PRELIMINARY OBSERVATIONS ON THE DISTRIBUTION AND ABUNDANCE OF THE STONE CRAB, *Menippe mercenaria*, IN SOUTH CAROLINA WATERS[1]

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ABSTRACT

Collections of stone crabs were made at seven locations near Charleston, South Carolina from July - September 1982. In each location sampled, five commercial wire blue crab traps with two entrance holes and five wooden-lath stone crab traps, similar to those used in the Florida fishery, were fished for two and three days in paired sets. Twice as many stone crabs were collected in the blue crab trap as in the stone crab trap, and for six of the sites sampled, catches in the blue crab trap were significantly greater than those in the stone crab trap. No significant differences were found in the number of crabs per trap between two-day and three-day sets for either trap type. For all sites sampled, catch per unit of effort showed a decline when plotted against cumulative catch of the blue crab trap, suggesting that either sites were being fished out; that stone crabs were emigrating from these areas; or that they were no longer susceptible to active fishing because of a behavioral change. Catch per unit of effort showed no relation to cumulative catch of the stone crab trap probably because of the relatively low numbers of crabs collected with that trap. Data collected on sexual maturity, sex ratios, carapace width frequency, and handedness are presented and compared to similar information from the Florida fishery.

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Acknowledgements

It would have been impossible to carry out this project without the generous help of personnel from the S.C. Wildlife and Marine Resources Dept., interested friends, and commercial crabbers. Thanks are extended to everyone who participated in the field sampling, and especially to C. Wenner, R. Beatty, J. Williams, S. Newsom, W. Jenkins and R. Smiley who volunteered on a regular basis. We are most grateful to D. Cupka and G. Ulrich who supplied us with designs of the Florida trap. G. Ulrich along with R. Low, D. Oakley, N. Jenkins, W. McCord, and B. Seaborn, helped to construct the Florida traps. B. Moise (Law Enforcement Division) and J. Bishop (MRRI) kindly supplied us with most of the blue crab traps. R. Rhodes (SCWMRD), P. Eldridge (NOAA), and T. Bert (Yale University) kindly supplied some literature. D. Theiling and J. Smith (SCWMRD) made available their information on 1982-83 stone crab landings from South Carolina.

Current and former crabbers who supplied information included L.C. Hawkins, Glen Welch, Mac McLeod, W.R. Mauldin and R. Wade Lewis. L.C. Hawkins also supplied all of the bleach bottles which were used as bait wells. R. Bruland and T. Daniels (Keys Fisheries) were gracious hosts on the Lady and provided us with an opportunity to observe what a first-class stone crabbing operation is like. We are also grateful to L. Burgess who assisted on all aspects of the project. Additional technical assistance was provided by K. Swanson who drafted the figures; G. Gash, L. Rigsbee, and J. Stribbling who assisted with data processing; and N. Beaumont who typed the manuscript. T. Bert (Yale University) supplied valuable information on the Florida fishery and arranged the trip with commercial stone crabbers.

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Introduction

The stone crab, Menippe mercenaria, ranges from the Yucatan peninsula of Mexico, along the Gulf Coast, into the Caribbean, and along the east coast of the United States to Cape Hatteras, North Carolina (Rathbun, 1930; Williams, 1965; Powers 1977). Stone crabs occur from the intertidal zone (McRae, 1950) to 54 m (Bullis and Thompson, 1965).

Despite its wide geographic range in warm temperate, subtropical and tropical waters, the North American commercial utilization of M. mercenaria is confined primarily to Florida where the stone crab fishery constitutes the third largest crustacean fishery. In Florida, the stone crab fishery did not show much growth until the early 1960's. Prior to that time, stone crabs were caught incidentally to spiny lobsters, Panulirus argus (Schroeder, 1924). Although the current stone crab fishery in Florida is small in comparison to the state's shrimp industry and spiny lobster fishery, landings of stone crab claws (the only saleable portion of the crab) have increased from 0.2 million pounds in 1957 to 2.4 million pounds in 1976 (Savage et al., 1975). An expanded market, composed primarily of metropolitan restaurants, has been responsible for the rapidly rising volume and value of stone crab claws (Bert et al., 1978).

At present, there is no directed fishery for stone crabs in South Carolina. Those claws which are sold commercially are taken almost exclusively in crab pots being fished for blue crabs (Callinectes sapidus). Although no data exist to document whether catches of stone crabs have increased in South Carolina in recent years, it has become evident that demand for claws is greater. Stone crab claws have become a regular saleable item at many South Carolina seafood markets, and reporting of landings is now required for all seafood dealers. Interest in the stone crab population has also resulted in legislation to preserve the stock. These regulations specify that: 1) only the larger of the two claws of any stone crab may be removed, 2) the live crab must be returned immediately to the water, 3) the claw removed must have a propodus length of at least 70 mm, and 4) claws may not be taken from ovigerous female crabs.

Because information on stone crab stocks in South Carolina was so limited, the South Carolina Wildlife and Marine Resources Department, under contract with the Gulf and South Atlantic Fisheries Development Foundation, began a study to determine whether potential existed for expanded commercial utilization of stone crabs in South Carolina. This report describes the results of that study. Specific research objectives were to determine whether catches of stone crabs in South Carolina could be improved by adopting the trap used in the Florida fishery and whether different soak times affected catches. An additional objective was to describe the composition of the catch in terms of size and sex.

Methods

Information concerning abundance of stone crabs in South Carolina was obtained in two ways: (1) by polling seafood dealers who buy and sell blue crabs and (2) by actual sampling of stone crabs in selected areas near Charleston, S. C.

Dealer Reports

In May and June 1982, 33 of 54 dealers who were licensed to buy and ship blue crabs in South Carolina were contacted by telephone to determine whether they sold stone crab claws from crabs caught in the state. Only those dealers who actually resided in South Carolina were contacted. Additional information from dealers was obtained from dealer-report forms of the Fisheries Statistics Section, S.C. Wildlife and Marine Resources Department.

Field Sampling

Collections of stone crabs were made at seven locations near Charleston, S.C. from July - September 1982 (Figure 1). Because the study involved exploratory fishing for stone crabs, not every chosen site consistently yielded crabs. Therefore, sampling at several locations was discontinued after one month if catches were low, and an alternate site was selected. By this method, locations were sampled according to the following schedule: Beatty's Creek (July), Lighthouse Creek (July), Whitesides Creek (August), Capers Creek (August), Morris Island (August and September), Breach Inlet (September), and Lighthouse Inlet (July - September).

In each location sampled, five blue crab traps constructed of vinyl-coated wire and having two entrance holes and five wooden-lath stone crab traps, similar to those used in the Florida fishery (Figure 2), were fished for two and three days in paired sets. A paired set entailed attaching each blue crab trap via a 30' length of 1/4" polypropylene line to a stone crab trap. This pair of traps was then attached by poly line to a wooden stake driven into the bank. Although the length of line attaching each paired set to a stake varied with location, it was always long enough for the traps to remain submerged at normal low tides. At extremely low tides, the traps were at least partially submerged. Although traps were set perpendicular to the bank, strong tidal action, especially at the inlet sites, frequently moved traps closer to the bank and into shoaler water. Staking of traps was preferred to using floats since we wanted to minimize theft and poaching. Because stakes were not visible at maximum flood or high slack tide, all traps were pulled; rebaited with menhaden; and set at late ebb, low slack or early flood tide. Surface temperature, salinity and tidal stage were recorded at each site when traps were set and pulled.

For each trap pulled, the total catch of stone crabs, blue crabs, and incidental species (except hermit crabs) was recorded. Additional information taken on each stone crab included sex, carapace width (measured as the maximum distance across the carapace between the posteriormost pair of lateral teeth, Figure 3), propodus length (measured as the distance along the base from the tip of the fixed dactyl to the proximal portion, Figure 3), body weight, handedness (side with crusher), missing chelipeds, stridulatory pattern (Figure 4), and cooked claw weight. All stone crabs collected were tagged and released near the capture site. Tagging was not done for purposes of population assessment but was merely used to identify previously caught crabs so data would not be duplicated.

Data Analysis

Catch per unit of effort, expressed as number of crabs per trap and number of crabs per trap per day, was used to evaluate abundance of stone crabs. After testing for homogeneity of variances, one-way analysis of variance was performed on catch data to determine whether differences in catch occurred between soak times, months, or trap type.

Significant differences in the morphometric relationships of male and non-ovigerous female crabs for cooked claw weight regressed on propodus length and propodus length regressed on total width were determined by analysis of covariance. Following analysis of covariance, a functional regression equation (Ricker 1973) was calculated for each morphometric relationship. Because of increased growth variations associated with crabs having recently regenerated appendages, only stone crabs having unregenerated claws, as indicated by normal stridulatory patterns, and those with beaded-normal patterns were used in regression analyses. Because of heterogeneous variances, an approximate t-test (Sokal and Rohlf, 1969) was used to determine whether differences existed between males and non-ovigerous females for propodus length and cooked-claw weight. The non-parametric Kruskal-Wallis test (Siegel, 1956) was used to determine whether differences in carapace width occurred between sexes, stations and months.

Sex ratios and the frequency of handedness in stone crabs was determined by chi-square analysis. The significance level for all statistical testing was 0.05.

Results

Commercial Landings

Of the 33 dealers in South Carolina who bought and shipped blue crabs during May and June, 16 sold stone crab claws from crabs caught locally and indicated that demand for claws exceeded supply. Of the remaining dealers which were contacted, 14 did not sell stone crab claws on a regular basis, two had gone out of business, and one sold claws which were obtained from Florida because local exvessel prices were too high. Landings of stone crab claws reported by 39 dealers during 1982 totalled only 3,943 lbs., with reported landings being highest in spring and early summer (Table 1).

Distribution, Relative Abundance and Catch Composition

Description of Study Sites - All locations sampled were characterized by having salinities > 28 $^{0}/oo$; hard bottom with sessile invertebrate growth, especially the cnidarian *Leptogorgia virgulata* and the sponge *Microciona prolifera*; and dense beds of American oyster, *Crassostrea virginica*, fringing both banks. Beatty's Creek, Whiteside Creek and Capers Creek were located behind Capers Island off the Intracoastal Waterway (Figure 1). Whereas Whiteside Creek and Capers Creek were large and had numerous smaller creeks feeding into them, Beatty's Creek was narrow and dry about 1/4 mile from the mouth at low tide. The remaining locations

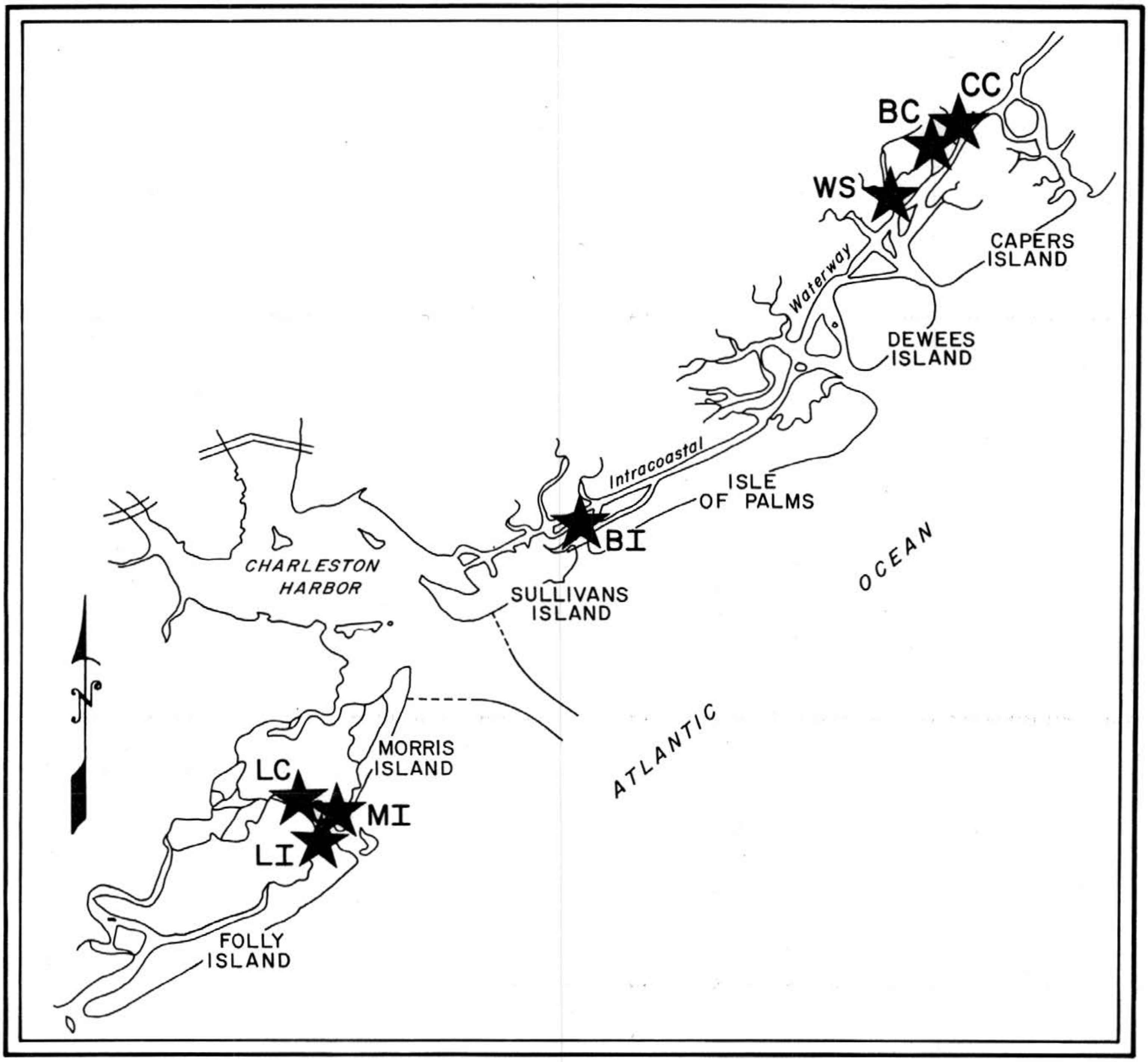

FIGURE 1. THE SEVEN SITES WHERE TRAPS WERE DEPLOYED. LC = LIGHTHOUSE CREEK, LI = LIGHTHOUSE INLET, MI = MORRIS ISLAND, BI = BREACH INLET, WS = WHITESIDE CREEK, BC = BEATTY'S CREEK, CC = CAPERS CREEK.

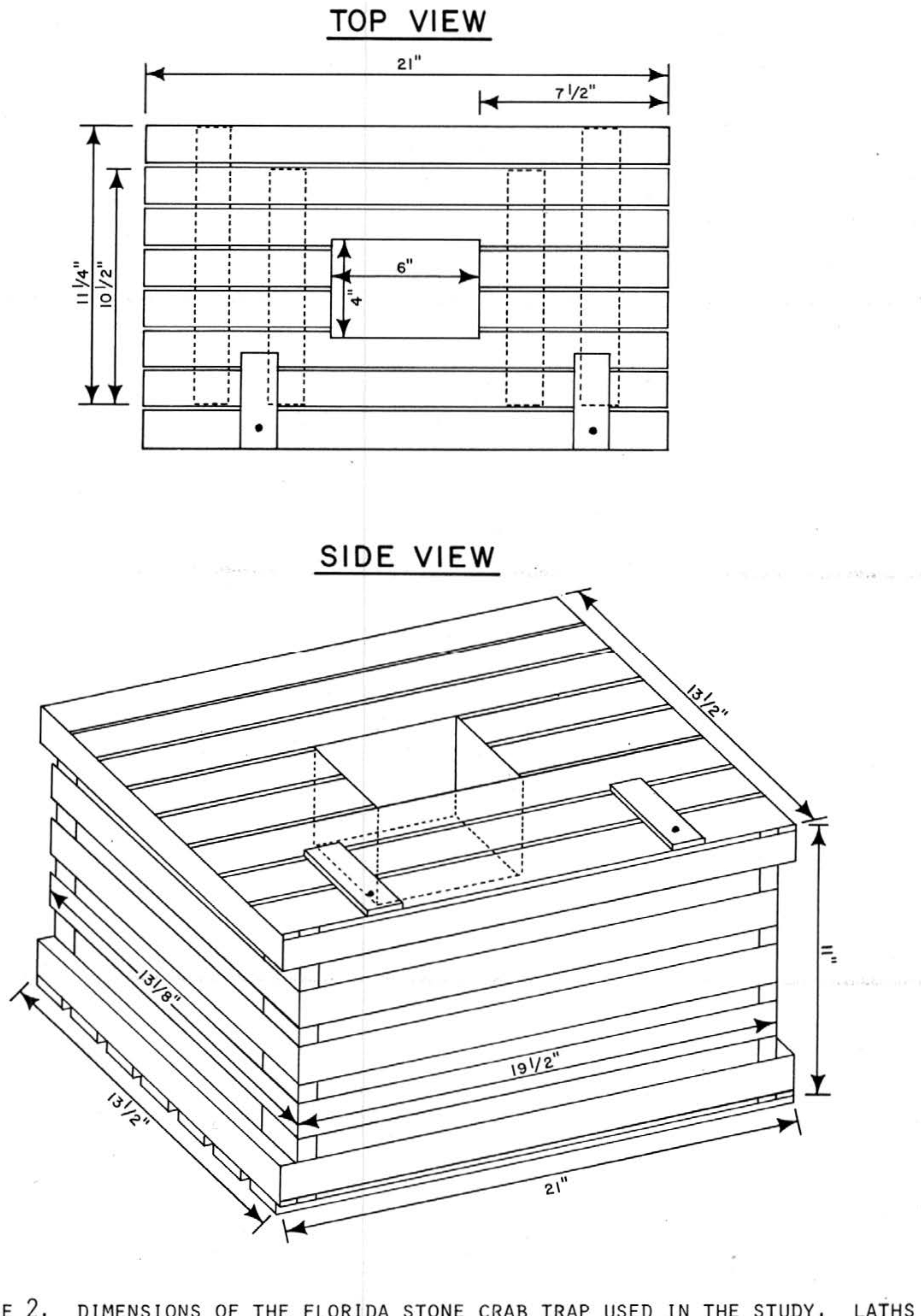

FIGURE 2. DIMENSIONS OF THE FLORIDA STONE CRAB TRAP USED IN THE STUDY. LATHS WERE SPLIT FROM PRESSURE-TREATED 1" X 2" PINE AND ARE FASTENED TO CORNER 1" X 2" END FRAMES WITH HEAVY-DUTY STAPLES. CEMENT COVERED THE BOTTOM OF THE TRAP. A BAIT BOX WAS CONSTRUCTED AND NAILED INTO THE END OF THE TRAP NEAR THE TOP.

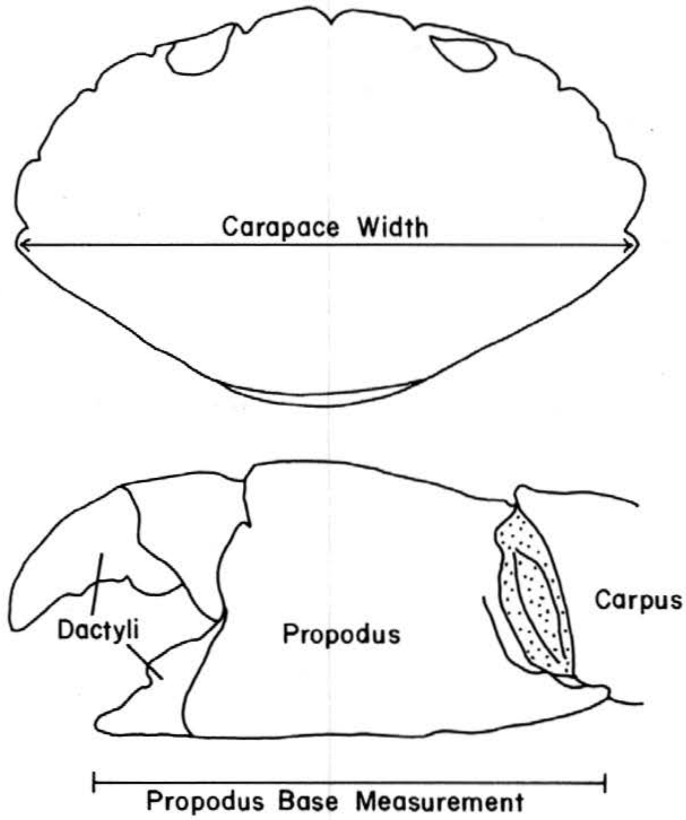

FIGURE 3. MEASUREMENTS OF CARAPACE WIDTH AND PROPODUS LENGTH USED DURING THE STUDY. A PROPODUS BASE MEASUREMENT OF $\geq$ 70 MM DEFINES A LEGALLY HARVESTABLE CLAW.

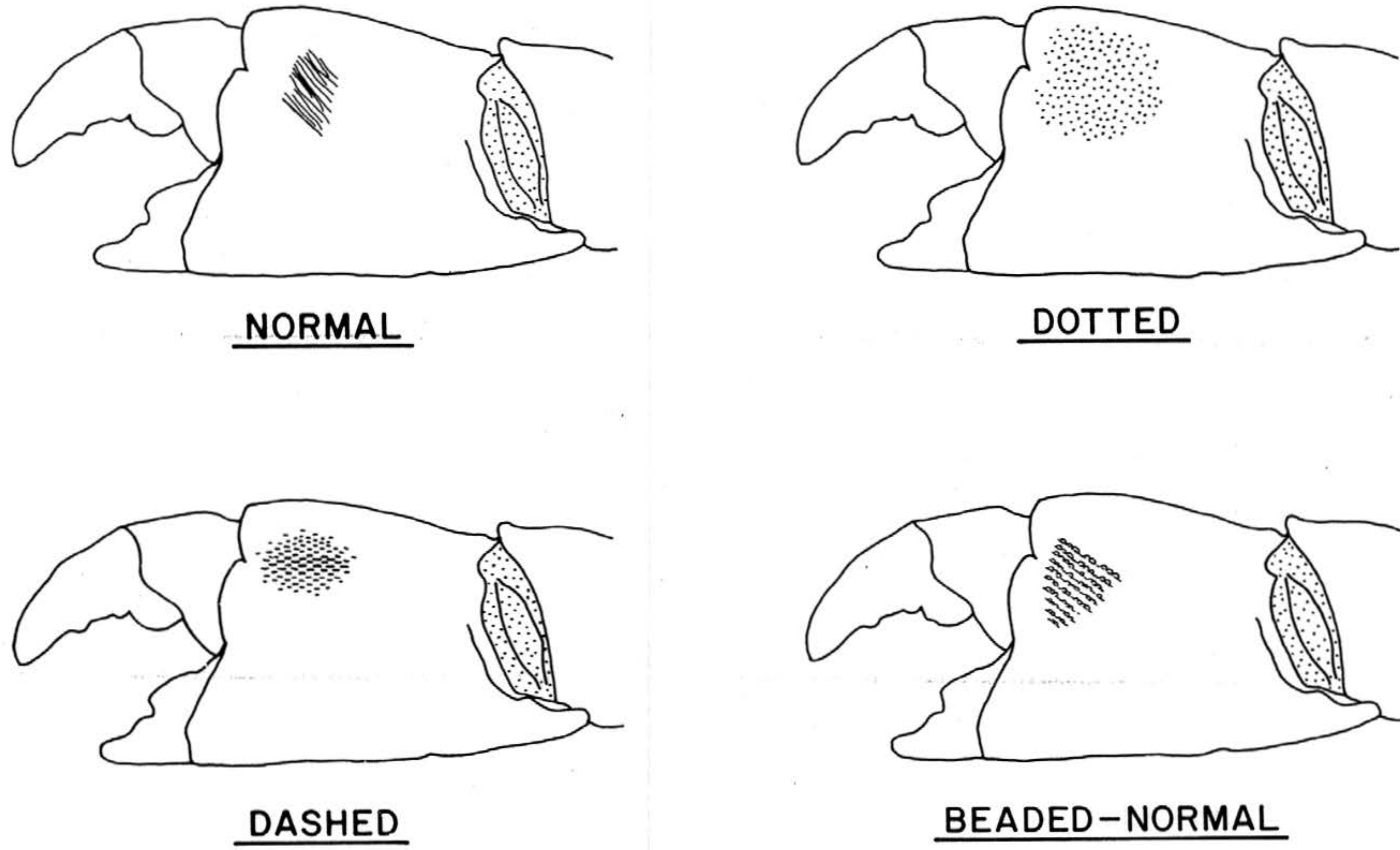

FIGURE 4. STRIDULATORY PATTERNS FOUND ON CHELIPEDS OF MENIPPE MERCENARIA. THE NORMAL PATTERN IS FOUND ON UNREGENERATED CLAWS, WHILE DOTTED, DASHED AND BEADED-NORMAL PATTERNS REPRESENT SUCCESSIVE STAGES OF THE REGENERATED CLAW.

Table 1. Pounds of stone crab claws landed in South Carolina, by month, for year 1982. Data are based on landings reported by 39 dealers.

Month	Pounds
January	3
February	12
March	73
April	1,201
May	801
June	806
July	551
August	25
September	129
October	151
November	112
December	79*
	3,943

*December is incomplete.

(Lighthouse Creek, Lighthouse Inlet, Morris Island, and Breach Inlet), which were immediately adjacent to the Atlantic Ocean, had swifter water flow and steeper banks than the other sites.

Although current flow and water depth differed between sites, hydrographic conditions of temperature and salinity were similar (Table 2). In addition, little difference was noted between months for temperature or salinity.

Relative Abundance - A total of 781 stone crabs were collected with traps during two- and three-day sets for the three month duration of the study. Other organisms collected in the traps are listed in Appendix 1. Twice as many stone crabs were collected in the blue crab trap as in the stone crab trap; and the difference in catch, expressed as number of crabs per trap, was found to be statistically significant ($t = -3.60$, 12 df, $P < 0.05$) between the two trap types. Furthermore, the transformed [log (x+1)] number of crabs per trap was significantly greater for the blue crab trap at every site except Lighthouse Inlet (Table 3) and during each month of the study except July (Table 4).

No consistent differences in the catch per unit of effort were noted between two- and three-day soak durations for either trap type (Figure 5). Analysis of variance confirmed that no significant difference in the transformed [log (x+1)] number of stone crabs per trap existed between two- and three-day sets for either the stone crab or blue crab traps (Table 5).

For all sites sampled, catch per unit of effort (CPUE) showed a decline when plotted against cumulative catch of the blue crab trap (Figures 6 and 7). However, only CPUE from Morris Island and Beatty's Creek sites showed a continuous decline with cumulative catch, suggesting that either these sites were being fished out, that stone crabs were emigrating from these areas or that they were no longer susceptible to active fishing because of a behavioral change. At the other sites, CPUE showed no relationship to cumulative catch when we first began fishing; however a gradual decline was eventually noted at these sites also. Catch per unit of effort showed no relation to cumulative catch of the stone crab trap probably because of the relatively low numbers of crabs collected with that trap. A one-way analysis of variance revealed no significant difference in transformed [log (x+1)] number of crabs per trap per day between months for either the stone crab ($F = 2.85$, 2/58 df, $P > 0.05$) or blue crab trap ($F = 0.07$, 2/57 df, $P > 0.05$).

Size and Sex Composition

Carapace width frequency distributions for males, females, and ovigerous females indicated that traps were primarily sampling the population of stone crabs which were > 65 mm. The frequency distribution for sampled male crabs was bimodal with peaks at 95 mm and 105 mm, whereas the distribution of non-ovigerous females and ovigerous females was unimodal with peaks at 95 mm and 90 mm, respectively (Figure 8). Mean carapace width of male stone crabs was greater than that for females or ovigerous females (Table 6). Ovigerous females had the smallest mean carapace width of the trappable population. The Kruskal-Wallis test indicated that significant differences in median carapace width existed between males, females, and ovigerous females ($H = 17.367$, df = 2, $P < 0.01$).

The frequency distribution of propodus lengths for male and non-ovigerous female stone crabs having normal or beaded-normal stridulatory patterns showed that most of the males collected had at least one harvestable claw. Modal propodus lengths for males occurred at 80 and 100 mm (Figure 9). In contrast, modal propodus length for female stone crabs was 65 mm, with slightly over half (51%) of the females measured having a legal-sized claw of ≥ 70 mm propodus length. For the total sample of crabs (N = 503) whose propodus length was measured, 54% possessed at least one claw of legally harvestable size. An approximate t-test indicated that the mean propodus length for male crabs ($\bar{x} = 85$ mm) was significantly greater than that for females ($\bar{x} = 69$ mm) [$T's\ (11.39) > T'_{.05}\ (1.75)$] (Table 6).

Examination of mean carapace width and propodus length by sampling site reflected stable areal distribution by size of stone crabs in the study area (Table 7). Differences between means were not assessed because of drastically unequal sample sizes. For each site sampled, the mean propodus length was greater than 70 mm, the size of a legally harvestable claw. Frequency distributions of carapace width and associated statistics were also examined by month. The Kruskal-Wallis test indicated that median carapace width of all stone crabs sampled was significantly different between months ($H = 11.853$, df = 2, $P < 0.01$). Inspection of means, however, revealed a relatively stable temporal distribution of stone crabs by size:

	Mean	Standard Error	Sample Size
July	90.1	0.80	253
August	93.4	0.59	356
September	92.2	0.83	218

Analysis of covariance between carapace width (x) and propodus length (y) for males and non-ovigerous females revealed significant differences in slope, elevation, and variance ($F_{reg} = 118.9$, 1/549 df; $F_{adj.\ mean} = 654.2$, 1/550 df; $F_{var} = 2.7$, $\frac{200}{349}$ df). Thus, separate functional regression equations for males and females were calculated to explain the relationship between carapace width and propodus length (Figures 10 and 11). Regression analysis revealed that males entering our traps had harvestable claws at carapace widths ≥ 83 mm,

TABLE 2. Extremes (minimum and maximum) and mean ($\bar{x}$) temperature and salinity at sampling sites during July, August and September.

	July						August						September					
	Temperature			Salinity			Temperature			Salinity			Temperature			Salinity		
	$\bar{x}$	min.	min.	$\bar{x}$	min.	max.	$\bar{x}$	min.	max.	$\bar{x}$	min.	max.	$\bar{x}$	min.	max.	$\bar{x}$	min.	max.
Lighthouse Inlet	29	28	30	29	27	30	29	28	32	31	28	34	28	27	29	32	30	32
Lighthouse Creek	28	28	30	30	30	30			Not Sampled						Not Sampled			
Morris Island			Not Sampled				29	28	32	31	28	34	28	27	29	32	30	32
Breach Inlet			Not Sampled						Not Sampled				27	25	29	34	34	25
Beatty's Creek	30	26	36	32	30	34			Not Sampled						Not Sampled			
Capers Island			Not Sampled				29	28	31	33	30	35			Not Sampled			
Whitesides Creek			Not Sampled				29	28	31	34	32	36			Not Sampled			

TABLE 3. Number of stone crabs, number of trap hauls, and catch per trap haul (C/T) for the stone crab trap and blue crab trap at each site. Summary of results of analysis of variance to determine significant differences in transformed [log (x+1)] catch per trap haul between the two trap types is shown.

	Stone Crab Trap			Blue Crab Trap			ANOVA Results		
	No. Crabs	No. Trap Hauls	C/T	No. Crabs	No. Trap Hauls	C/T	F	df	P
Beatty's Creek	18	30	0.60	54	29	1.86	7.24	1/10	<0.05
Lighthouse Creek	16	30	0.53	49	28	1.75	10.39	1/10	<0.01
Whitesides Creek	13	30	0.43	47	30	1.57	19.35	1/10	<0.01
Capers Creek	1	30	0.03	13	30	0.43	7.88	1/10	<0.05
Morris Island	48	55	0.87	113	55	2.05	4.57	1/22	<0.05
Breach Inlet	18	29	0.62	61	28	2.18	7.70	1/10	<0.05
Lighthouse Inlet	134	86	1.56	196	81	2.42	3.22	1/35	>0.05
Total	248	290		533	281				

Table 4. Number of stone crabs, number of trap hauls, and catch per trap haul (C/T) for the stone crab trap and the blue crab trap for each month of the study. Summary of results of analysis of variance to determine significant differences in transformed [log (x+1)] catch per trap haul between the two trap types is shown.

	STONE CRAB TRAP			BLUE CRAB TRAP			ANOVA RESULTS		
	NO. CRABS	NO. TRAP HAULS	C/T	NO. CRABS	NO. TRAP HAULS	C/T	F	df	P
July	103	89	1.16	156	85	1.84	2.78	1/35	>0.05
August	69	117	0.59	243	116	2.09	19.22	1/46	<0.01
September	76	84	0.90	134	80	1.68	7.52	1/34	<0.05

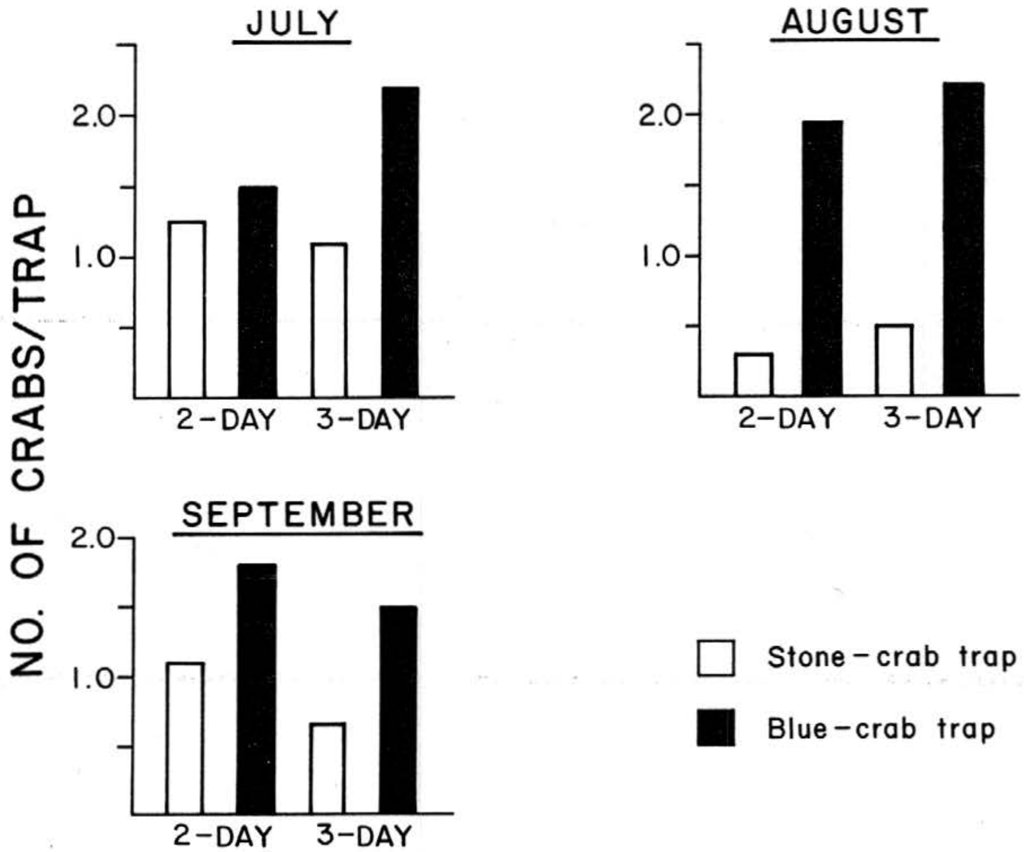

FIGURE 5. NUMBER OF CRABS COLLECTED IN THE STONE CRAB AND BLUE CRAB TRAPS DURING TWO- AND THREE-DAY SOAK DURATION.

TABLE 5. Number of stone crabs, number of trap hauls, and catch per trap haul (C/T) for two- and three-day soak duration. Summary of analysis of variance to determine significant differences in transformed [log (x+1)] catch per trap haul between two- and three-day soaks is shown.

	Two-day			Three-day			ANOVA Results		
Stone crab trap	No. Crabs	No. Trap Hauls	C/T	No. Crabs	No. Trap Hauls	C/T	F	df	P
July	55	44	1.25	48	45	1.07	0.02	1/17	>0.05
August	38	59	0.64	31	58	0.53	0.09	1/22	>0.05
September	49	43	1.14	27	41	0.66	3.30	1/16	>0.05
Blue crab trap									
July	65	43	1.51	91	42	2.17	1.16	1/16	>0.05
August	115	58	1.98	128	58	2.21	0.03	1/22	>0.05
September		41	1.88	57	39	1.46	0.69	1/16	>0.05

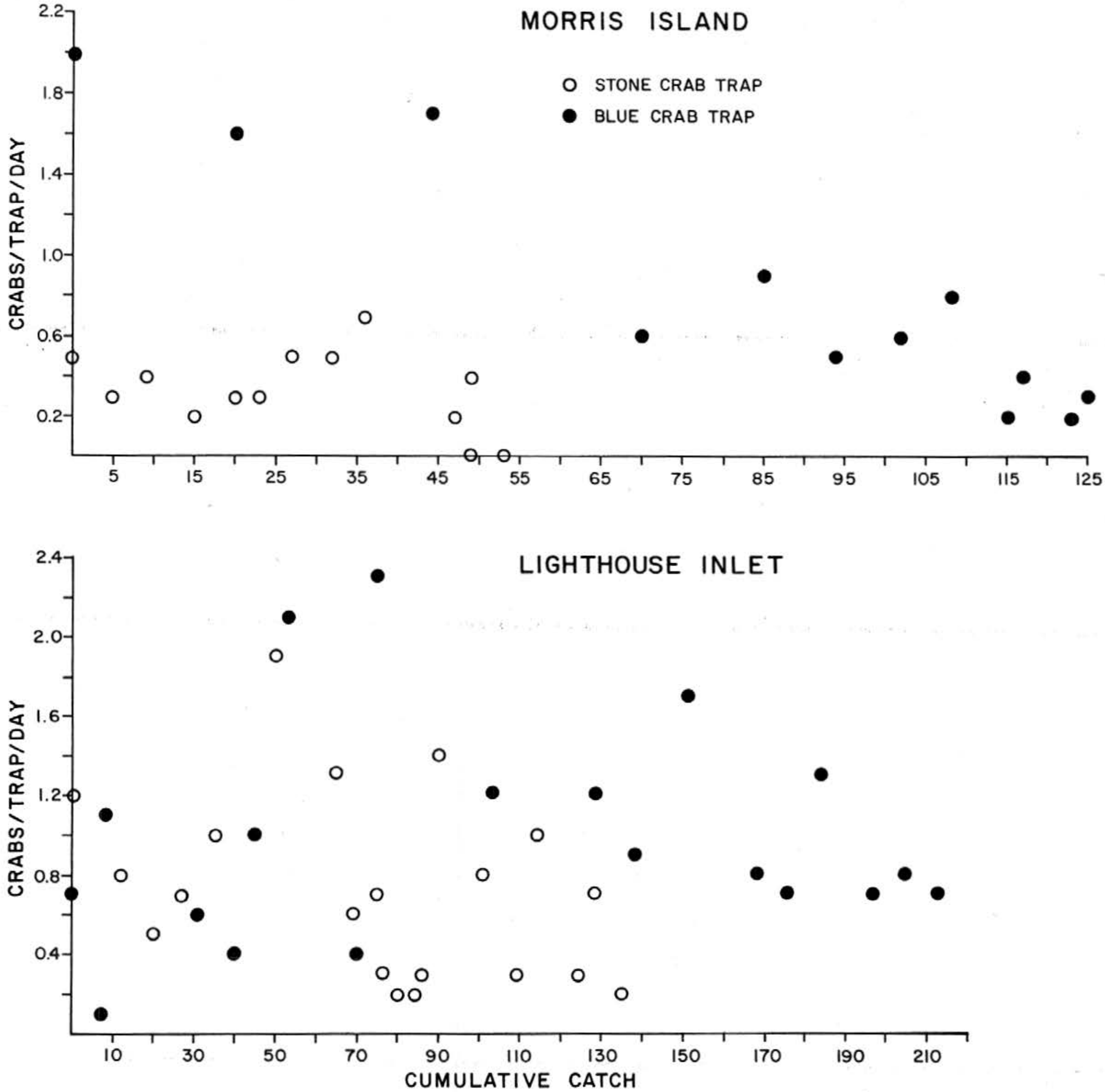

FIGURE 6. RELATIONSHIP BETWEEN CATCH PER UNIT OF EFFORT AND CUMULATIVE CATCH OF THE STONE CRAB TRAP AND BLUE CRAB TRAP.

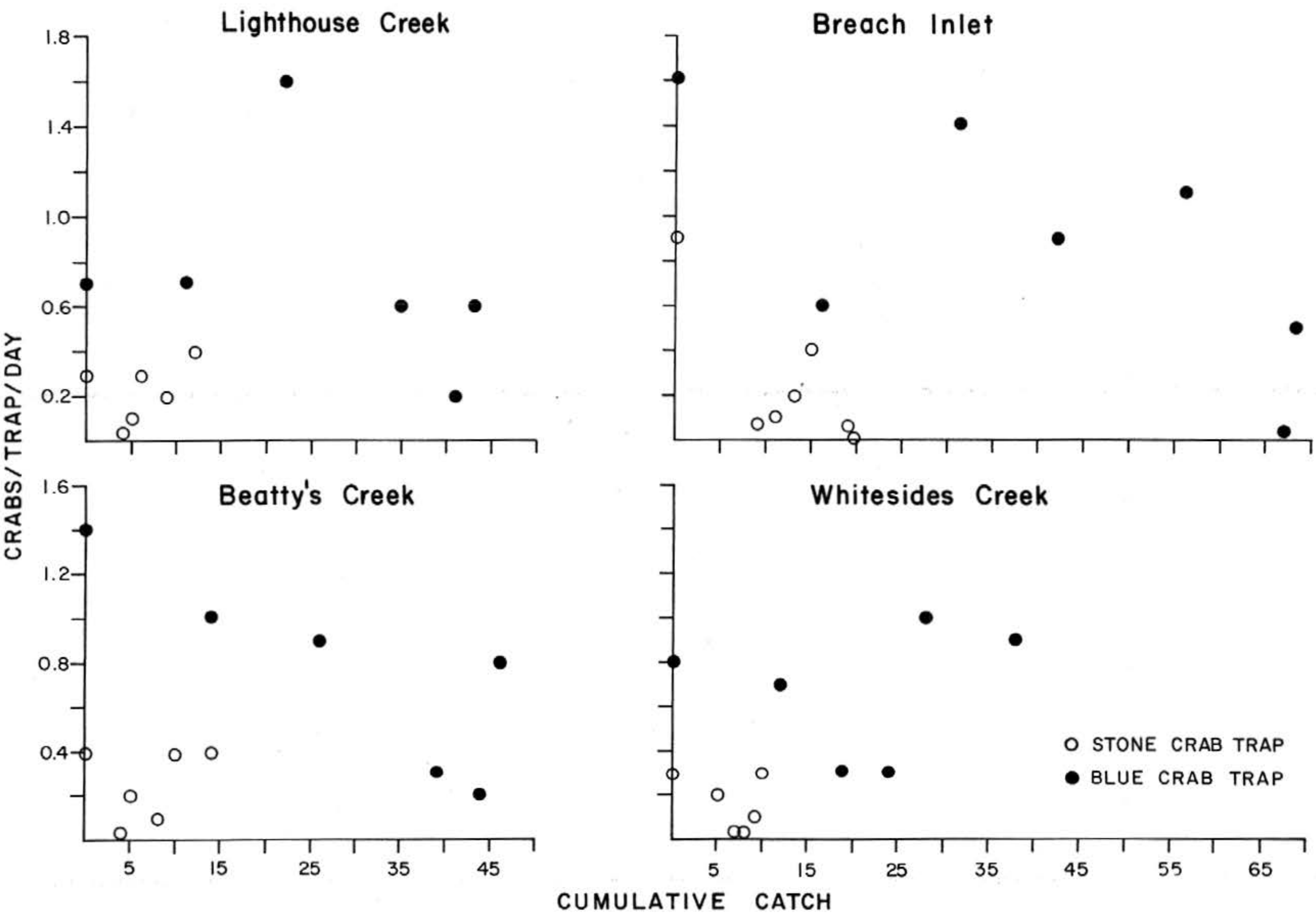

FIGURE 7. RELATIONSHIP BETWEEN CATCH PER UNIT OF EFFORT AND CUMULATIVE CATCH OF THE STONE CRAB TRAP AND BLUE CRAB TRAP.

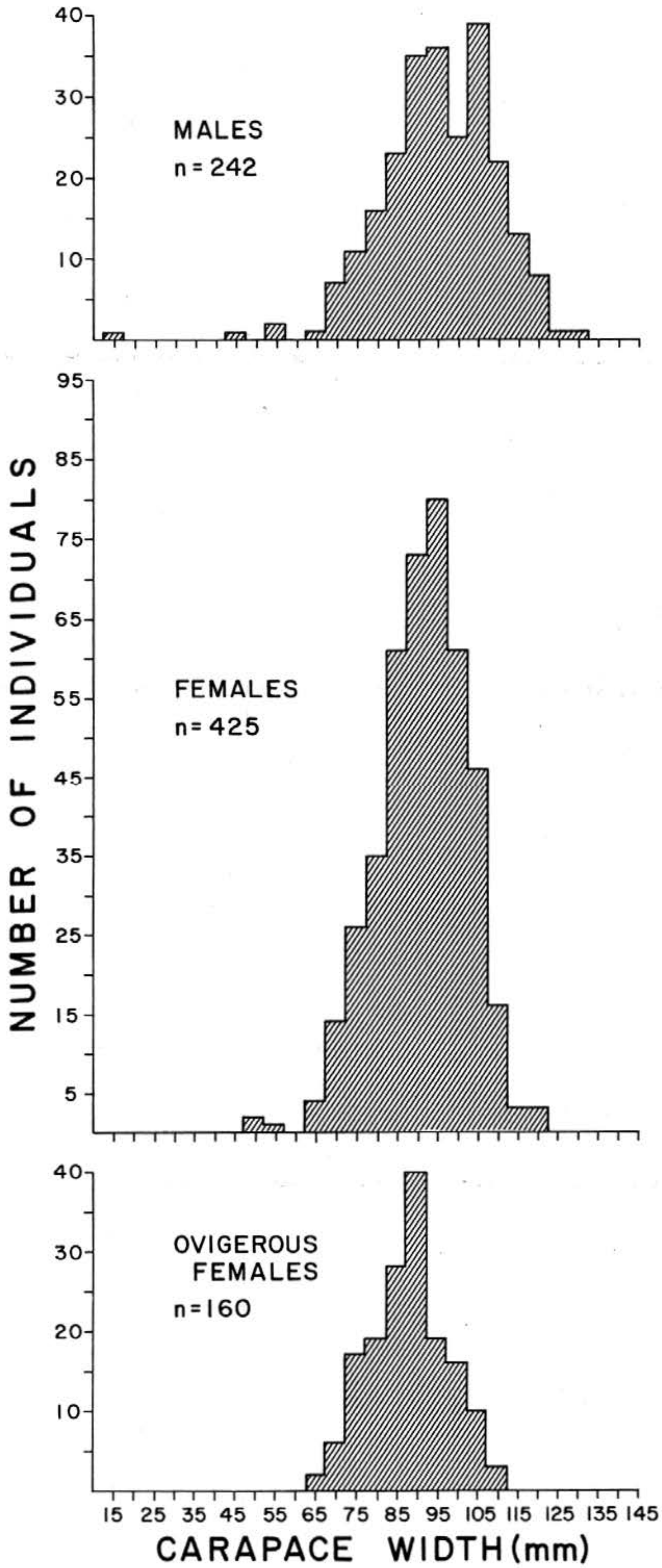

FIGURE 8. FREQUENCY DISTRIBUTION OF CARAPACE WIDTH FOR MALE, FEMALE, AND OVIGEROUS FEMALE STONE CRABS.

Table 6. Number of individuals measured (n), extremes, mean ($\overline{x}$) and standard error ($s_{\overline{x}}$) of carapace width and propodus length for male, female, and ovigerous stone crabs.

	Carapace width (mm)				Propodus Length (mm)			
Sex	n	Extremes	$\overline{x}$	$s_{\overline{x}}$	n	Extremes	$\overline{x}$	$s_{\overline{x}}$
Male	242	13-129	95	0.93	175	36-126	85	1.34
Female	425	50-120	92	0.53	328	39-98	69	0.54
Ovigerous Female	160	65-112	88	0.76				

Table 7. The number of individuals measured (n), mean ($\overline{x}$) and standard error ($s_{\overline{x}}$) of carapace width and propodus length for each site.

	Carapace width			Propodus Length		
Site	$\overline{x}$	$s_{\overline{x}}$	n	$\overline{x}$	$s_{\overline{x}}$	n
Beatty's Creek	89.8	1.75	66	79.5	3.62	31
Breach Inlet	91.3	1.33	95	72.2	1.51	64
Capers Creek	102.5	2.68	14	93.4	5.66	10
Lighthouse Creek	88.9	1.30	62	73.8	2.77	29
Lighthouse Inlet	91.4	0.62	349	72.0	0.93	217
Morris Island	92.7	0.79	178	77.0	1.27	121
Whitesides Creek	98.7	1.86	60	80.8	4.36	28

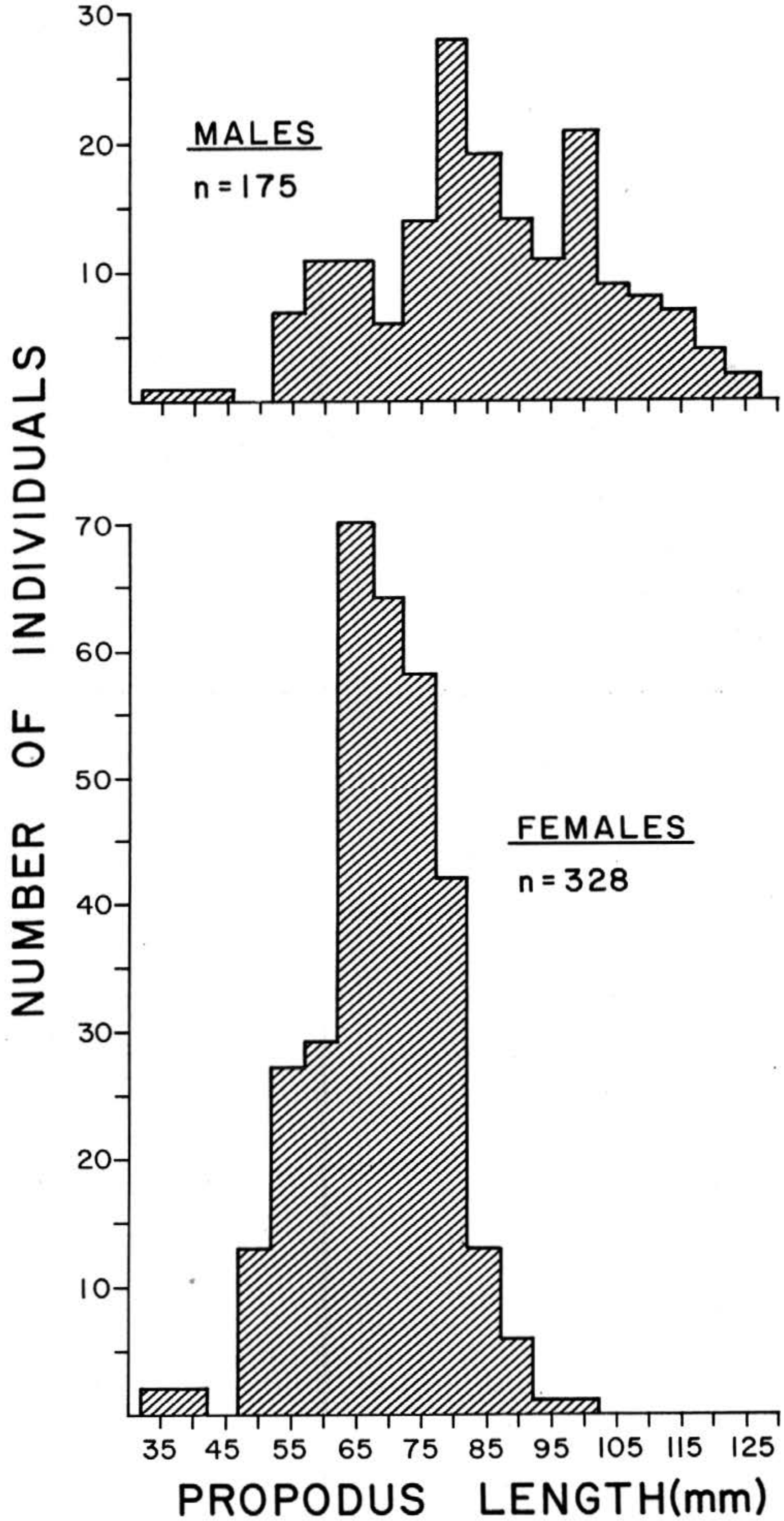

FIGURE 9. FREQUENCY DISTRIBUTION OF PROPODUS LENGTH FOR MALE, FEMALE, AND OVIGEROUS FEMALE STONE CRABS.

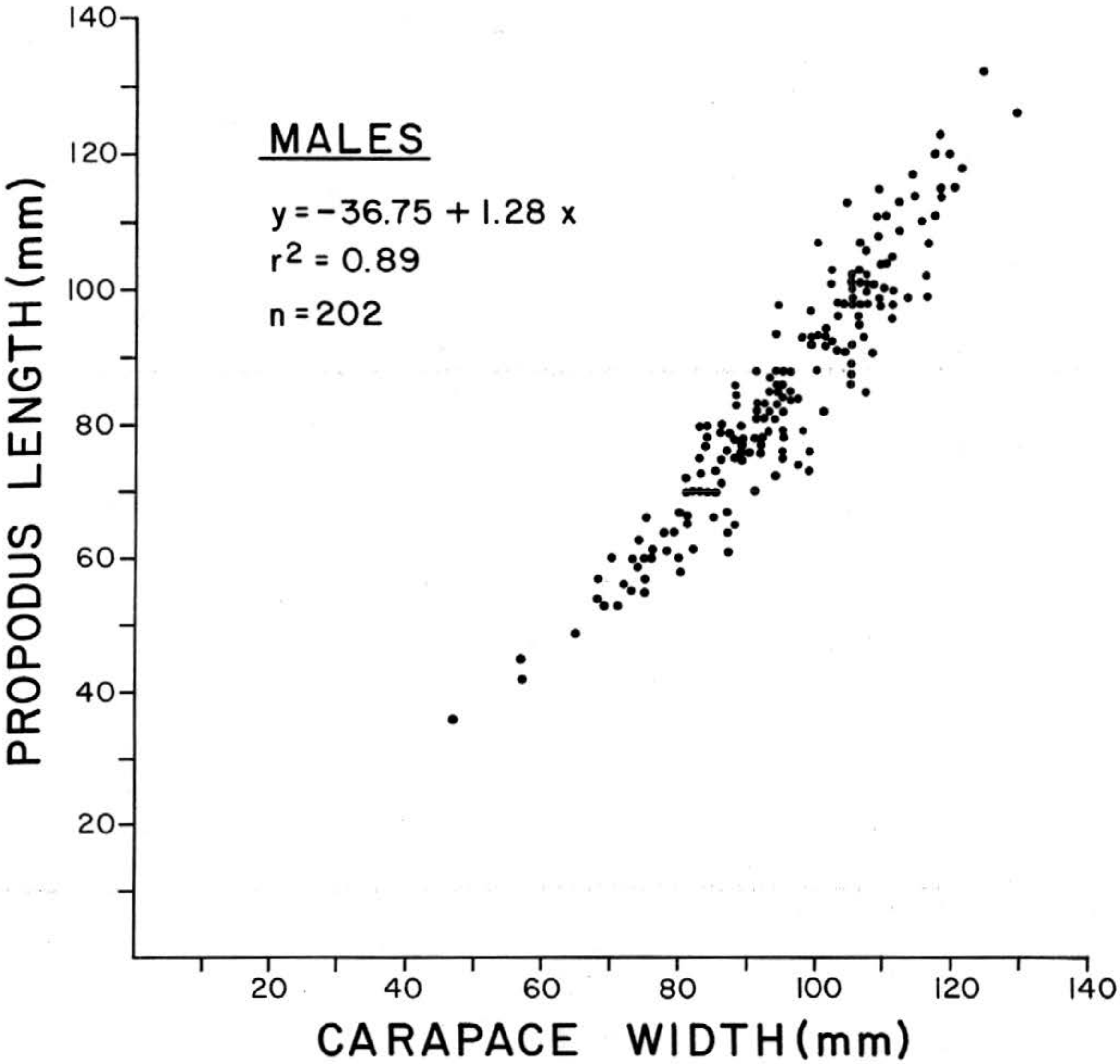

FIGURE 10. FUNCTIONAL REGRESSION EQUATION FOR THE RELATIONSHIP BETWEEN PROPODUS LENGTH AND CARAPACE WIDTH OF MALE STONE CRABS. COEFFICIENT OF DETERMINATION (r^2) INDICATES AMOUNT OF VARIATION EXPLAINED BY REGRESSION.

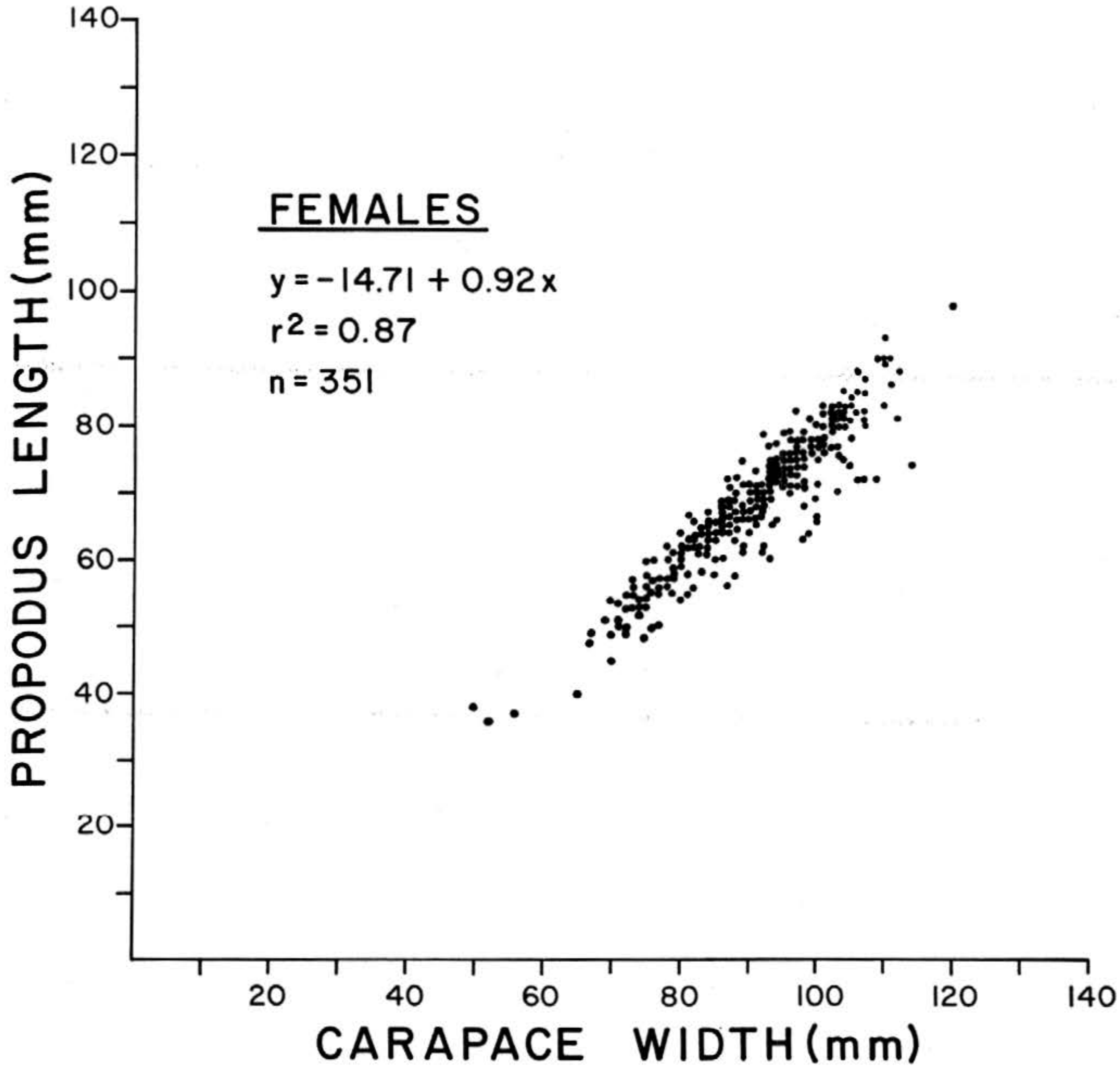

FIGURE 11. FUNCTIONAL REGRESSION EQUATION FOR THE RELATIONSHIP BETWEEN PROPODUS LENGTH AND CARAPACE WIDTH OF FEMALE STONE CRABS.

whereas harvestable claws of females occurred at $\geq$ 92 mm.

Significant differences between the sexes were also found by analysis of covariance for the relationship between the logarithmically (log_{10}) transformed variables of propodus length (x) and weight of the cooked claw (y). Elevations were not significantly different ($F_{adj.}$ mean = 0.1213, 1/152 df), but significant differences were noted for slopes (F = 5.04, 1/151 df) and variances (F = 1.94, 65/86 df). The functional regression of cooked claw weight on propodus length for male stone crabs revealed that a cooked claw weight $\geq$ 52 g (1.8 oz) would result from legal-sized claws of $\geq$ 70 mm (Fig. 12). No functional regression equation was calculated to explain the relationship between these variables for female stone crabs since only 38% of the variance was explained by regression analysis.

Incidence of missing claws among the 842 stone crabs collected in the study was small. Only 12% of the sampled population was missing one claw, while 6% was missing both claws. Among individuals having both claws, right major claws occurred more than twice as frequently as left major claws, indicating that left-handed crabs constituted only about 38% of the population. The deviations from 1:1 ratio were significant for males (x^2 = 37.07, $P < 0.01$) females (x^2 = 61.6, $P < 0.05$), and ovigerous females (x^2 = 16.0, $P < 0.05$) (Table 8).

Examination of stridulatory patterns of the major cheliped for crabs possessing both claws and the remaining cheliped for crabs having one claw revealed that > 70% of males, females and ovigerous females had claws with the normal pattern, indicating an unregenerated claw. Claws with other stridulatory patterns (dotted, dashed, and beaded normal) representing successive stages in regeneration of the claw (Savage et al., 1975) constituted 22%, 23%, and 27% of the males, females and ovigerous females sampled, respectively.

Monthly sex ratios indicated significant dominance by females, who constituted 73% of the sampled crabs in July, 69% in August, and 71% in September (Table 9). Most females (48%) were ovigerous in July with a marked reduction in number of ovigerous females occurring in September. Examination of the egg mass revealed that 68% of the ovigerous females carried orange eggs indicative of recent spawning. The proportion of females bearing orange eggs increased to 77% in August.

Discussion

Reported landings of stone crabs and the results of preliminary trapping suggest that stone crab stocks in South Carolina are not of sufficient magnitude to support an intensive directed fishery. Although landings of claws in S.C. should increase because of added interest in stone crabs and awareness of the potential for a fishery, it is unlikely that the stone crab population here could withstand fishing pressure of a magnitude comparable to that of the Florida fishery without adverse effects. Estimates of effort in Florida for 1979-1980 showed that 297,600 traps were deployed from 291 boats and larger vessels, resulting in a total value of $5,135,422 for the reported commercial catch ($\sim$ 1.9 million lbs.) of stone crab claws (Zuboy and Snell, 1980). The effort trend in the Florida fishery increased slowly from 1962-1971, and then increased dramatically from 1972 to 1977. In 1978, substantially fewer traps were used; however there was a large increase in the number of traps the following year which resulted in a record number of 300,000 traps. The catch trend in Florida generally followed the effort trend with the exception that catch rates were lower than those of effort. A major exception to the relationship between catch and effort occurred in 1979 when catch did not show an increase in spite of the record high number of traps in the fishery. This indicated to Zuboy and Snell (1980) that the western Florida stone crab stocks may be fully exploited over the current fishing area and led them to speculate that a further increase in effort could not likely result in a corresponding increase in yield. Based on results of our study, it is hypothesized that catch per unit of effort (CPUE) would not be as high as 6 lbs. claws/trap which is the 1980 CPUE for the Florida fishery (Zuboy and Snell, 1980); however, until data are available on effort and yield of stone crab claws from commercial S.C. crabbing operations, it will be impossible to properly assess existing stone crab stocks.

Although all areas fished during our study were characterized by high salinities and live oyster beds, catch per unit of effort was highly variable between locations. The creek sites which had less steep banks and current than the inlets yielded fewer crabs. Catches per month were highest for the Lighthouse Inlet and Morris Island sites, which were immediately adjacent to the ocean. Possible explanations for the differences in catches between areas include differences in suitability of substrate for burrowing and availability of shelter for protection from predators. Published information on the distribution of stone crabs indicates that adults dwell on a variety of bottom types, including grass flats (McRae, 1950), rocky or shell bottom (McRae, 1950; Powell and Gunter, 1968; Whitten et al., 1950), sand and mud (Powell and Gunter, 1968). In southwestern Florida,

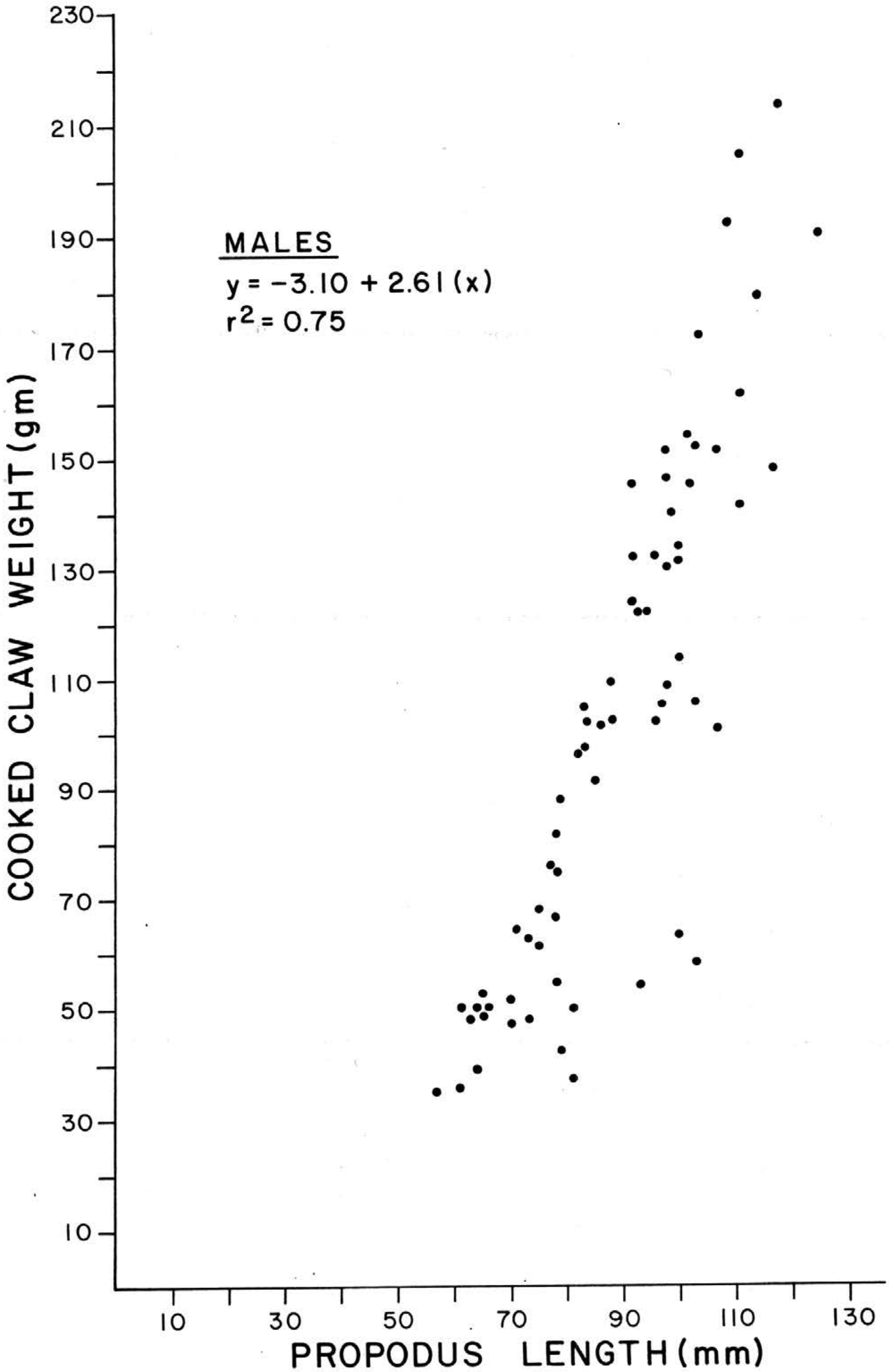

FIGURE 12. FUNCTIONAL REGRESSION EQUATION, BASED ON TRANSFORMED [$\log_{10}$] VALUES, FOR THE RELATIONSHIP BETWEEN COOKED CLAW WEIGHT AND PROPODUS LENGTH OF MALE STONE CRABS.

Table 8. Frequency of handedness in male, female, and ovigerous female stone crabs. Handedness ratios (R:L) significant at $\alpha = 0.05$ are marked with asterisks.

SEX	SIDE WITH CRUSHER RIGHT	LEFT	R:L
♂	129	48	2.7:1*
♀	259	89	2.9:1*
Ovigerous ♀	96	48	2.0:1*

Table 9. Number of male and female stone crabs, and the percent of females bearing eggs for each month of study. Sex ratios (F:M) significant at $\alpha = 0.05$ are marked with asterisks.

	July	August	September
Male	68	110	64
Female	185	246	154
% ovigerous	43	29	6
Ratio F:M	2.7:1*	2.2:1*	2.4:1*

adult stone crabs characteristically inhabit burrows on turtle grass (Thalassia) flats or along the banks of channels (Bender, 1971). However, Bender (1971) found that catch per unit of effort changed with season and sediment type. Thalassia flats consistently yielded more stone crabs than did mud bottom where crabs had difficulty digging and maintaining open burrows (McRae, 1950). In Texas and northwestern Florida, stone crabs inhabit oyster bars (Powell and Gunter, 1968) and rock jetties (Whitten et al., 1950). Apparently, the shell substrate of oyster bars provides reinforcement for creation of stable burrows, as well as protection from predators. Jetties also provide habitat for stone crabs, and scuba divers have reported large stone crabs from jetties at Murrells Inlet, S.C. (Dale Calder, pers. comm., 1981, Marine Resources Research Institute, Charleston, S.C.). However, attempts to sample jetties and groins in the Charleston area were unsuccessful. Rough seas and strong currents moved the traps away from the rocks into open water. Had the traps been anchored to the rocks by concrete blocks attached to the trap lines, stone crab catches might have been higher. However, rough seas near jetties and groins make setting and retrieval of traps risky.

Comparisons of stone crab catches (no./trap) between the Florida stone crab trap and the wire blue crab trap clearly indicated the superiority of the latter. Because stone crabs are primarily caught incidentally to blue crabs, no new gear need be adopted to maximize stone crab catches in South Carolina. However, the unquestionable success of the wooden trap in the Florida fishery begs an answer to the question of why its catches were significantly lower. Unfortunately, the preliminary nature of this study permits only speculation about differences in trap performance.

Because the design of a trap affects the crabs' success of entry and the trap's maximum catch (Miller, 1980), the difference in design between the traps is one possible explanation. Location of the entrance has been shown to affect trap catches (Miller, 1980). In the blue crab trap, two opposite tunnel-shaped entrances which sloped upward from the bottom of the trap permitted entrance by crabs, whereas the smaller stone crab trap provided a single top entrance which must legally be no larger than 10.2 x 16.5 cm (Bert et al., 1978). Miller (1979) found that the most effective trap design is one in which the bait odor leads crabs to the trap entrance, not to the trap. He found that the cancroid crab, Cancer productus, entered the side entry trap more frequently than the top entry trap, if opposing entrances were parallel to the current. Furthermore, Miller (1979) found that a greater percentage of crabs entered the side entry trap in the first hour of observation; and that because of their success in finding an entrance, there were few agonistic encounters resulting from an accumulation of crabs around the base of the trap. By closing the two side entrances of American lobster traps and fitting a top entrance, Stasko (1975) found that catches of Homarus americanus decreased. Similarly, Kessler (1969) obtained greater catches of spot prawn, Pandalus platyceros, in traps with a long-tunnelled side entrance and lower catches in traps with a top entrance. The poorer performance of the top entrance traps may result from the organism circling the base of the trap rather than swimming or crawling over it.

A similar comparison between trap types needs to be done in southwestern Florida, where the habitat of stone crabs is markedly different from S.C.. The clarity of water in the Florida Bay area may be a factor which favors use of the wooden trap since stone crabs may readily enter the trap which provides the most shelter. This may not be the case in S.C. where estuarine waters are turbid. Historical precedence and fishermen's bias undoubtedly influence choice of trap type. The wooden stone crab trap is basically a scaled-down version of the spiny lobster trap which has historically been used in the most popular and profitable crab fishery of southwestern Florida. Stone crabbers also experiment with the design of their wooden traps and are strongly opinionated as to which modifications are most effective for catching crabs (Bert et al., 1978; Raymond Bruland, pers. comm., 1982, Keys Fisheries, Marathon, Fla.).

The lack of significant difference in catches between soak times is probably related to the fact that trap catches of decapod crustaceans routinely do not increase in proportion to soak time (Miller, 1980). In fact, studies have shown that the average catches of most traps are not even close to filling the traps, but catches are limited due to saturation (Sinoda and Koyayasi, 1969; Krouse and Thomas, 1975; Robinson and Dimitrion, 1963; Skud, 1979). Miller (1980) found that saturation can start limiting catches after 4-6 h. Catches level off because additional entrants to traps replace those that escape. He attributed trap saturation to threat displays and intimidation by crabs inside traps which discouraged those outside from entering. In the Florida stone crab fishery, it is not unusual for traps to be soaked 10-15 days prior to being pulled (R. Bruland, pers. comm., 1982, Keys Fisheries, Marathon, Fla.). However, with a long soak time, it is expected that the total catch per trap haul would peak and perhaps even decrease either because of escapement or mortality in the trap due to starvation, cannibalism or predation (Austin, 1977).

Since the objective of the commercial crabber is to maximize the catch per trap day and the net economic return from crabbing, it would be beneficial to increase the saturation level of traps. Miller (1980) indicates this can be done by increasing trap size, preventing escapement, and increasing the quantity of bait. Therefore, it would appear that the increased size of the wire blue crab trap is another reason why it outperformed the smaller stone crab trap and is the better trap to use in S.C. waters. Crabbers in S.C. interested in maximizing catches of stone crabs should also consider using a long-lasting bait such as strips of cowhide or elasmobranch meat, both of which are very popular in the Florida fishery (Savage et al. 1975). Finally the commercial crabber should carefully consider how many traps he must fish to maximize profits. Miller (1980) and Austin (1977) present equations which determine profit maximizing soak time, including the value of the catch, the cost of traps, and parameters which relate catch per trap and soak time. Using the equation, Miller (1980) found that increasing soak from 2 days to 4 days increased the value of the catch of rock crabs and spider crabs (Hyas araneus) but also increased trap costs. Considering the importance of soak time as a fishing strategy for the commercial crabber, there is justification to further study the relationship between catch and soak time, as well as the effect of variable soak times on profits of South Carolina crabbers.

Comparisons of carapace width frequencies of stone crabs from South Carolina with those from Florida indicated that crabs become trappable at > 45 mm (Sullivan, 1979). In Florida, crabs ranging from 45-60 mm carapace width are representative of the first year class (one plus years old). In the trappable portion of the Florida population, the two large size classes for each sex overlap, with sizes for males centered around 80-103 mm and a major mode for females found at 80-100 mm. Size comparisons between the sexes showed that mean carapace size for males was larger than for females in Florida (Bender, 1971) as well as South Carolina. Bender (1971) attributed sexual differences in size to molting of males when females are spawning. Crabs of both sexes from Florida which measure ∿ 80 mm are about two years old, whereas those around 100 mm are primarily Year III crabs with some contribution by Year IV individuals (Sullivan, 1979). In the Florida population, smaller crabs (45-60 mm carapace width) are observed in summer when waters are closed for trapping. However, modal size for both sexes are greatest in winter and spring and tend to remain high through summer. Sullivan (1979) indicates that modal size for females declines in October and November, whereas this decline occurs during September and October for males. Bender (1971) found that most crabs measured < 60 mm and > 95 mm in late fall. He attributed this to recruitment from juveniles which are reaching sexual maturity in fall. Year-round information is clearly needed on stone crabs from South Carolina before any assessment of recruitment or year class strength can be obtained and relevant comparisons made with Florida stocks.

The carapace width at which stone crabs from South Carolina possess legally harvestable claws (≥ 70 mm) was comparable to results obtained for the Florida population. Our results revealed that males attain harvestable claws at carapace widths ≥ 83 mm, whereas females possess legal-sized claws at ≥ 92 mm. In Florida, males attain harvestable major claw sizes at about 80 mm, and major claws from females are obtained at about 87 mm carapace width (Sullivan, 1979). Furthermore, male claws for all carapace widths were larger than those for females in collections from both South Carolina and Florida. The smaller size of claws from females is probably related to differential growth rates of males and females. Sullivan (1979) noted that females exhibited smaller average incremental carapace width and claw growth increases than did males.

Slightly over half of the stone crabs sampled during the trapping study possessed at least one legally harvestable claw. A high incidence of the normal stridulatory pattern indicated that most of the crabs sampled had not regenerated a claw. Normal claws also account for a high percentage of claws in the Florida fishery (Savage et al. 1975). Savage et al. (1975) hypothesized that incidence of regenerated claws is influenced by water temperatures. Consequently, the greatest frequency of regenerated claws occurs in the first months of the legal season, which begins in October, because the water temperatures from the preceding summer months were conducive for molting and regenerative growth of claws. Over an annual cycle the frequency of regenerated claws from crabs in S.C. should show similar fluctuations, although the relative proportion of the population having regenerated claws will probably be less than is seen in Florida where fishing pressure is much greater.

The low percentage of regenerated claws in the Florida fishery has been used as evidence to suggest that declawing is of limited value as a fishery management technique (Davis et al. 1978). Bender (1971) noted that due to the length of time needed to regenerate a claw to harvestable size, a stone crab may not live long enough to regenerate the claw for a second harvest. Furthermore, Davis et al. (1978) found that removal or loss of claws greatly increased mortality in controlled laboratory experiments with 47% of the declawed crabs (n = 101) dying after removal of both claws and 28% (n = 100) dying following removal of a single claw. Mortality may be further increased in the natural environment due to predation, competition, and stressful hydrographic conditions. Bender (1971) proposed that an alternative to present crabbing laws in Florida would be to harvest the entire male crab with minimum size set at a carapace measurement above the mean carapace width. The current law in South Carolina which permits harvesting of one claw only is based on the assumption that a crab with one remaining claw will have a better change of survival. This is probably true since the removal of both claws restricts the selection of accessible food items and leaves the stone crab far more vulnerable to predation. In addition, the claws perform an essential role in courtship and mating behavior (Bert et al. 1978). However, laws which protect the reproducing population also imply that stocks are dependent on a strong spawner-recruit relationship. Whether due to a contracted spawning season, unfavorable environmental conditions that affect larval survival, or paucity of suitable habitat, the fact remains that stone crab abundance is much lower here than in Florida. Until more information is obtained on *M. mercenaria* near the northern limit of its range, the current, albeit unenforcable, legislation on claw removal should not be changed.

With the current practice of claw removal, mortality may be decreased by development of declawing techniques which minimize wounds and thus assure a clean break at the basi-ischium juncture. A method of declawing which was used during the current study resulted in clean breaks due to autotomization by the crab. This simple but effective technique involved insertion of a sharp knife point into the membrane-covered joint of the carpus and pushing distally until the autotomizer muscle was stimulated. Savage and Sullivan (1978) noted that a similar technique was successful in reducing mortality following declawing. Unfortunately, the usage of this technique may be limited because seafood dealers are reluctant to purchase claws which have wounds to the exoskeleton or muscle (R. Bruland, pers. comm., 1982, Keys Fisheries, Marathon, Fla.)

Molting is not only important to insure regeneration of claws, but is also an important factor to consider when marketing claws. Claws from crabs which have recently molted ("lights") are culled from the catch at seafood processing houses. The claw meat from a recently molted crab is flaccid and watery, making it undesirable as a market item. A method used by commercial stone crabbers in Florida to distinguish "lights" involves examination of the teeth on the major cheliped. A newly molted individual has prominent, unworn teeth which are black, whereas an intermolt crab wears down the teeth through feeding so that they become smooth and white in color (Bender, 1971; R. Bruland, pers. comm., 1982, Keys Fisheries, Marathon, Fla.). Undoubtedly, much of the variability in the regression of cooked claw weight on propodus length was caused by inclusion of claws from recently molted crabs. If the frequency of crabs undergoing ecdysis increased in spring and summer because of warm water temperatures as noted by Savage et al. (1975), then cooked claw weights would be highly variable during those time periods.

The predominance of right-handed stone crabs occurs in Florida as well as South Carolina. Savage et al. (1975) found that right-handed crushers were nearly three times as common as left-handed crushers in Florida. Cheung (1976) implied that right-handedness is the normal situation for stone crabs. He hypothesized that left-handedness was developed secondarily through claw reversal after the autotomy of the crusher found on the right. Claws exhibiting features intermediate between crushers and pincers were reported by Savage et al. (1975) and were observed in the present study, further suggesting that claw reversal does occur.

The predominance of female stone crabs during the summer has been reported by Bender (1971), McRae (1950) and Noe (1967) for the Florida population. However, they indicate that sexual dominance changes seasonally, so that more males are trapped in winter. Several explanations have been proposed concerning seasonal changes in sexual dominance. Sullivan (1979) suggested that decreases in relative numbers of legal-sized males over the duration of the fishing season (Oct. - May) resulted from harvest-induced mortality. In addition, seasonally related onshore or offshore movement by the different sexes may have affected sex ratios observed in a particular area. Bender (1971) also noted that seasonal differences in sex ratios indicate a seasonal migration primarily by one sex. Bert et al. (1978) surmised that this directional movement is primarily caused by males who move shoreward to mate with molting females who are year-round residents of shallow seagrass flats. Other non-directional movements (*sensu* Bert et al. 1978) have also been reported for the Florida population and are attributable to increased activity of stone crabs following storms and strong northeasterly winds (R. Bruland, pers. comm., 1982, Keys Fisheries, Marathon, Fla.). Whether similar seasonal changes in sex ratios occur in the South Carolina population remains to be determined. If sexual segregation exists during part of the year, location of the males would be necessary to maximize catches of crabbers who fish year-round.

The spawning season, determined by the presence of ovigerous females, has been reported by Williams (1965) to extend from May through July in North Carolina. Bert et al. (1978) noted that spawning season lengthens in duration toward the southern part of the crab's geographic range, so that ovigerous females are found throughout the year in southeastern Florida. Temperature has been found to be the most important factor influencing reproduction, with optimum ovarian development occurring at 28°C (Cheung, 1969). If a strong spawner-recruit relationship is present for stone crabs, the apparently limited spawning season in South Carolina may be one explanation for the lower relative abundance of stone crabs.

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LIST OF APPENDICES

APPENDIX I. Species other than stone crabs and blue crabs which were collected in traps.

STONE CRAB TRAP

Opsanus tau
(oyster toadfish)

Chaetodipterus faber
(Atlantic spade fish)

Centropristis striata
(black sea bass)

Archosargus probatocephalus
(sheepshead)

Arius felis
(hardhead catfish)

BLUE CRAB TRAP

Leiostomus xanthurus
(spot)

Chaetodipterus faber
(Atlantic spade fish)

Arius felis
(hardhead catfish)

Lagodon rhomboides
(pinfish)

Opsanus tau
(oyster toadfish)

Chilomycterus schoepfi
(striped burrfish)

Centropristis striata
(black sea bass)

Paralichthys lethostigma
(southern flounder)

Archosargus probatocephalus
(sheepshead)

Paralichthys dentatus
(summer flounder)

Pomatomus saltatrix
(bluefish)

Libinia emarginata
(spider crab)

Pagurus pollicaris
(hermit crab)