EXPLORATION FOR GOLDEN CRAB, *GERYON FENNERI*, IN THE SOUTH ATLANTIC BIGHT: DISTRIBUTION, POPULATION STRUCTURE, AND GEAR ASSESSMENT[1]

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ABSTRACT

Exploratory trapping for golden crab, *Geryon fenneri*, was conducted from 5 August 1985 to 21 February 1986 off South Carolina and Georgia. A buoyed system with strings of six traps (three side-entry Fathoms Plus and three top-entry Florida traps) was fished in six depth strata: 274-366 m, 367-457 m, 458-549 m, 550-640 m, 641-732 m, and 733-823 m. A total of 3,152 *G. fenneri* (2,661.9 kg) were collected at sampled depths between 296 and 810 m. The only other numerically important species caught was the jonah crab, *Cancer borealis* (864 individuals, 227.5 kg).

Catches of golden crab were highly variable between strata. Catch per trap increased from 1.6 crabs (1.67 kg) in the shallowest stratum sampled to a maximum abundance of 22.3 crabs/trap (18.04 kg/trap) in the 458-549 m depth zone. Catches abruptly declined in the deeper strata sampled.

Number of golden crab per trap (1.7:1) and weight per trap (1.6:1) in the Florida trap exceeded that in the Fathoms Plus trap for all completed sets. Traps yielded golden crab as small as 85 mm CW but the greatest proportion of crabs was >100 mm CW. Over 90% of all individuals exceeded 114 mm CW which is the minimum size of red crab, *G. quinquedens*, accepted for commercial utilization. Male golden crab were more numerous and larger than females.

Crabs of the genus *Geryon* (Brachyura: Geryonidae) are deepwater inhabitants of the Atlantic, Indian, and Pacific Oceans (Rathbun 1937; Monod 1956; Christiansen 1969; Manning and Holthuis 1981). Species reported off the United States in the western Atlantic and Gulf of Mexico include the red crab, *G. quinquedens* Smith, and the golden crab, *G. fenneri* Manning and Holthuis. At the time *G. fenneri* was described (Manning and Holthuis 1984), its geographic and bathymetric distribution included the continental slope off eastern Florida, the Florida Straits, and the Gulf of Mexico. An exploratory fishing effort in 1984 collected the first known specimens of golden crab off South Carolina[4], and it is now known that golden crab occur in waters off Bermuda (Luckhurst in press).

Both *G. quinquedens* and *G. fenneri* have been the target of limited and sporadic commercial fishing efforts off the east coast of the United States (Gerrior 1981), in the Gulf of Mexico. (Otwell et al. 1984; National Marine Fisheries Service 1986[5]), and off Bermuda (Luckhurst in press). Although much information is available concerning the biology and commercial fishery of red crab (summarized by Gerrior 1981), biological information on golden crab is more limited. Otwell et al. (1984) demonstrated exploratory trapping and processing techniques for golden crab from the Gulf of Mexico.

The initiation of a small commercial crabbing enterprise during 1984 in South Carolina yielded promising quantities of golden crab[6]. We began the present study to determine the fishery potential, compare trap designs, delineate bathymetric distribution, and describe the biology of golden crab in the South Atlantic Bight. This report documents results on catch rates, size and sex compo-

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[5]National Marine Fisheries Service. 1986. Species profile: deep red crab, *Geryon quinquedens*, Smith and golden crab, *Geryon fenneri*, Manning and Holthius, 1984 from the southeastern U.S. south of Cape Hatteras, N.C. U.S. Dep. Commer. Natl. Mar. Fish. Serv., NOAA, Pascagoula Lab., Latent Resour. Rep., 17 p.

[6]H. Holley, commercial fisherman, Charleston, SC, pers. commun. 1985.

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sition of *G. fenneri* as a function of depth and trap type, and examines aspects of adult life history and reproductive biology of this species in the South Atlantic Bight.

METHODS

Cruises were made during the period from 20 June 1985 to 21 February 1986 on board the South Carolina Wildlife and Marine Resources Department (SCWMRD) research vessels *Oregon* and *Lady Lisa*, and the NOAA ship *Chapman*. All vessels were equipped with large capacity hydraulic systems and a heavy duty pot hauler.

Two commercially available trap designs were used to sample crabs. The Fathoms Plus[7] traps are oval (85 cm long × 66 cm wide × 30 cm high) and constructed of injection molded plastic. The trap has two side-entry funnels that can be enlarged by removing more of the plastic funnel's inner lip. The original, oval funnel opening is 10 cm × 20 cm. Both funnels were cut out to a maximum opening size of 14 cm × 22 cm. Traps were weighted with chain, making the total weight of each trap 11 kg. The Florida trap is an injection molded, high-impact plastic version of a Florida spiny lobster trap (82 cm long × 61 cm wide × 45 cm high). The top of the trap is constructed of wood lathing to provide a biodegradable escape panel. The top entrance funnel has adjustable panels and is 20 cm × 25 cm in the most open position, as fished throughout the study. Two strips of poured concrete in each end of the trap provided ballast, making the total weight of the trap about 22.7 kg.

Traps were baited with 1.2-1.6 kg of clupeids. Three Florida and three Fathoms Plus traps were alternately attached at 61 m intervals to 365.6 m of groundline. The groundline was constructed of 8 mm diameter Iceline, a dacron, polyethylene line that has a high tensile strength relative to its diameter. A small weight consisting of ~9.0 kg of chain was attached to one end of the groundline and an anchor (~25 kg) was attached to the buoyline end of the gear. Buoy lines were 366 m sections of 8 mm Iceline joined together to achieve at least a 2:1 ratio of line to water depth. Four inflatable net buoys and a spar buoy with radar reflector were attached to the buoyline.

Six depth strata were sampled between lat. 29°53.1'-32°20.0'N and long. 78°01.5'-79°24.8'W: 274-366 m (stratum 1), 367-457 m (stratum 2), 458-549 m (stratum 3), 550-640 m (stratum 4), 641-732 m (stratum 5), and 733-823 m (stratum 6). Three sets of six traps each were made approximately 1-2 km apart within a depth stratum over a 24-h period. Sampling locations for each set were selected by making fathometer transects of the potential fishing area to determine depth and bottom type. Because of bad weather and logistical constraints all strata did not receive equal effort (Table 1).

The first trap type on the groundline was randomly selected with trap type alternating until six traps (three of each type) were attached. The exception to this arrangement occurred in the deepest stratum (733-823 m) where only the Fathoms Plus trap was used.

Fishing duration was standardized at 20 hours; however, poor weather conditions and logistical considerations altered this. Average fishing duration within strata exceeded 17 hours (Table 1).

Bottom temperature was determined in each depth stratum by reversing thermometers. Bottom sediments were sampled by a geological rocket grab for each group of three sets made in an area. Sediments retrieved were frozen on board and examined under a microscope for gross characterization in the laboratory. Sampling depth and location were recorded at deployment of the anchor.

Decapod crustaceans in each trap were identified, counted, and weighed. Catches from damaged traps or those sets that moved due to currents were excluded from analyses of distribution and abundance, but were included in biological studies of size and sex composition. Each golden crab was individually sexed, measured to the nearest millimeter (carapace width, CW, distance between the tips of the fifth lateral spines; carapace length, CL, distance from the diastema be-

TABLE 1.—Mean, standard deviation, minimum, and maximum fishing duration of trap sets, for *Geryon fenneri*, within six strata sampled from August 1985 to March 1986.

		Fishing duration (h)			
Stratum	No. sets	$\bar{y}$	(s)	Min.	Max.
1	8	17.5	3.75	12.4	21.2
2	32	18.8	2.36	14.0	23.2
3	16	20.5	2.07	16.2	23.7
4	6	22.9	1.15	21.5	24.7
5	4	17.2	0.73	16.4	18.1
6	4	20.2	5.69	11.7	23.3

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

tween the rostral teeth to the posterior edge of the carapace, along the midline), and most were weighed to the nearest gram. The number of missing chelae and pereopods was recorded for each crab, as was molt condition and presence of chitinolysis and poecilasmatid barnacles, *Trilasmis inaequilaterale*, on the exoskeleton. Molt condition of *G. fenneri* was modified from criteria established by Beyers and Wilke (1980) for *G. quinquedens* (probably *G. maritae* Manning and Holthius) and consisted of five categories:

1) Hard - carapace at maximum strength, fouling by barnacles or chitinolytic bacteria minimal,
2) Hard old - carapace strong but heavily fouled by barnacles and abraded or blackened by chitinolytic bacteria,
3) Soft old - resorptive line along posterolateral sides of the carapace is weak; carapace heavily fouled as with hard-old condition,
4) Soft new - carapace soft or jellylike with no fouling, and
5) Hard new - carapace cracks under pressure and is not fouled.

Female *G. fenneri* were examined for evidence of egg extrusion and mating. Presence of eggs or egg remnants on pleopods and the size, shape, and physical condition of vulvae, as described by Haefner (1977), were noted. We examined seminal receptacles for presence of sperm or spermatophores and for relative size.

Ovaries from 72 of the 166 female *G. fenneri* captured were initially classified by relative size and color following the scheme described by Haefner (1977) for *G. quinquedens*. After gross classification of ovaries, tissues were removed for histological preparation and examination in order to describe ovarian structure and validate assigned ovarian stages. Tissues were fixed for at least 48 hours in 10% seawater formalin. After fixation, tissues were dehydrated, cleared, and embedded in paraffin. Sections were cut at 6-9 μm and were stained with Gill's hematoxylin and counterstained with eosin-Y. Oocytes from *G. fenneri* were measured using an ocular micrometer.

Testes and vas deferentia from three *G. fenneri* were fixed for 24 hours in 2.5% glutaraldehyde, rinsed in cacodylate buffer, and dehydrated in ethanol. Tissues were then critical-point dried, sputter coated, and examined using a Jeol JSM-35C scanning electron microscope (SEM).

RESULTS

Distribution and Relative Abundance

The 70 valid sets (416 individual trap observations) caught 3,152 *G. fenneri* (2,661.9 kg) at sampled depths between 296 and 810 m. The only other numerically important species caught was the jonah crab, *Cancer borealis* (864 individuals, 227.5 kg).

Catch per trap increased from 1.6 crabs (1.67 kg) in the shallowest stratum to a maximum abundance of 22.3 crabs/trap (18.04 kg/trap) in the 458-549 m depth zone (Fig. 1). Catches then abruptly declined with increasing depth. The absence of golden crabs in traps fished between 550 and 640 m appears to be related to unsuitable

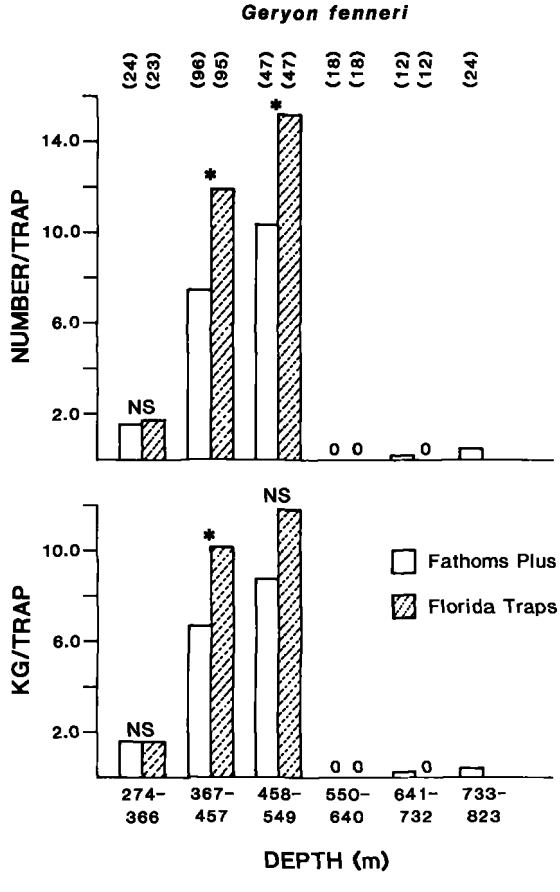

FIGURE 1.—Catch per trap of *Geryon fenneri* for six depth strata sampled. Effort (number of traps) is shown in parentheses. Statistical significance of catches between trap types, as determined by two sample *t*-test, is indicated by * ($P < 0.05$). NS indicates no significant difference in catch rates between the two trap types.

sediments at sites in this stratum since grab samples contained coral fragments and rubble. At shoaler locations where golden crabs were abundant, sediments were a mixture of soft silt-clay, molluscan shell fragments, and foraminiferan tests. Temperatures at sites where golden crabs were collected ranged from 7.14° to 9.15°C.

The number of golden crab per trap (11.4) and the weight of golden crab per trap (9.37 kg) in the Florida trap exceeded that in the Fathoms Plus trap (7.0 individuals, 6.16 kg) for all combined sets (Table 2). Statistical results by strata using the two-sample t-test or an approximate t-test when variances were heterogeneous (Sokal and Rohlf 1983), indicated significantly more crabs were collected with the Florida trap than with the Fathoms Plus trap from 367 to 457 m (stratum 2) and from 458 to 549 m (stratum 3) (Fig. 1, Table 2). Weight per trap was significantly different for the 367-457 m stratum only.

Size and Sex Composition

Male *G. fenneri* were significantly more numerous than females, outnumbering them by ~18:1. No ovigerous females were collected during the sampling period. Dominance of males was statistically significant for strata 1-3 (Table 3). In these depth strata, males were 20 times as numerous as females. In depths of 550-732 m, a male was the only crab collected. In the deepest stratum sampled (733-823 m), females significantly outnumbered males 2.9:1. Although the Florida trap caught significantly more crabs than the Fathoms Plus trap overall, no significant difference was noted in the number of female crabs between those two trap types (χ^2 test, $P > 0.5$).

The 3,217 golden crabs which were measured ranged from 85 to 193 mm in carapace width and weighed from 100 to 2,109 g. Average weight of male golden crab collected during the study was 927 g ($s = 373.448$, $n = 1{,}640$) while average weight of females was 443 g ($s = 289.385$, $n = 86$). Carapace width-frequency distribution for *G. fenneri* gave modes at 155 mm for males and 100 mm for females (Fig. 2). The largest crab collected measured 193 mm and weighed 2,091 g.

Linear least-squares and functional regression equations (Ricker 1973; Sokal and Rohlf 1983) relating carapace length and live wet body weight with width are in Table 4. Width-weight relationships were calculated from data on individuals that were not missing appendages.

Of the 3,183 golden crabs examined for missing appendages, 2.4% were missing one or both chelae. Pereopods were missing from 307 individuals (9.6%).

Examination of carapace width and weight statistics for each depth stratum showed that mean size of male *G. fenneri* was greatest for the shallowest (274-366 m) and deepest (733-823 m) strata sampled (Table 5). For females, however, mean carapace width and weight were greatest in the deepest zone. At depths of peak abundance, mean carapace width ($t_s = 4.70$, $P < 0.001$) and mean body weight ($t_s = 2.70$, $P < 0.01$) of male crabs were significantly greater in the 367-457 m than in the 458-549 m depth stratum. No signifi-

TABLE 2.—Results of t-test (T_s) comparisons of mean number and weight (kg) per trap for two trap types (FM+ and FLA) fished in each depth stratum for *Geryon fenneri*. Standard deviation is noted in parentheses; * indicates significance at 0.05 level.

	Number/trap			Weight/trap		
Stratum	FM+	FLA	T_s	FM+	FLA	T_s
1	1.6(1.92)	1.8(2.21)	0.14	1.66(1.912)	1.80(2.157)	0.14
2	7.5(5.96)	11.9(9.95)	2.16*	6.67(5.097)	10.02(7.651)	2.06*
3	10.4(5.08)	15.2(7.08)	2.22*	8.82(4.164)	11.84(4.752)	1.91
4	0	0	—	0	0	—
5	0.1	0	—	0.07	0	—
6	0.5(0.28)	—	—	0.43(0.321)	—	—
Total	7.0(5.98)	11.4(9.38)	8.51*	6.16(5.052)	9.37(7.078)	6 18*

TABLE 3.—Frequency of male and female *Geryon fenneri* within each depth stratum. Asterisks denote significant deviation ($P < 0.05$) from 1:1 by Chi-square analysis.

	Strata (m)					
Sex	274-366	367-457	458-549	550-640	641-732	733-823
Male	84*	1,790*	1,165*	0	1	11
Female	3	91	41	0	0	32*

cant differences, however, were noted in mean carapace width ($t_s = 0.85$, $P > 0.05$) and mean body weight ($t_s = 1.48$, $P > 0.05$) of females from these same strata.

Of the two traps used, the Fathoms Plus trap caught larger and heavier golden crabs than did the Florida trap. Mean carapace width ($\bar{y} = 143$ mm, $s = 19.69$, $n = 1303$) of crabs in the Fathoms Plus trap was significantly larger than that of crabs in the Florida trap ($\bar{y} = 139$, $s = 20.21$, $n = 1914$) [$t_s = 5.478$, $P < 0.001$]. A statistically significant difference was also noted for mean weight (Fathoms Plus: $\bar{y} = 928$, $s = 366.77$, $n = 775$; Florida: $\bar{y} = 881$, $s = 377.69$, $n = 951$) [$t_s = 2.598$, $P < 0.001$].

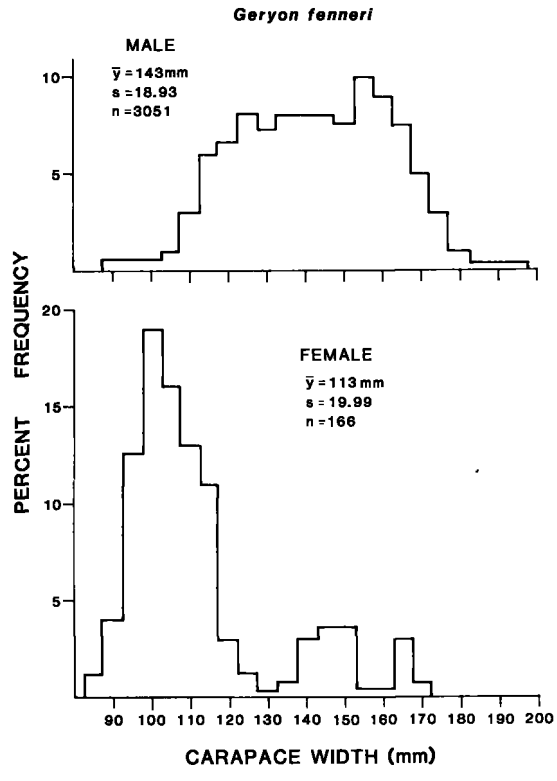

FIGURE 2.—Width-frequency distributions of male and female *Geryon fenneri* caught in traps. $\bar{y}$ = mean; s = standard deviation; n = number of individuals.

TABLE 4.—Least-square linear and geometric mean functional regression equations of carapace length (CL) and live body weight (WT) on carapace width (CW) for each sex of *Geryon fenneri*. Length and width units are millimeters while weight units are kilograms. All least square regressions were significant at $\alpha = 0.05$.

Sex	Least squares equation	n	r^2	GM functional equation
Male	CL = −9.5 + 0.9 CW	3,042	0.95	CL = −11.9 + 0.9 CW
	$\log_{10}$ WT = −4.74 + 3.54 ($\log_{10}$ CW)	1,453	0.94	$\log_{10}$ WT = −4.99 + 3.66 ($\log_{10}$ CW)
Female	CL = 4.0 + 0.8 CW	141	0.92	CL = 0.7 + 0.8 CW
	$\log_{10}$ WT = −3.97 + 3.14 ($\log_{10}$ CW)	74	0.91	$\log_{10}$ WT = −4.27 + 3.29 ($\log_{10}$ CW)

TABLE 5.—Size and weight statistics of male and female *Geryon fenneri* from sampled depth strata. $\bar{y}$ = mean; s = standard deviation, n = number of individuals.

Sex	Stratum (m)	Carapace width (mm)					Weight (g)		
		$\bar{y}$	Min.	Max.	s	n	$\bar{y}$	s	n
Male	274-366	156	117	186	14.4	84	1,064	339.15	84
	367-457	144	100	190	18.1	1,790	937	354.03	983
	458-549	140	88	193	19.9	1,165	884	373.47	561
	550-640	—	—	—	—	—	—	—	—
	641-732	139	—	—	—	1	809	—	1
	733-823	161	135	181	11.7	11	1,112	225.22	11
Female	274-366	105	92	113	11.2	3	189	80.88	3
	367-457	105	85	145	8.6	91	265	103.13	35
	458-549	104	85	137	9.7	41	228	70.06	16
	550-640	—	—	—	—	—	—	—	—
	641-732	—	—	—	—	—	—	—	—
	733-823	149	117	170	13.6	31	768	201.09	32

Reproductive Biology

We obtained satisfactory histological sections from 39 of 72 female golden crabs examined. From histological and gross examination we described four ovarian developmental stages: 1) early, 2) intermediate, 3) advanced, and 4) mature.

In the early stage of development, the slightly lobate ovary is very small, transparent to white in color, and bounded by fibrous connective tissue. Oocyte diameter ranged from 58 to 92 μm with a mean of 75 μm (Fig. 3A). Nuclei and nucleoli are readily apparent in the early oocytes, as are follicle or accessory cells which surround each

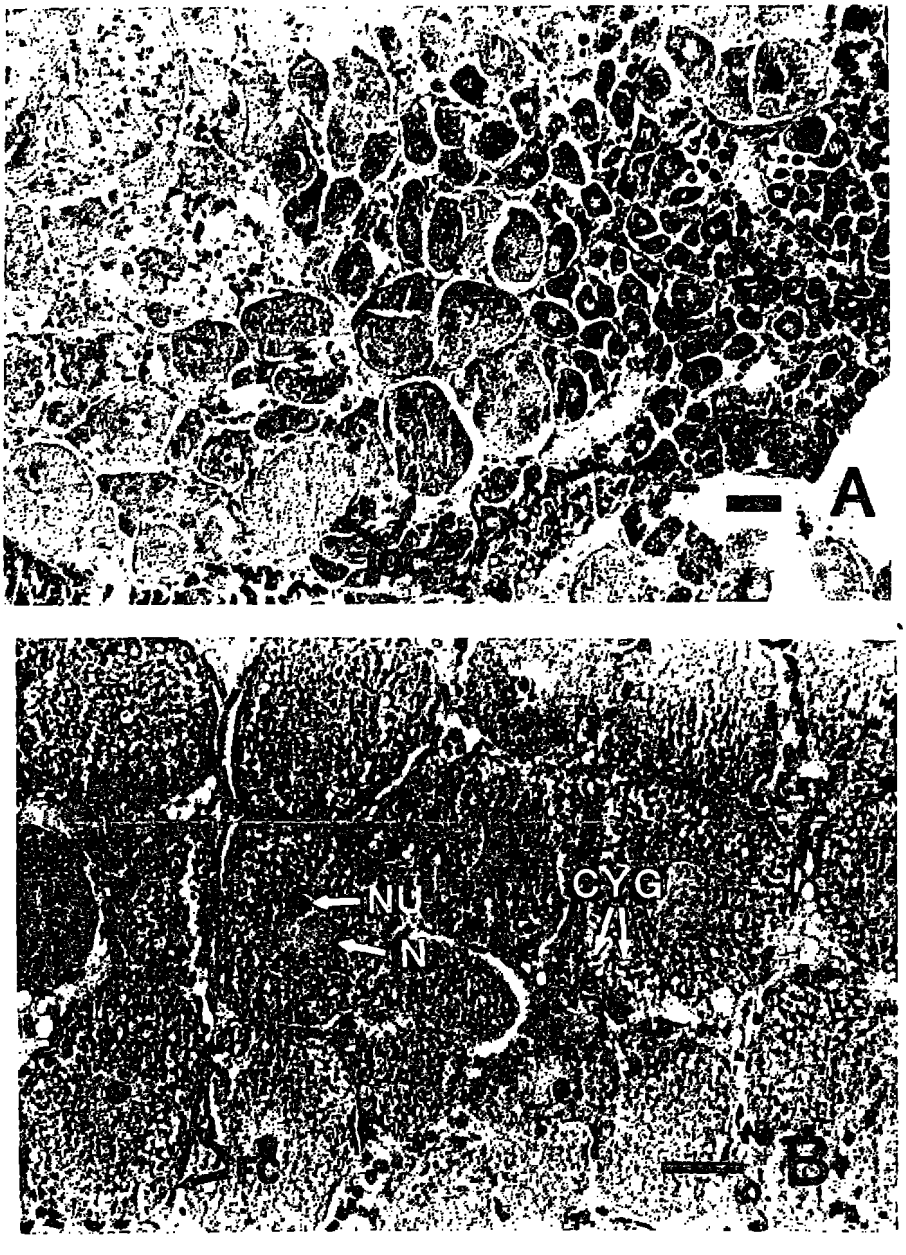

FIGURE 3.—Ovarian and testicular tissue of *Geryon fenneri*.

A. Ovarian tissue showing early (EOC) to intermediate oocyte (IOC) development. Oocytes range in size from 30 to 100 μm. Scale bar 60 μm.

B. Oocytes at the intermediate stage of development. Nucleus (N), nucleolus (NU), cytoplasmic yolk globules (CYG), follicle cells (FC). Oocyte size extremes are 100-125 μm. Scale bar 50 μm.

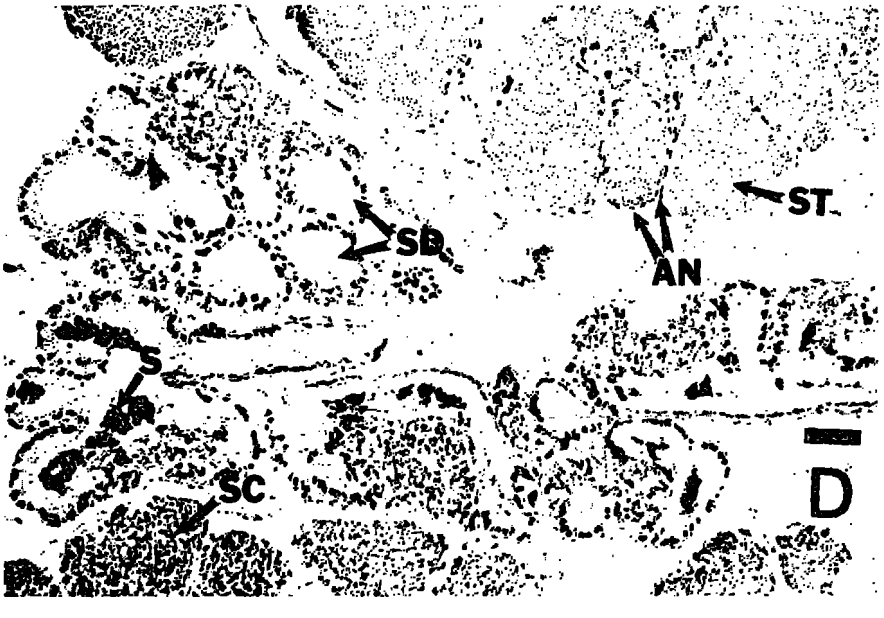

FIGURE 3.—*Continued.*

C. Oocytes in the advanced stage of development. Nucleolus (NU), cytoplasmic yolk granules (CYG). Oocytes 200-300 μm in size. Scale bar 30 μm.

D. A portion of a mature testis showing the seminiferous duct (SD) and testicular lobes containing spermatocytes (SC), spermatids (ST) and sperm (S). Accessory cell nuclei (AN). Scale bar 100 μm.

cell. In the larger oocytes, cytoplasmic vitellin globules indicative of vitellogenesis are present.

The intermediate stage ovary is yellow in color, has more pronounced lobation, and is larger than the early stage ovary. The diameter of oocytes ranged from 112 to 175 μm with a mean diameter of 145 μm. Most oocytes were undergoing vitellogenesis in this stage (Fig. 3B).

As the ovary matures to the advanced stage, the ovarian lobes become enlarged and the color becomes light orange to orange-red in color. The anterior portion of the ovary obscures the anterior hepatopancreas from dorsal view. Oocytes were 175-300 μm in diameter ($\bar{y}$ = 240 μm) and enlarge as vitellogenesis continues (Fig. 3C).

The mature ovary, brown to purple in color, is the dominant visible organ and obscures the hepatopancreas in dorsal view. Oocytes are filled with yolk globules and average 300-400 μm in diameter as vitellogenesis nears completion.

Size at sexual maturity was difficult to assess because of the small number of females collected. Overlap existed in the size of female *G. fenneri* in each stage of development.The carapace width of females in early ovarian development ranged from 85 to 116 mm ($\bar{y}$ = 104 mm, n = 27). Intermediate ovaries were present in females measuring 105-169 mm CW ($\bar{y}$ = 127 mm, n = 13) while advanced ovaries occurred at sizes from 110 to 136 mm CW ($\bar{y}$ = 123, n = 2). The 30 females with mature ovaries ranged from 97 to 169 mm CW ($\bar{y}$ = 141).

Five vulval forms were identified among the 142 females examined. Most of the females had immature vulvae (types a and b) suggesting that these crabs had not mated. The observed ovarian condition in a subsample (n = 26) of these females indicated that all had ovaries in an early stage of development (Table 6). Only one female (111 mm CW) with immature vulvae contained sperm in the seminal receptacles, indicating copulation had occurred. Type c vulvae were noted on two females, one with ovaries in early development and lacking sperm in the seminal receptacles while the other crab had mature ovaries and sperm present. Type e and f vulvae were found on the largest females collected, all of which had at least intermediate stage ovaries. Eight of the fourteen females with these vulval types whose seminal receptacles were examined had been inseminated.

Three male *G. fenneri* examined exhibited typical brachyuran reproductive morphology. The testes, which are dorsal to the hepatopancreas, were tubular and highly lobate. The testicular lobes, adjacent to the central seminiferous duct, contained spermatocytes, spermatids, and spermatozoa, suggestive of asynchronous development (Fig. 3D). In mature individuals, ripened spermatozoa were found in the seminiferous duct. Examination of the testes and vas deferentia by SEM revealed germ cells at various stages of development. Spermatids (Fig. 4A), surrounded by supportive tissue, were composed of a central nucleus framed in cytoplasm. With spermiogenesis, multiple projections or spikes form which are characteristic of developed sperm (Fig. 4A). Another portion of the same testis yielded a more advanced germ cell displaying well-defined cytoplasmic spikes (Fig. 4B). A sagittal section through the vas deferens revealed stellate spermatozoa (Fig. 4C), which had previously been embedded in this complex of supportive tissue (Fig. 4D).

TABLE 6.—Incidence of vulval type (after Haefner 1977) in relation to carapace width and gonadal condition of female *Geryon fenneri*. n = number of individuals examined.

Type	n	Carapace width (mm)	n	Gonadal condition
a	112	85-119	22	early
b	4	98-116	4	early
c	2	97-109	1	early
			1	mature
d	0	—	0	—
e	19	105-156	8	intermediate
			1	advanced
			9	mature
f	5	124-169	2	intermediate
			3	mature

Molt Condition and Fouling

Most (80%) of the 3,183 male and female *G. fenneri* were in the intermolt stage. Less than 1% of the 3,041 male golden crab showed evidence of having recently molted. The incidence of imminent or recently molted female golden crab was higher than that observed for males, with four individuals classified as premolt (soft-old) and two in the newly molted (soft-new) condition.

Most (95%) of the 3,183 *G. fenneri* examined for molt condition had blackened abraded areas on the exoskeleton, indicative of damage by chitinolytic bacteria. Exoskeleton damage was most prevalent on individuals in the intermolt (75%) and premolt (19%) condition.

DISCUSSION

Although the results of this study suggest that *G. fenneri* has a wide bathymetric occurrence in the South Atlantic Bight, the depth extremes for the species probably extend beyond those encompassed by our sampling design. Records of *Geryon* sp. and *G. affinis* (which were probably *G. fenneri*) from the Gulf of Mexico indicate a depth distribution of 365-1,455 m (Pequegnat 1970), while Luckhurst (in press) reported golden crabs from 786 to 1,462 m near Bermuda.

Although a broad bathymetric range for the species is likely, maximum abundance occurs between 367 and 549 m in our study area. This depth range coincides with that reported by Stone and Bailey (1980) for maximum trap catches of *G. quinquedens* along the Scotian Shelf and approximates the limits (320-530 m) determined by Wigley et al. (1975) by trawl and photographic methods to be most productive for that species off the northeastern United States.

Information on sediment composition taken coincidentally with fishing activities suggests that abundance of both *G. fenneri* and *G. quinquedens* is influenced by sediment type at these optimum depths. Our catches were highest on substrates containing a mixture of silt-clay and foraminiferan shell. In contrast, no golden crab were collected on rock and coral rubble bottom such as was encountered in the 550-640 m stratum. Other studies have described an association of *G. quinquedens* with soft substrates. Wigley et al. (1975) noted that bottom sediments throughout the area surveyed for red crab from offshore Maryland to Corsair Canyon (Georges Bank) consisted of a soft, olive-green, silt-clay mixture. If golden crabs preferentially inhabit soft substrates, then their zone of maximum abundance may be limited within the South Atlantic Bight. Surveys by Bullis and Rathjen (1959) indicated that green mud occurred consistently at 270-450 m between St. Augustine and Cape Canaveral, FL (30°N and 28°N). This same depth range from Savannah, GA to St. Augustine was generally characterized by Bullis and Rathjen (1959) as extremely irregular bottom with some smooth limestone or "slab" rock present. Our study indicates, however, that the bottom due east between Savannah and St. Catherines Island, GA at 270-540 m consists of mud and biogenic ooze. Further north from Cape Fear, NC to Savannah, bottom topography between 270 and 450 m is highly variable with rocky outcrops, sand and mud ooze present (Low and Ulrich 1983). Additional information on sediment type during future fishing efforts will be necessary before any validation of sediment preference by golden crab can be made.

The catch data for golden crab in our survey compares favorably with catch rates reported by Otwell et al. (1984) in the Gulf of Mexico. Although their study was not intended to assess the resource, they reported mean catch per trap values of 7.4-8.4 for the nested design fished between 210 and 340 fathoms. Information on catch rates of red crab from trap surveys and the fishery is perhaps more relevant to our study. Ganz and Herrmann (1975) reported an overall unculled mean catch per pot of 40-93 red crabs off southern New England; their study used four types of double parlor offshore lobster pots. An average catch of 26.8 red crabs per trap (conical-top entry) was reported in 360-540 m depths on the Scotian Shelf by Stone and Bailey (1980). The only available information on weight per trap was provided by Gerrior (1981) who found seasonal catch rates that ranged from a low of 8.4 kg in March to a high of 11.1 kg per pot in June. Although comparison of catch per unit of effort between these studies is questionable because trap type and fishing duration, as well as physical features of the sampling areas differ, catch per trap of golden crab in depths of maximum abundance off South Carolina and Georgia appears promising.

Comparison of catches (no./trap) between the Fathoms Plus trap and the Florida trap clearly indicate superiority of the latter for golden crab. These two traps also differed in the size and weight of individuals caught, with larger and heavier golden crab occurring in the Fathoms Plus trap. Advantages of the Fathoms Plus traps for commercial fishing operations would include their lighter weight, ease of handling, and stackable configuration which conserves deck space. Differences observed between traps may be related to trap design which affects success of entry and maximum catch (Miller 1980) or behavioral interactions which affect probability of capture (Richards et al. 1983). Although no studies have been done to evaluate behavior of *G. quinquedens* or *G. fenneri* in regard to traps, responses of the spider crab, *Hyas araneus*, and the rock crab, *Cancer irroratus*, to top and side entry traps were reported by Miller (1980). He found success of entry by *C. irroratus* was greater, escapement was reduced, and fewer agonistic encounters occurred in top entry traps. In a complementary study, however, *Cancer productus* had highest

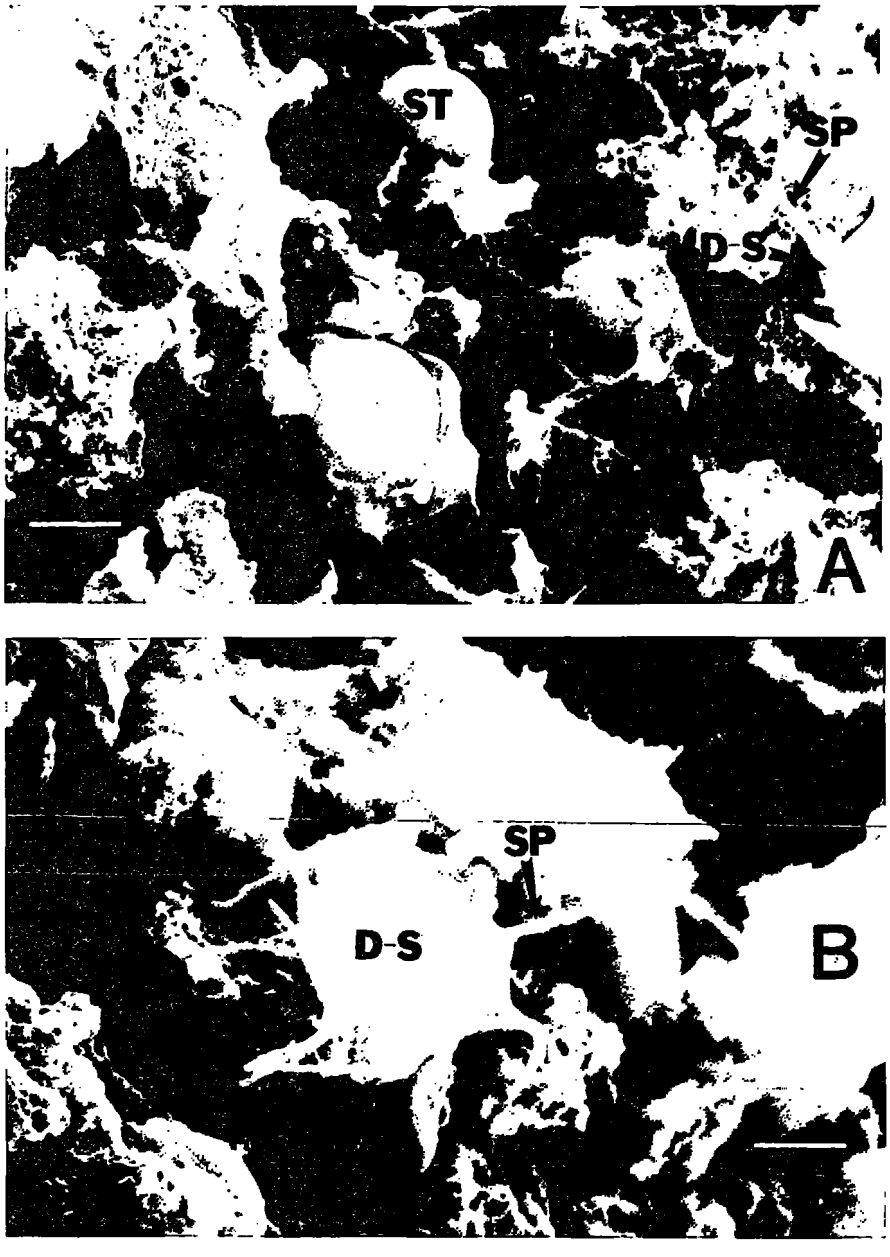

FIGURE 4.—Scanning electron micrograph of testis and vas deferens from male *Geryon fenneri*.
A. Testis: Maturing germ cells (spermatids, ST) surrounded by sustentacular tissue. Developing sperm (D-S), cytoplasmic spike (SP); × 3200. Scale bar 3 μm.
B. Testis: A developing sperm (D-S) possessing partial to fully formed cytoplasmic spikes (SP); × 3200. Scale bar 3 μm.

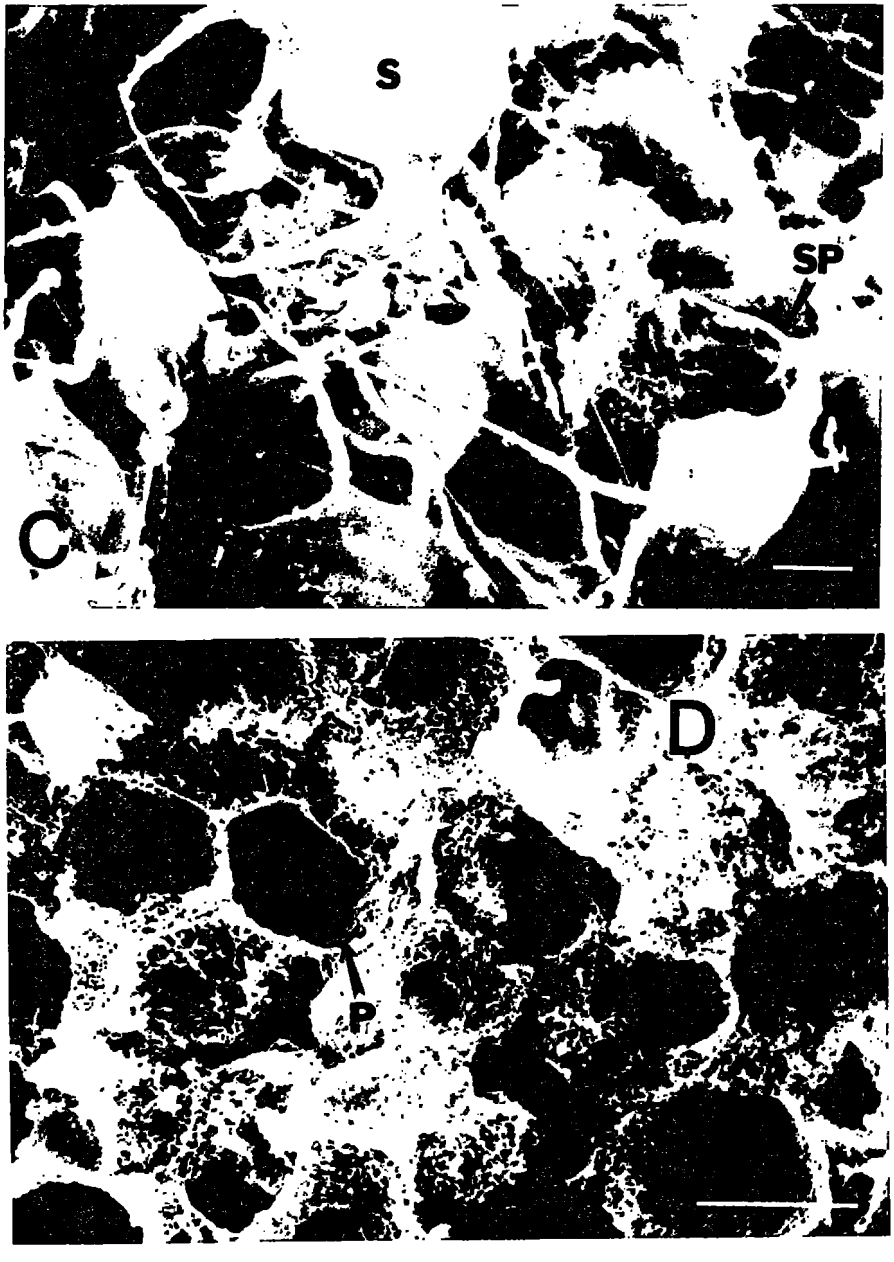

FIGURE 4.—*Continued.*

C. Vas deferens:- Mature multiple stellate sperm (S) showing cytoplasmic spike (SP); × 3840. Scale bar 2 μm.

D. Vas deferens: Pockets (P) within the vas deferens previously occupied by the mature stellate sperm; × 1600. Scale bar 10 μm.

success in entering a side entry trap whose entrances were parallel to the current (Miller 1978). Although our traps were deployed parallel to surface current, their orientation on the bottom relative to bottom current is unknown. We are assuming that golden crabs were successful in locating the entrance and were retained longer in the top entry Florida trap than in the Fathoms Plus trap. It is possible, however, that golden crab were equally or more successful in locating the side entrances of the Fathoms Plus trap but that escapement, especially of smaller golden crab, was higher. This would explain the capture of fewer but larger individuals by the Fathoms Plus trap.

The overwhelming dominance of males in this study contrasts with results reported in other geographic areas for golden crab. Luckhurst (in press) noted that sex ratio in his sample (n = 244) of *G. fenneri* from Bermuda waters was approximately 1:1. Otwell et al. (1984) noted that males tended to be more abundant at greater depths (>540 m) in the Gulf of Mexico; however, they cautioned that trap design may influence the percentage of male crabs caught. Commercial crabbers noted a decline in catch rates and number of male *G. fenneri* with increasing depth on the slope in the eastern Gulf of Mexico (National Marine Fisheries Service fn. 5). We also found increased abundance of females at greater depths, although our results are limited due to the small number of females collected. This is apparently not an artifact of sampling with only the Fathoms Plus trap in the deepest stratum since more females were collected in the Florida trap than with the Fathoms Plus trap when only strata 1-3 were considered. Segregation of the sexes by depth has been observed in several studies of *G. quinquedens*. Wigley et al. (1975) collected more female red crabs than males, but this dominance was limited to intermediate depths (320-503 m). Ganz and Herrmann (1975) similarly noted dominance by male red crab at depths >685 m off Rhode Island. This same pattern was noted for red crab in the vicinity of Norfolk Canyon where females were more abundant than males from depths <600 m (Haefner and Musick 1974; Haefner 1978). In Canadian waters, however, female red crabs were reported by Stone and Bailey (1980) to be considerably less abundant than males. Although they attributed this discrepancy to trap bias, another study in the same general area found females were present but highly contagious in distribution. Whether seasonal migrations related to mating or spawning occur as hypothesized by Wigley et al. (1975) for *G. quinquedens* remains to be substantiated. What is evident from our results is that male *G. fenneri* are dominant in depth strata where catch per unit of effort is highest.

Size-related distribution of *G. fenneri* with depth, similar to that reported for red crab, may occur in the South Atlantic Bight. We found the largest crabs in the shallowest (274-366 m) and deepest (733-823 m) strata. A clear trend of size-related up-slope migration such as Wigley et al. (1975) reported for *G. quinquedens* is not apparent, however, because of trap bias for capture of larger crabs of both sexes. Otwell et al. (1984) also noted no pattern in size of golden crab by depth for either sex. Tagging studies of red crab off southern New England provided no evidence for migration patterns and indicated instead that tagged crabs seldom moved more than 20 km from their site of release (Lux et al. 1982).

The size composition of golden crab from our study showed that crabs become trappable as small as 85 mm CW but that the greatest proportion of trapped individuals is >100 mm CW. Over 90% of all individuals collected exceeded 114 mm CW which is the minimum size of red crab accepted for commercial utilization (Wigley et al. 1975). A much smaller proportion (52%) of golden crab >114 mm was indicated in size-frequency distributions of trap-caught golden crab near Bermuda (Luckhurst in press). Although Otwell et al. (1984) did not present size and weight-frequency data for golden crab in the Gulf of Mexico, they found mean size of male crabs ranged from 155 to 163 mm with mean weight extremes of 1.07-1.15 kg, while females were smaller with mean CW ranging from 119 to 135 mm and mean weight extremes of 0.45-0.50 kg. These data and those from our study suggest that the average size of golden crab from the South Atlantic Bight and Gulf of Mexico is larger than the average size of red crab reported along the eastern United States and Canada. Wigley et al. (1975) reported average width of male *G. quinquedens* was 99 mm with an average weight of 413 g. Average width of all females from their study was 90 mm with a mean weight of 244 g. Comparisons of size composition between the two studies must be qualified, however, by a caveat that differences in sampling methods probably influenced sample statistics. The apparent larger size of golden crab may be better substantiated by maximum width and weight measurements, which for our study were

193 mm and 2,109 g, respectively. These values were markedly larger than those reported for red crab in the vicinity of Norfolk Canyon (Haefner 1978), off northeastern United States (Wigley et al. 1975), or the Scotian Shelf (Stone and Bailey 1980; McElman and Elner 1982).

The small number of females collected during the first year precludes any definitive statements regarding ovarian cycles or spawning patterns. Ovarian developmental stages are similar to those reported by Haefner (1977) for *G. quinquedens*. We also found his use of vulvae condition as an external indicator of copulation to be fairly reliable, but examination of the seminal receptacles for sperm or spermatophores provided the only true indication of mating. Tentative interpretations on ovarian development, vulval condition, and presence of seminal products suggest that females may become sexually mature at 97 mm CW. Haefner (1977) suggested that female *G. quinquedens* become sexually mature within the intermolt size of 80-91 mm CW.

A lack of ovigerous females in our first-year sampling effort could be indicative of a restricted spawning season similar to that reported for red crab (Haefner 1977; Wigley et al. 1975). Absence of ovigerous females from our samples, however, may be related to the small number of female golden crab collected.

Observations on molting and mating of a female (110 mm CW), which had been held in a refrigerated aquarium since February 1986 and had completed ecdysis in late May 1986, confirmed that female golden crab molt just before mating occurs. This behavior, as well as the observed premolt embrace, has been described for *G. longipes* (Mori and Relini 1979), although it has not been reported previously for either *G. quinquedens or G. fenneri.*

Stage of ecdysis is an important factor affecting meat condition and yield in golden crab. Crabs which have recently molted generally have a very poor meat yield and are not marketable[8]. Since most golden crab in the intermolt stage had blackened abraded areas or poecilasmatid barnacles on the exoskeleton, their presence was useful in distinguishing premolt from postmolt crabs which were brighter in color and had few abrasions.

[8]W. Lacy, Seafood Marketing Section, South Carolina Wildlife and Marine Resources Department, Charleston, SC 29412, pers. commun. 1985.

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