ponds. Three of these groups contained different ratios of males and old shell females, and one group contained only old shell females. In outdoor ponds, matings could not be observed, so the walking legs of the females placed with males were wrapped with electrician's tape to ensure that new grasping marks would be identifiable. In addition, 20 females with tape-wrapped legs were isolated from males during the mating and egg extrusion period. This group served as a control to determine if grasping-like marks would be left on the tape by the females themselves. The tape on all isolated females remained unmarked. In this report, the term "old shell female" refers to individuals that have already produced at least one egg clutch and have a carapace at least one year old.

Approximately one month after extrusion of new eggs, 112 old shell females with access to males were killed, examined for grasping marks, and their eggs counted and spermathecae examined for fresh sperm. Egg counts were also made for a similar number of old shell females, which were captured just prior to the mating season and forced to use stored sperm to fertilize their clutch. Following the extrusion of a new egg clutch, the spermatheca of each female was examined visually for the presence of fresh ejaculate. Fresh ejaculate is deposited as a dense, white semi-solid, while ejaculate that has been stored from previous matings forms a distinctive amalgamated mass which is slightly yellow or brown. Some of the old shell females forced to use stored sperm were held segregated from males for two years, and the percentage which produced eggs in the second year was determined.

Sperm counts were also made from material stored in the spermathecae of southeastern Bering Sea C. bairdi that mated in the ocean, but otherwise their mating history was unknown.

OBJECTIVE FIVE

Females that did not produce eggs in the laboratory were classified as reproductively active if their ovaries were in an advanced state of oogenesis. Conversely, they were classified as having atrophied ovaries. In this report, the term "barren" implies a female without externally attached eggs. Additionally, ADF&G biologists made observations on the percent of female crab that were barren in waters near Kodiak, Alaska.

OBJECTIVE SIX

Males were mated to several females and the sperm counts in the spermathecae of female mates determined.

RESULTS AND DISCUSSION

It proved difficult to quantify the length of time prior to molting that a female C. bairdi attracts a grasping male. Males in tanks often grasped pubescent females, but released them prior to the molt. Our limited observations suggest that males are attracted to females up to 14 days prior to her maturity molt. In most observations, males grasped and permanently held females on the day of her maturity molt. Laboratory conditions and the contrived nature of the matings preclude an accurate estimation of the length of the premolt embrace.

During 1982, 80 pubescent females molted to maturity while isolated from males. At varied intervals after the maturity molt, 48 of these females were put in tanks with males, mated, and extruded eggs. Those which mated within four weeks of their maturity molts generally produced viable eggs; however, following longer intervals, females typically extruded non-viable eggs (Table 1). One female was bred at day 67, but did not extrude any eggs. Thirty-one of the 80 females, without access to males, extruded non-fertile eggs without mating (Table 2). These unfertilized eggs appeared normal, but failed to divide and showed obvious signs of deterioration after approximately eight to 12 weeks. It is noteworthy that in 1981, eight of 14 unmated primiparous females resorbed their unextruded eggs, whereas the remaining six females extruded infertile eggs.

Laboratory mating behavior of C. bairdi has been described by Takeshita and Matsuura (1980), and Adams (1982). Generally, it is similar to that reported for C. opilio by Watson (1972). Chionoecetes bairdi females, newly molted to maturity, typically breed in winter; thus the majority of them do not compete with spring breeding multiparous females for mates. In the laboratory, several soft-shell females were eaten by other females. Protection from predation and cannibalism, often provided to soft-shell primiparous females by attending males, may be an important aspect of the reproductive behavior of this species. Permanent grasping marks, the result of mating embraces, were not left on the walking legs of any of the primiparous females mated in the laboratory. A detailed description of mating behavior observed during this project is summarized in Adams (1982).

The results of this study demonstrate that if primiparous C. bairdi are not bred soon after molting to maturity, a significant portion of them will not produce viable eggs.

The smallest male observed by scuba divers grasping a pubescent female prior to her maturity molt was approximately 75 mm carapace width (Figure 1). The average carapace width of male graspers was 112 mm; males between 100 and 120 mm formed the predominant size group (Figure 1). In all cases, the male mate was larger than the female, with females averaging 81 mm carapace width (Figure 2). However, there was a poor correlation ($r^2 = 0.05$) for the regression describing the relationship of male and female carapace widths in grasping pairs (Figure 3).

Considerable variation was observed in the number of sperm cells present in the spermathecae of C. bairdi females mated to males 65 to 140 mm carapace width. The average number of sperm cells present in the spermathecae ranged

Table 1. Elapsed time between the molt to maturity and female *C. bairdi* breeding in 1982

Elapsed Time (Days)	Eggs (Viable)	Female (Number)	Elapsed Time (Days)	Eggs (Viable)	Female (Number)
0.0	Yes	566	19.0	No	507
0.0	Yes	603	19.7	Yes	532
0.0	Yes	592	19.9	Yes	580
0.0	Yes	581	20.4	Yes	574
0.0	Yes	595	21.0	Yes	578
0.1	Yes	561	21.1	Yes	550
0.1	Yes	598	21.6	Yes	546
0.2	Yes	552	22.4	Yes	547
0.5	Yes	604	23.6	Yes	558
0.6	Yes	570	25.0	Yes	531
1.6	Yes	573	25.5	Yes	563
2.0	Yes	553	25.5	Yes	554
4.4	Yes	601	25.6	Yes	577
5.0	Yes	518	25.6	Yes	548
9.2	Yes	571	26.2	Yes	542
11.2	Yes	599	27.7	Yes	602
11.5	Yes	584	28.0	No	583
12.4	Yes	591	28.3	Yes	506
13.5	Yes	590	30.0	No	501
14.0	Yes	514	30.1	Yes	529
16.0	Yes	582	39.0	No	557
16.0	Yes	530	39.5	No	533
18.4	Yes	564	44.0	No	572
18.7	Yes	522	67.0	---	502*
			68.0	No	576

* 502 did not produce eggs.

Table 2. The length of time following the maturity molt that infertile eggs were extruded by primiparous *C. bairdi* held isolated from males

Date Molted (Mo./Day)	Date Extruded (Eggs Mo./Day)	Number of Days (From Molt)	Crab (Number)	Date Molted (Mo./Day)	Date Extruded (Eggs Mo./Day)	Number of Days (From Molt)	Crab (Number)
2/2	2/2	0	524	2/12	2/20	7	559
1/30	1/30	0	538	1/23	1/31	8	503
1/29	1/29	0	539	1/27	2/4	8	528
1/27	1/28	1	527	2/12	2/20	8	559
1/30	1/31	1	525	2/14	2/22	8	606
1/31	2/1	1	556	2/17	2/25	8	18
2/7	2/8	1	555	2/23	3/6	14	242
2/7	2/8	1	569	3/3	3/24	21	253
2/12	2/13	1	597	3/30	4/24	25	266
2/16	2/17	1	596	1/14	2/19	36	210
3/13	3/14	1	269	2/2	3/16	42	579
2/4	2/6	2	537	2/28	4/27	58	248
2/5	2/7	2	544	1/26	N.O.*	--	515
1/31	2/2	3	575	1/29	N.O.*	--	540
1/28	2/1	4	535	1/31	N.O.*	--	536
1/30	2/4	5	549				

* N.O. = Not Observed

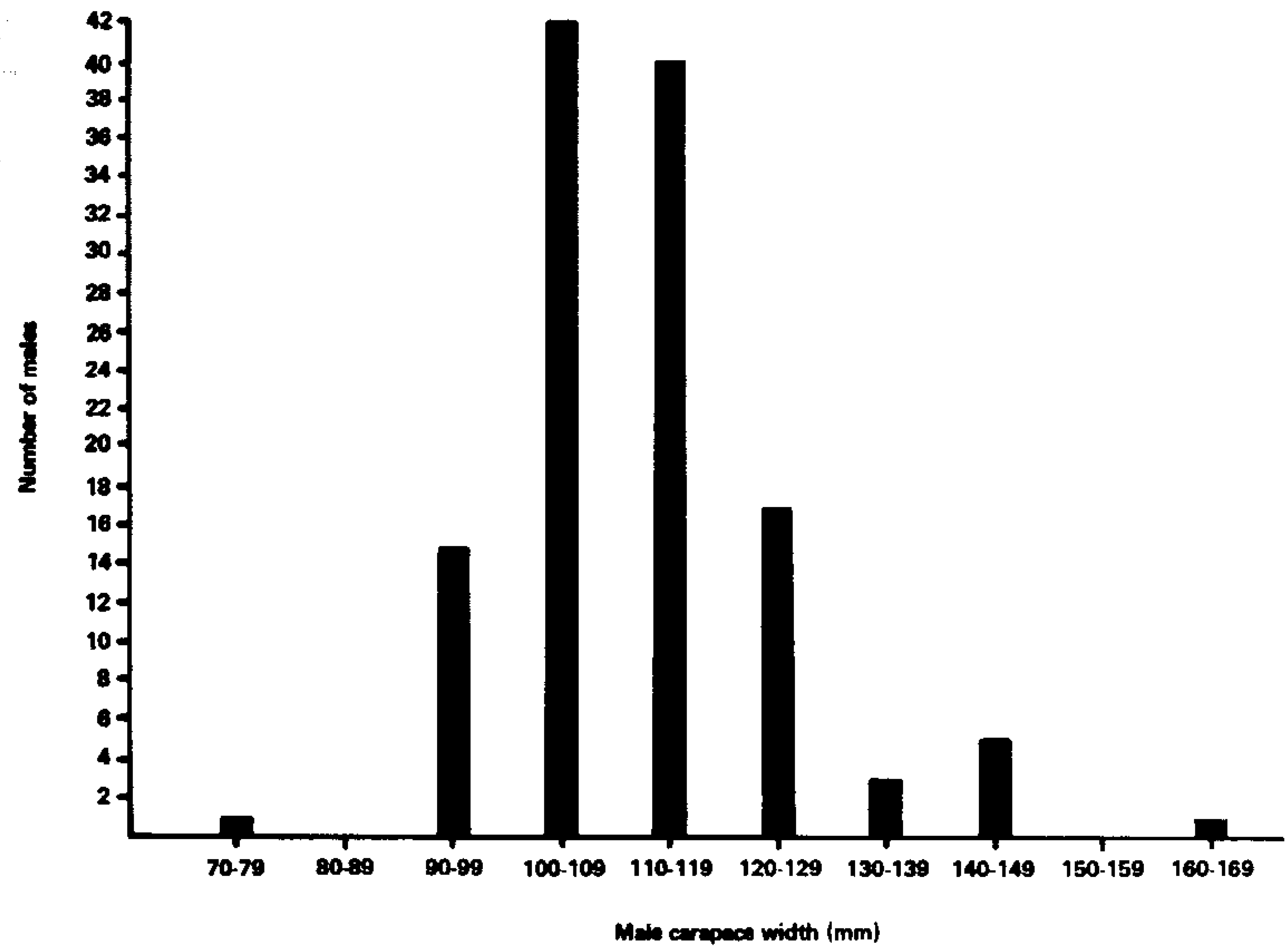

Figure 1. Male carapace widths in 124 grasping pairs of *Chionoecetes bairdi* captured by scuba divers. Average male size was 112 mm.

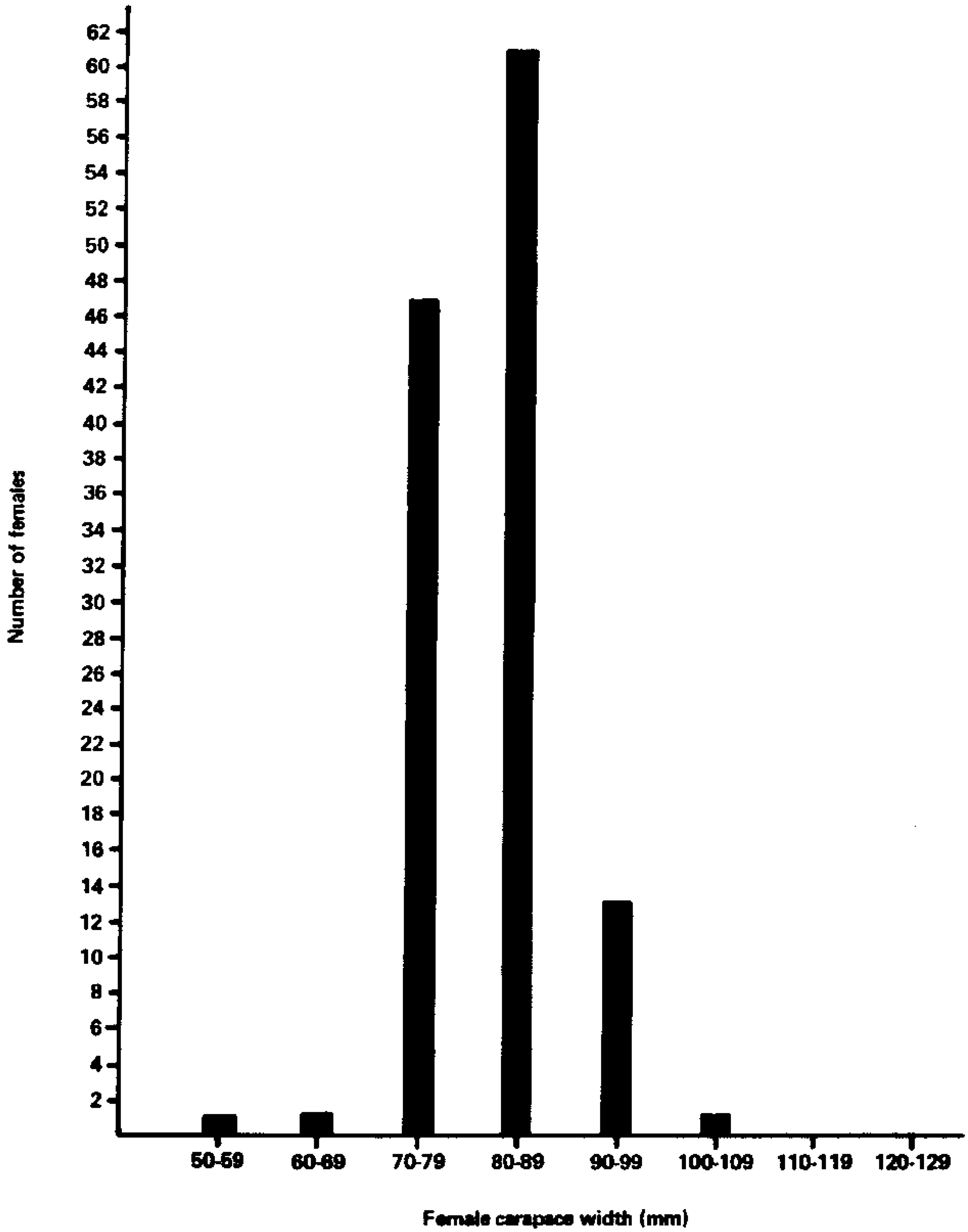

Figure 2. Female carapace widths in 124 grasping pairs of *Chionoecetes bairdi* captured by scuba divers. Average female size was 81 mm.

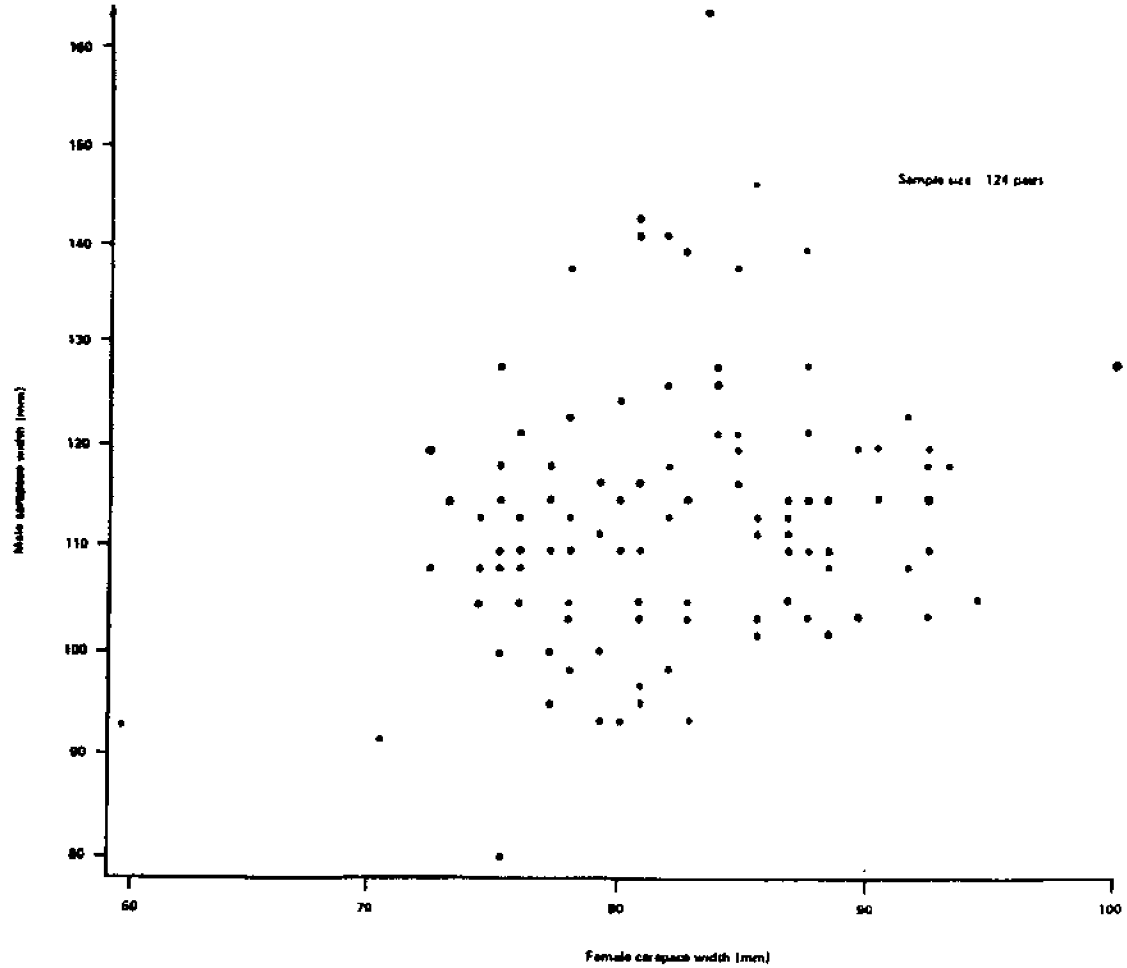

Figure 3. Regression for male *Chionoecetes bairdi* carapace width and pubescent female carapace width in grasping pairs captured by scuba divers.

from 5.8×10^5 for 65 to 75 mm males to 1.6×10^6 for 106 to 115 mm males (Table 3). The maximum and minimum numbers of sperm cells counted were 49×10^5 and 40×10^3 cells deposited by a 108 mm very old shell and an 83 mm new shell male respectively. The regression equations for male carapace condition and number of sperm in a spermatheca all had r^2 values less than 0.3, suggesting no clear relationship exists between these variables (Figure 4, Table 4).

Males 65 to 110 mm, whose mates extruded viable eggs, provided sufficient numbers of sperm cells to fully fertilize a female's first egg clutch. Eleven males 56 to 58 mm carapace width mated with primiparous females, but non-viable eggs were produced from the matings, which suggests that these small males were not fully mature.

The process of fertilization has been described for only one species in the crab family Majidae. Hinsch (1971) demonstrated that several sperm are expended in the fertilization of each egg of the majid crab Libinia emarginata. Spatial limitations, the high concentration of sperm within the spermatheca, and the close phylogenetic relationship of these two species suggest that more than one sperm may also be expended in the fertilization of each C. bairdi egg.

Multiparous C. bairdi annually produce an average of 170,000 eggs (Hilsinger 1976). Therefore, assuming one sperm per egg, at least 170,000 stored sperm cells are required for each subsequent egg clutch. However, it is probable that several sperm are lost for each egg fertilized and sperm requirements are much higher than 170,000 per clutch. The number of sperm cells present in paired spermathecae of a primiparous female is generally sufficient to fertilize the first and perhaps subsequent egg clutches (Table 3). However, 7 percent of the laboratory bred females had insufficient stored sperm to fully fertilize a second clutch (Table 3).

Based on morphometry, the current estimations of size at which 50 percent of male C. bairdi are sexually mature is 109 to 117 mm carapace width (Brown and Powell 1972; Somerton 1981). In this study, several males under 110 mm were successful breeders with primiparous females. A histological study of gonad maturation is necessary to complement this report before the reproductive potential for specified size classes of male C. bairdi can be adequately described.

The number of eggs extruded by primiparous C. bairdi exhibited no apparent relation to male parent size (Figure 5, Table 5). A total of 18 females producing viable eggs had mates smaller than themselves. Within this group, 44 percent, 28 percent and 28 percent of them had mates whose carapace widths were 4 to 15 mm, 16 to 25 mm and 26 to 35 mm smaller, respectively, than their own. A Student-t test comparing the number of eggs extruded by females mated to smaller males and 12 females whose mates' carapace widths were at least 25 mm larger than their own indicated no significant difference (P=99) in the number of eggs extruded by these two groups of females (Table 6). These results are explainable, in part, because most females receive sufficient sperm from a mating to fertilize more than one egg clutch (Table 3).

The frequency of mating for old shell females was found to be between 47 and 100 percent (Table 7). At sex ratios of one male to eight or fewer females,

Table 3. **Number of sperm cells remaining in one spermatheca following egg extrusion by a primiparous *Chionoecetes bairdi* mated to males of a known carapace width**

Male Width (mm)	Sperm Count in One Spermatheca			
	Mean	Standard Deviation	Range	Sample Size
65-75	580,290	421,357	140,000-1,471,000	8
76-85	921,500	924,350	40,000-2,110,000	5
86-95	554,400	424,487	105,000-1,730,000	11
96-105	1,174,166	436,902	540,000-1,680,000	6
106-115	1,645,000	1,514,000	250,000-4,900,000	10
116-125	904,785	812,167	98,000-2,820,000	14
126-135	576,000	371,646	103,000-1,087,000	7
136-140	595,000	---	--- ---	1

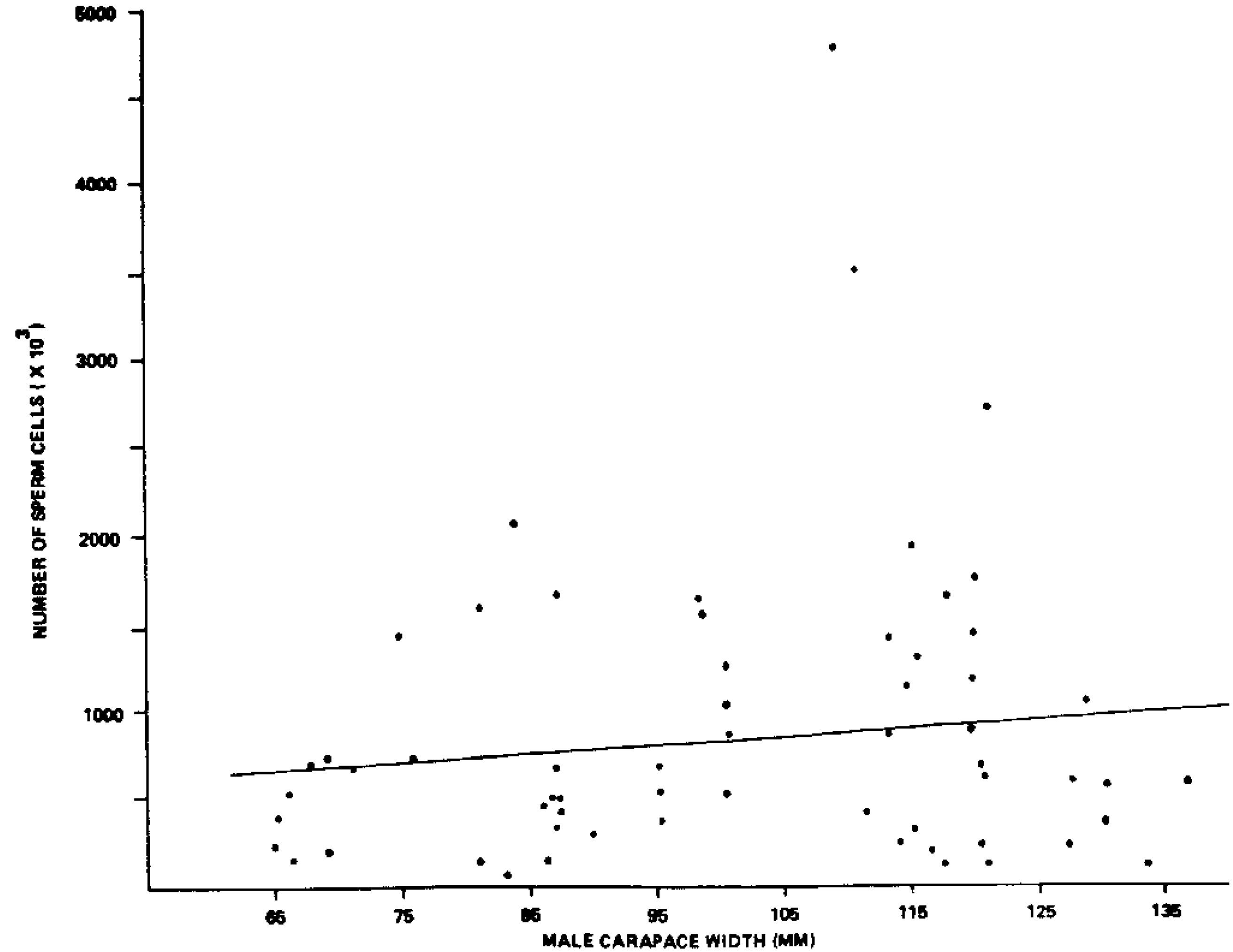

Figure 4. Regression for male *Chionoecetes bairdi* carapace width (mm) and the number of sperm remaining in one spermatheca of their primiparous mates following extrusion of the first egg clutch.

Table 4. **Regression equations for male *Chionoecetes bairdi*: carapace width (mm) versus number of sperm cells present in one spermatheca of a primiparous female after extrusion of the first egg clutch**

Male Type	Regression	r^2	n
All males (Fig. 2)	$\bar{x}$ No. sperm (10^3) = 336 + 5.4 (carapace width mm)	0.02	63
New shell males	$\bar{x}$ No. sperm (10^3) = 226 + 3.0 (carapace width mm)	0.14	18
Old shell males	$\bar{x}$ No. sperm (10^3) = -488 + 16.0 (carapace width mm)	0.27	25
Very old shell males	$\bar{x}$ No. sperm (10^3) = 770 - 0.3 (carapace width mm)	0.01	20

$\bar{x}$ = Mean
r^2 = Correlation coefficient
n = Sample size

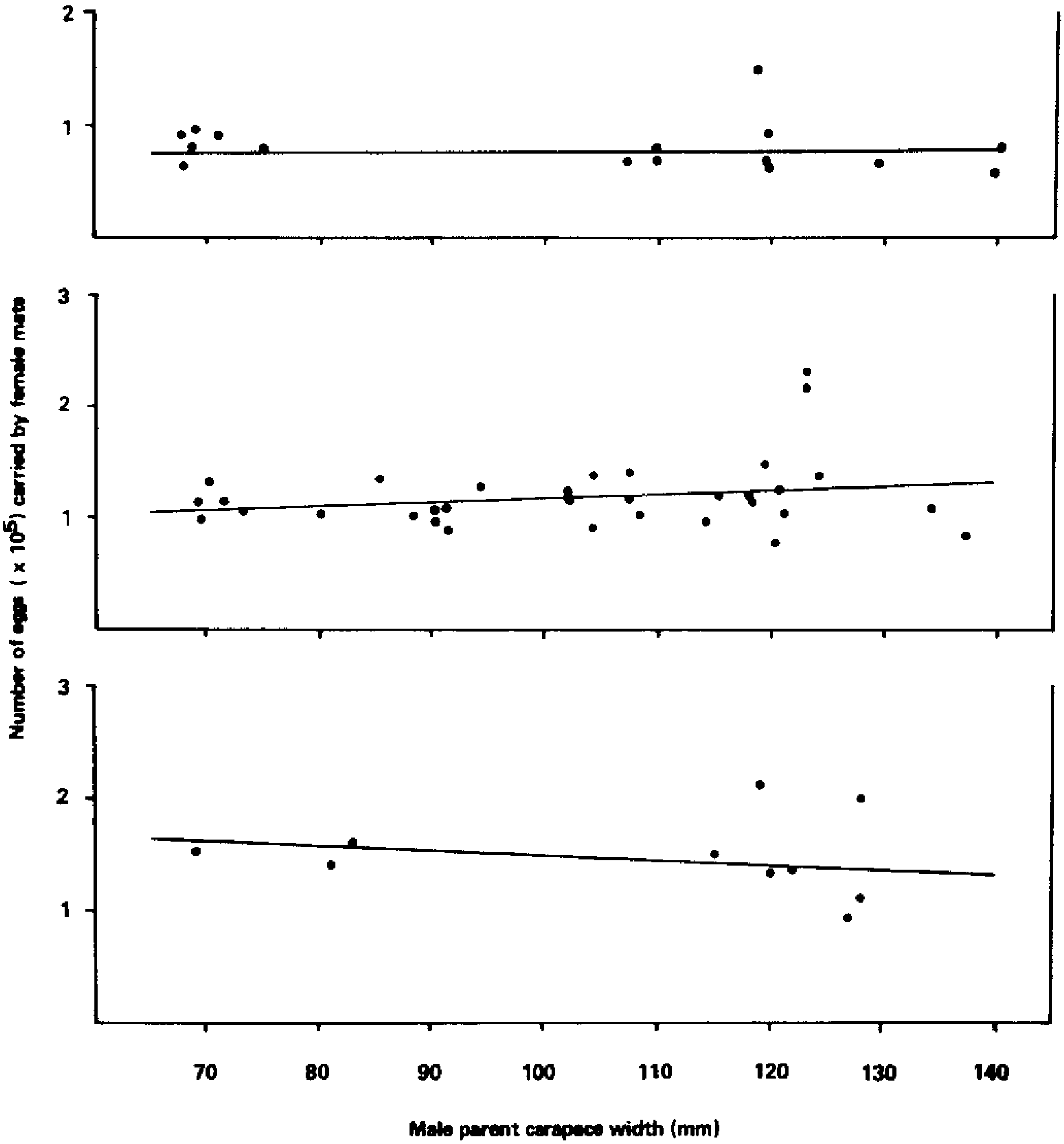

Figure 5. Number of eggs carried by primiparous Chionoecetes bairdi: carapace widths 80 to 89 mm (upper), 90 to 99 mm (middle) and 100 to 110 mm (lower) in relation to male parent size. (See Table 5 for regression equations.)

Table 5. Regression equations for parent *Chionoecetes bairdi*: male carapace width (mm) versus number of eggs produced by three size classes of primiparous females

Female Width (mm)	Regression	r^2	n
80-89	$\bar{x}$ Egg no. (10^3) = 86 + 0.06 (male carapace width mm)	0.01	18
90-99	$\bar{x}$ Egg no. (10^3) = 67 + 0.51 (male carapace width mm)	0.06	32
100-110	$\bar{x}$ Egg no. (10^3) = 182 - 0.32 (male carapace width mm)	0.06	11

$\bar{x}$ = Mean
r^2 = Correlation coefficient
n = Sample size
no. = Number

Table 6. A Student-t test comparison of the number of eggs produced by primiparous *C. bairdi* mated to males smaller and larger than themselves

Female Larger Than Male			Male More Than 25 mm Larger Than Female		
Female Carapace Width (mm)	Male Carapace Width (mm)	Number of Eggs (x 10^3)	Female Carapace Width (mm)	Male Carapace Width (mm)	Number of Eggs (x 10^3)
81	65	68	85	120	68
82	75	79	85	120	63
85	71	82	87	120	92
90	65	110	87	130	67
90	86	90	88	119	152
90	86	101	90	116	78
92	76	114	90	119	284
92	87	106	94	119	214
92	87	85	95	130	118
93	65	94	95	133	82
93	84	98	100	127	97
95	90	124	102	128	111
96	66	129			
96	69	101			
96	81	133			
100	81	144			
101	69	153			
102	83	161			

t-Statistics = -1.21
Degrees of Freedom = 28

Table 7. Mating frequency of old shell female *Chionoecetes bairdi* in relation to sex ratio

Number of Females	Sex Ratio Male/Female	% Females Bred	% Females Bred with Grasping Marks	No. Barren Females Active Ovaries	No. Barren Females Degenerate Ovaries
112	1/1.2	100	96	0	0
28	1/1.8	96	96	0	1
32	1/4	97	97	0	1
30	1/8	100	100	0	0
17	1/17	47	30	5	4

over 96 percent of the females with active gonads were bred. However, at a sex ratio of one male to seventeen females, 38 percent of the females with gonads classed as reproductively active were not bred. Fresh grasping marks were readily apparent on most of the recently-mated old shell females (Table 7).

The smallest male to breed with old shell females was 110 mm carapace width. That male was the only male in a tank with six old shell females and mated with the three of them that had reproductively active gonads. In another group there were 16 males of various sizes and 28 females. Male parent sizes and frequency of breeding were observed in 15 additional matings with old shell females (Table 8). In the set of observations, where 16 males were present in the tank with 28 old shell females, all but one mating male in this group bred more than one female (Table 8). Fifty-six percent of the males present, most of which were new shell males under 118 mm carapace width, were not observed to mate (Table 8). One 130 mm male in a tank with several females bred eight old shell females (Table 9). The average size of males observed breeding with old shell females was 133 mm, with a range of 110 to 152 mm (Table 9).

To determine if using stored sperm had any effect on the number of eggs extruded by old shell females, 184 individuals carrying eggs that would soon hatch were placed in a 10^6 liter saltwater pond containing no males. After new eggs were extruded, 110 of them were killed and their eggs counted. New eggs were extruded by 107 (97 percent) of them and only three were barren. A comparison of the number of eggs produced by these females and a similar number of mated females using fresh sperm to produce eggs occurs in Figure 6. There appears to be no marked difference in the number of eggs produced by females using fresh sperm and females using sperm stored for at least one year. Two of the three barren females were killed and their gonads examined. Both individuals had empty spermathecae, but their ovaries were filled with new eggs which were ready for spawning. To test the hypothesis that limited sperm availability precluded the extrusion of eggs by these three females, the remaining barren female was isolated for a week, then placed in a tank with males where she was observed to breed and extruded fertile eggs.

Seventy-two of the 184 old shell females were kept isolated from males for two breeding seasons. In April, normal appearing egg clutches were produced by 78 percent of these females in the second year they were isolated from males. The non-egg producing females consisted of fourteen individuals whose gonads appeared to be reproductively active and two with atrophied gonads. Thus, 20 percent of the 70 females that appeared to be reproductively viable failed to produce eggs after being isolated from males for two years. These females were held for one week following the ingestion of the old egg shells, then were placed with males. Six of them bred and then extruded eggs. The others remained barren. The spermathecae of the barren females were typically less than half full and contained only a hard amalgamated mass. By November, when this report was compiled, six more of these females had lost 100 percent of their eggs, which were not dividing. As a result, 28 percent of the 70 females held isolated from males for two years were barren.

In some instances, mating occurred while old shell females still carried a few unhatched eggs. In other cases, old shell females mated as late as one week after all the eggs hatched. However, the mating failure of eight of 14

Table 8. Size and mating frequency of C. bairdi held in a tank with 28 old shell females (1981 data)

Male Carapace Width (mm)	Male Carapace Condition	Number Females Mated*
92	1	0
99	1	0
100	1	0
100	1	0
111	1	0
112	2	0
118	1	0
124	1	2
124	1	0
126	1	0
127	1	2
136	1	1
138	1	4
138	1	2
142	3	2
152	2	2

* 12 other females in the tank with these males were bred unobserved.

Table 9. Observations of *Chionoecetes bairdi* male size and frequency of mating with old shell females

Year Observed	Male Carapace Width (mm)	Number of Females Mated With
1980	110	3
1981	124	2
1981	127	2
1981	136	1
1981	138	4
1981	138	2
1981	142	2
1981	152	2
1982	130	8
Mean Male Size	133	

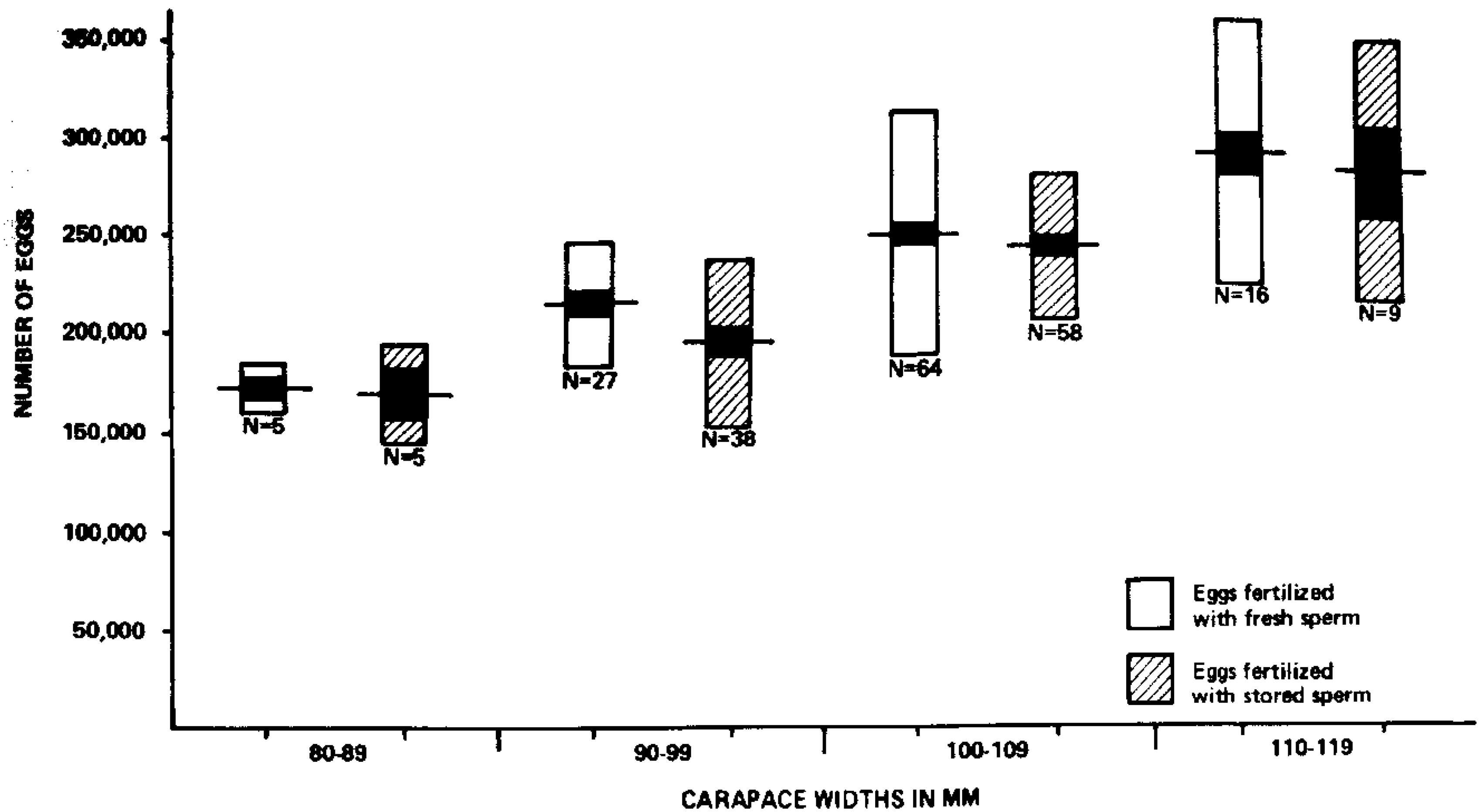

Figure 6. A comparison of egg production by multiparous Chionoecetes bairdi utilizing sperm acquired by mating just prior to egg extrusion, and sperm stored in the spermatheca for at least one year. The horizontal line denotes the mean, the larger box denotes two times the standard deviation, and the black box denotes two times the standard error of the mean. N=sample size.

old shell females held isolated for one week after the hatching of their eggs suggests that old shell mating cannot be postponed for more than a few days after their larvae are released.

Sperm cells counts in spermathecae of southeastern Bering Sea primiparous C. bairdi mated in situ ranged from 132,000 to 1,221,000 (Table 10). Thus, if only one sperm cell was used to fertilize an egg, and the sperm remains viable, these primiparous crab could fertilize from less than 1 to 6 egg clutches using stored sperm. A similar examination of southeastern Bering Sea multiparous C. bairdi mated in situ suggest that, with these same unproven constraints, stored sperm could be used to fertilize from less than 1 to 9 egg clutches (Table 10). However, it is probable that some stored sperm are not viable and more than one sperm is lost for each egg fertilized (Hinsch 1971). Thus, fewer egg clutches could be fertilized with stored sperm.

It appears that stored sperm are utilized primarily as a safeguard against the possibility of a multiparous C. bairdi not encountering a prospective mate prior to extruding a new egg clutch. This is a successful strategy since 97 percent of the females that were isolated from males in the laboratory produced egg clutches of normal size and viability. However, stored sperm is generally used only when males are absent. The oviduct is positioned such that the most recently deposited sperm in the spermatheca will fertilize the eggs.

Sperm stored in the spermathecae of C. bairdi has been demonstrated to remain viable for at least two years. Continued observations are necessary to accurately measure the length of time stored sperm remains viable. The occurrence of 28 percent barrenness in apparently reproductively active females relying on stored sperm for two consecutive egg clutches suggests that any alteration in sex ratios that results in females consistently not encountering mates during the short period when they are receptive to mating, may have a negative effect on the reproductive potential of the population.

The percentage of barren multiparous C. bairdi in 202 new shell and old shell females, (very old shell carapace individuals excluded) held with males at sex ratios of one male to eight or less females in the laboratory was approximately 1 percent (Table 7). In a group of 112 multiparous individuals isolated from males during the breeding period 2.6 percent of the individuals were barren. ADF&G surveys for the Kodiak area suggest that 2 percent to 4 percent of the new shell and old shell crab will not produce an egg clutch, while more than 10 percent of the very old shell females will be barren (Table 11).

No obvious trends were observed for the number of sperm deposited in a spermatheca by males successively mated to more than one female (Table 12). Two males mated twice within 24 hour periods. In one case, the second female's spermatheca contained a greater number of sperm than the first female; in the other case, the reverse was true. Two individual males mated twice in 1 and 3 days respectively, and, in both cohorts, similar numbers of sperm were found in the spermathecae of both females. Sperm counts are available for six other males which were involved in multiple matings, with the average time interval between matings exceeding five days. One individual mated with seven females with an average time interval between matings of three days. In all multiple matings, males provided their mates with enough sperm to

Table 10. Estimated number of sperm cells stored in one spermatheca of *Chionoecetes bairdi* collected in the southeastern Bering Sea

Primiparous Females Mated in the Field			Multiparous Females Mated in the Field		
Amount Ejaculate Stored	Sperm Count In One Spermatheca	Number of clutches (200,000 Eggs) That Could Be Fertilized*	Amount Ejaculate Stored	Sperm Count In One Spermatheca	Number of clutches (200,000 Eggs) That Could Be Fertilized*
0.01 ml	240,000	1	0.01 ml	890,000	4
0.01 ml	160,000	<1			
0.01 ml	345,000	1			
0.01 ml	330,000	1			
0.01 ml	460,000	2			
0.01 ml	610,000	3			
0.01 ml	970,000	4			
0.02 ml	132,000	<1	0.02 ml	1,999,000	9
0.03 ml	433,000	2	0.03 ml	820,000	4
			0.03 ml	1,273,000	6
0.14 ml	1,221,000	6	0.14 ml	288,000	1
			0.14 ml	139,000	<1
			0.14 ml	1,358,000	6
0.16 ml	243,000	1	0.16 ml	370,000	1
0.21 ml	251,000	1	0.21 ml	60,928	1
0.40	217,250	1	0.40 ml	919,000	4

* Assumes sperm remains viable indefinitely and only 1 sperm cell is lost from the spermatheca for each egg fertilized. Both assumptions require verification.

Table 11. Tanner crab ovigerity index by shell condition for the Kodiak area (ADF&G surveys 1974-1982)

Female Ovigerousness (%)

Year	New Shell	Old Shell	Very Old Shell	% Barren All Classes
1974	98	96	--	--
1975	99	98	--	--
1976	99	96	82	3.1
1977	98	98	91	4.4
1979	100	97	66	6.7
1980	98	97	75	8.5
1981	99	95	--	3.4
1982	99	98	82	1.8

1979-1982 data from W. Colgate, ADF&G, Kodiak.

Table 12. The number of sperm cells found in one spermatheca of primiparous <u>Chionoecetes</u> <u>bairdi</u> mated to the same male

Male Carapace Width (mm)	Male Carapace Condition	No. Females Mated	No. Sperm in A Spermatheca	No. Days Between Mating (x)	(+sd)	(range)
86	Old Shell	2	470,000		-	-
			105,000	25		
87	Very Old Shell	5	1,730,000			
			672,000			
			331,400			
			420,000			
			492,000	6	(+ 2)	3-8
95	Old Shell	6	673,000			
			560,000			
			365,000	12	(+ 6)	4-21
			nc			
			nc			
			nc			
92	Old Shell	2	nc	6	-	-
98	Old Shell	2	1,680,000			
			1,605,000	3	-	-
100	Old Shell	5	1,060,000			
			540,000			
			1,280,000			
			880,000	5	(+ 4)	1-10
			nc			
112	Very Old Shell	7	nc	3	(+ 3)	0-7
114	Old Shell	2	1,186,700			
			2,010,000	8	-	-
119	Very Old Shell	4	1,814,000			
			903,750			
			1,484,000			
			1,216,100	14	(+15)	2-31
120	Very Old Shell	2	680,000			
			645,000	1	-	-
120	New Shell	2	200,000			
			630,000	0	-	-
130	Very Old Shell	2	578,000			
			366,200	0	-	-

nc = Not Counted

fertilize a full egg clutch. It appears that the probability of encountering a female ready to breed, rather than an ability to produce sperm, will regulate the number of females a reproductively active male will inseminate.

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APPENDIX

Table A-1. Incremental growth through puberty molting of <u>Chionoecetes bairdi</u> females

Carapace Width (mm)			Abdomen Width (mm)			
Pre-Molt	Post-Molt	Percent Increase	Pre-Molt	Post-Molt	Percent Increase	Crab Number
64	78	18	29	54	46	C-1
69	79	13	32	51	37	280
69	81	15	33	54	39	278
69	82	16	32	53	40	233
70	82	15	31	52	40	220
70	81	14	32	52	38	229
70	81	14	32	51	37	261
70	84	17	32	52	38	B-1
70	83	16	33	54	39	234
70	84	17	33	55	40	237
70	81	14	34	53	36	221
71	82	11	33	52	36	231
71	80	11	34	49	31	238
71	84	15	34	54	37	249
71	82	13	34	54	37	266
71	85	16	35	56	38	251
72	82	12	32	48	33	252
72	84	14	33	54	39	267
72	84	14	33	53	38	268
72	85	15	33	51	35	227
72	86	16	33	55	40	236
72	79	9	34	49	31	288
72	81	11	35	54	35	224
73	86	15	32	54	41	11
73	85	14	33	54	39	5
73	85	15	33	54	39	262
73	83	12	33	54	39	226
73	86	15	34	57	40	240
73	84	13	34	51	33	275
74	85	13	32	52	38	10
74	90	18	33	58	43	A-7
74	88	16	34	60	43	A-2
74	87	15	34	59	42	1
74	89	17	34	70	51	25
74	87	15	34	57	40	271
74	86	14	34	55	38	232
74	92	20	34	58	41	241
74	85	13	34	53	36	244
74	87	15	34	53	36	248
74	87	15	35	55	36	246
75	89	16	32	55	42	A-3
75	90	17	33	56	41	8
75	87	14	34	55	38	13
75	90	17	34	57	40	22

Table A-1 (cont'd.)

Carapace Width (mm)			Abdomen Width (mm)			
Pre-Molt	Post-Molt	Percent Increase	Pre-Molt	Post-Molt	Percent Increase	Crab Number
75	87	14	35	56	38	281
75	88	15	35	58	40	272
75	86	13	35	55	36	247
75	89	16	36	57	37	B-2
75	83	10	37	55	33	254
75	89	16	38	62	39	219
76	88	14	35	58	40	7
76	87	13	35	53	34	269
76	91	16	36	61	41	19
76	91	16	37	60	38	270
77	90	14	36	57	37	217
78	90	13	36	56	36	256
78	86	9	37	54	31	273
78	91	14	37	56	34	286
78	92	15	37	60	38	245
79	95	17	36	60	40	A-6
79	94	16	36	60	40	23
79	91	13	37	59	37	20
79	88	10	37	58	36	253
79	90	12	38	61	38	287
80	87	8	37	55	33	243
80	92	13	38	58	34	250
80	96	17	38	62	39	A-4
82	97	15	37	62	40	A-5
82	95	14	38	60	37	17
82	95	14	39	59	34	15
82	95	14	40	64	38	6
84	98	14	39	61	36	4
84	96	12	41	62	34	A-1
86	99	13	40	63	36	210
86	101	15	42	66	36	14
88	100	12	41	64	36	16
88	103	15	46	65	29	18
90	100	10	42	62	32	242
90	105	14	42	62	32	24
90	103	13	43	67	36	9
92	105	12	45	66	32	12

Table A-2. Incremental growth through molting of *Chionoecetes bairdi* juvenile females

Carapace Width (mm)			Abdomen Width (mm)			
Pre-Molt	Post-Molt	Percent Increase	Pre-Molt	Post-Molt	Percent Increase	Crab Number
60	72	17	26	33	21	260
61	77	21	27	38	29	216
63	78	19	29	39	26	213
64	79	19	27	36	25	211
65	82	21	29	39	26	214
68	85	20	31	40	22	279
75	93	19	34	46	26	222