Exploration for Golden Crab, *Geryon fenneri*, in the South Atlantic Bight: Distribution, Population, Structure, and Gear Assessment

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INTRODUCTION

Exploratory trapping and processing techniques for golden crab, *Geryon fenneri* (Manning and Holthius 1984), were first described for stocks in the Gulf of Mexico (Otwell et al. 1984). Since then, additional golden crab stocks were discovered off Bermuda (Luckhurst 1985), in the South Atlantic Bight (Wenner et al., in press), and off the southeast coast of Florida (W. Lindberg, pers. comm.). Commercial harvesting has been attempted in these areas but with limited success. Present exploration of golden crab is limited to South Carolina, Georgia and the east coast of Florida.

Much of the information currently available on golden crab off the southeastern United States resulted from a cooperatively funded research effort initiated in March 1985 by the Gulf and South Atlantic Fisheries Development Foundation, the South Carolina Wildlife and Marine Resources Department (SCWMRD), the South Carolina Sea Grant Consortium and the Marquette Foundation. The primary goals of this two-year project were to determine the extent of the resource of *G. fenneri* in the South Atlantic Bight, work with the private sector to establish appropriate fishing techniques, and provide information which will guide the private sector in entry and capitalization of the potential fishery for *G. fenneri* and other decapod species which co-occur on the continental slope. Specific research objectives for the project were to:

- define the bathymetric distribution of *Geryon fenneri* in the South Atlantic Bight;
- determine the density, size and sex composition of *G. fenneri* in the South Atlantic Bight;
- evaluate traps, soak time and gear performance in an effort to optimize fishing technique;

- describe adult life history in terms of habitat and reproductive biology; and assess other crustacean resources that co-occur with *G. fenneri*;
- cooperate with commercial processors and marketing experts on handling, processing and marketing of *G. fenneri*.

The first year of the project was devoted to exploratory trapping off South Carolina and Georgia in depths from 296-810 m. Results showed maximum abundance of golden crab occurred between 367-549 m (200-300 fm) on globigerina ooze. The only other numerically important species caught was the jonah crab, *Cancer borealis*. Of the two trap types fished, catches were significantly higher in the top-entry Florida trap. Male golden crab were more numerous than females in all strata except the deepest (733-823 m). Most of the golden crab caught exceeded 114 mm carapace width which is the minimum legal limit for red crab, *G. quinquedens*.

The second year of the study, whose results are presented herein, provide additional information on the distribution and life history of golden crab and jonah crab as well as trap saturation and performance.

METHODS

Distribution and Relative Abundance

Cruises to assess the distribution and abundance of golden crab were made from 19 May to 11 August 1986 (Appendix I) on board the SCWMRD research vessels *Oregon*, a 32 m converted tuna purse-seiner, and the *Lady Lisa*, a 22.1 m double-rigged shrimp trawler. Vessels were equipped with large capacity hydraulic systems and a heavy duty pot hauler.

Traps used in this study and their arrangement on trap lines were described by Wenner et al. (in press, 1987) for the first year. The first trap on the groundline was randomly selected with trap type alternating until six traps (three of each type) were attached (Figure 1).

Trap sets were made between lat. 30°20.4'-32°43.1' and long. 76°42.0'-79°33.6' in seven depth strata: 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), 733-823 m (stratum 6), and >823 m (stratum 7). Generally, three sets, which consisted of the gear arrangement shown in Figure 1, were made approximately 0.9 - 1.8 km apart within the same depth stratum over a 24-h period. Sampling locations were selected by fathometer transects of the potential fishing area to determine depth and bottom type. In the second year, more effort was planned for deeper strata which were not adequately sampled previously. Equal distribution of effort between strata was not achieved, however, due to poor weather conditions and gear loss and movement caused by strong currents (Table 1).

Fishing duration was standardized at 20 hours; however, poor weather conditions and logistical considerations altered this. Average fishing duration within strata exceeded 18 hours (Table 1).

Bottom sediments were sampled by a geological rocket grab whenever possible 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.

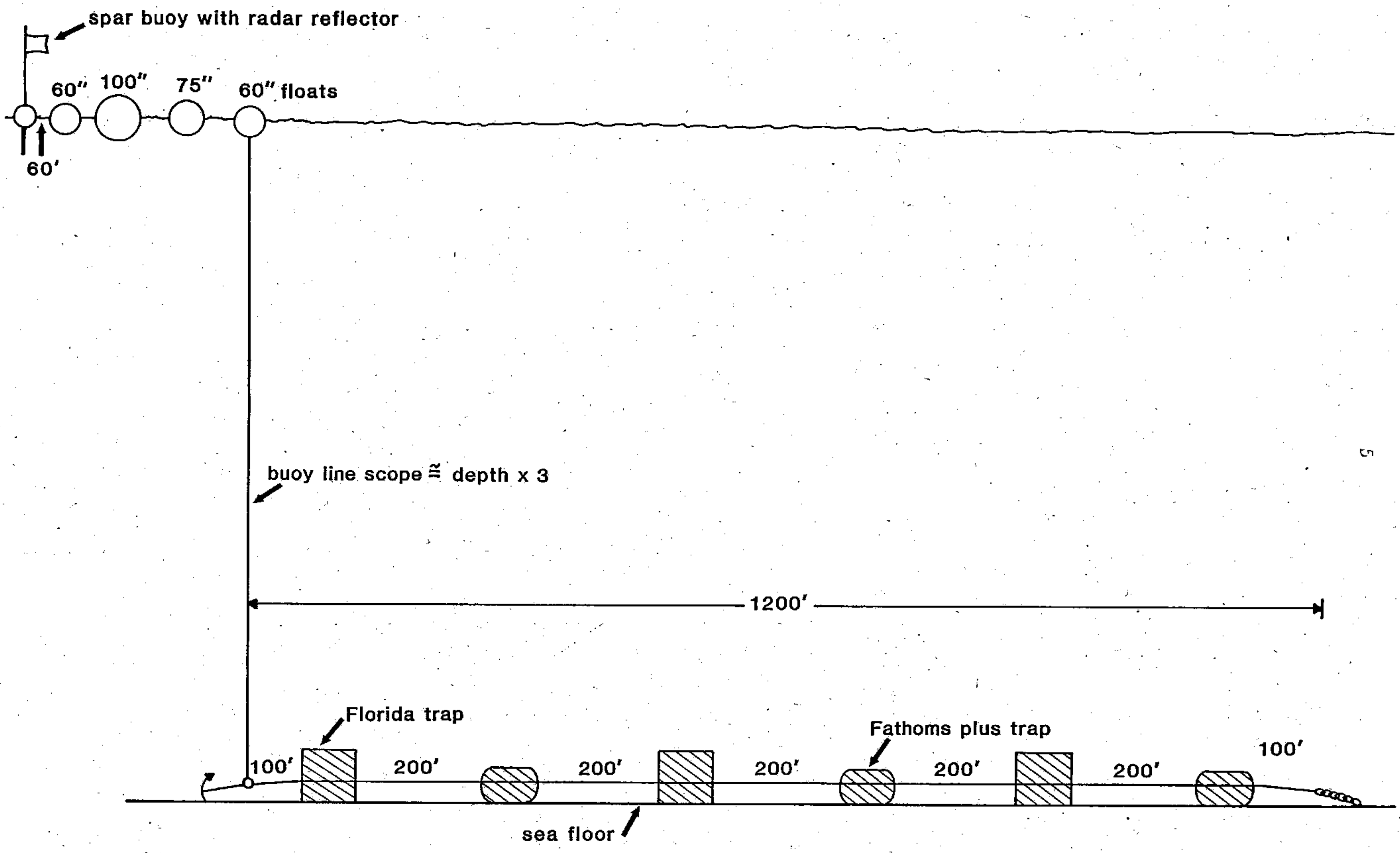


Figure 1. Schematic of a set of traps used in exploratory assessment of <u>Geryon fenneri</u>.

Table 1. Fishing duration in hours of trap sets within seven strata sampled during Year II for catch-per-unit effort.

Stratum	No. Sets	Fishing Duration (hours)			
		$\overline{x}$	(s)	min.	max.
1	4	22.0	1.34	20.6	23.8
2	21	20.3	4.28	10.2	25.0
3	6	18.3	6.21	11.2	25.7
4	2	19.1	0.71	18.6	19.6
5	2	19.2	0.78	18.7	19.8
6	16	20.5	1.11	18.8	22.5
7	9	19.9	1.29	18.2	21.9

Visual Assessment

In situ observations on habitat density and behavior of golden crab and jonah crab around traps were made from 23-27 August 1986, from the *Sea Link* I submersible of Harbor Branch Foundation, Inc. Observations were made from 480-555 m between lat. 31°49.1'-31°51.1' and long. 79°11.3'-79°12.9' (Table 2). Stations were selected from areas that had high yields of golden crab during the first year of the study. Location of the first transect was randomly chosen. Subsequent transects were a continuum or were parallel to the first. Loran C was used to record transect tracts in order to determine exact distance traversed.

Prior to beginning a transect, the submersible remained stationary, with minimum light emission for a three-minute acclimation period. On the first five transects, three one-minute stationary counts were made with full lighting immediately following the acclimation period. Because the same crabs for all three point estimates were noted on each transect, these point counts were abandoned on other dives in order to maximize transect time. Upon completing these procedures, the submersible proceeded along the transect for ~ 457 m and counts of *G. fenneri* and *C. borealis* were recorded. Time, depth, bottom water temperature, habitat characteristics, biological observations, and position of the submersible were recorded frequently. Sediment samples were collected *in situ* by a grab sampler for each transect and when bottom type changed

Videotapes and 35 mm still photographs were used to document changes in habitat and topography. Observations on videotape were simultaneously recorded on voice tape and both were used to assess the number of individuals for each visible decapod species encountered. Estimates of population density were determined for the area of each transect which was the product of transect distance (457.2 m) and horizontal visibility (3.1 m). Transect length and

Table 2. Summary of stations surveyed by submersible.

Dive No.	Station	Location	Depth (m)	Temp. (°C)	Sediment	Activity
1	Area A, Site 1	31°49.2'N-79°12.9'W	495-497	7.1	Globigerina ooze	Transects 1-5
2	Area A, Site 2	31°49.1'N-79°12.6'W	472-475	7.1	Globigerina ooze	Transects 6-11
3	Area A, Site 4	31°47.7'N-79°10.9'W	521-555	7.1	Globigerina ooze/ Coral rubble	Transects 12-18
4	Area A, Site 2	31°49.5'N-79°11.9'W	500-501	7.1	Globigerina ooze	Trap Obs.
5	Area A, Site 2	31°51.1'N-79°11.3'W	480	7.1	Globigerina ooze	Trap Obs.

position was determined from Loran C while horizontal visibility was the lighted arc of bottom as seen by the forward observer.

Behavior in the vicinity of six traps (three Fathoms Plus and three Florida traps) was evaluated 1-3 hours and 5-h following deployment. The order in which traps were attached to the groundline was randomized. Sequential observations were made for ~15 minutes at each trap and included: current direction, number of approaches (forward motion and contact with trap), number of crabs that left due to agonistic encounters, number that left due to other causes, number that entered, number that escaped, and number of crabs in vicinity of trap that did not approach. Videotape recordings and still camera photographs were used to document crab behavior around each trap. Following the observation period and departure of the submersible, gear was retrieved by the R/V Lady Lisa and the number of crabs in each trap recorded.

Trap Saturation

Cruises to determine whether the fishing power of the two trap types used in the study decreased as the catch per trap increased (e.g. gear saturation, *sensu* Beverton and Holt 1957) were conducted from 30 September - 1 Oct. 1986 and 20-21 April 1987. In September, two sets of baited traps were deployed at 31°45.6'N and 79°14.3'W in 426-477 m. The April cruise sampled at 31°35.3'-31°38.8'N and 79°22.1-79°25.5'W in 388-425 m; however, poor weather conditions and strong currents caused loss of gear and forced premature termination of this cruise.

Each set consisted of four baited Fathoms Plus and four baited Florida traps, arranged in random order on the groundline. Two traps of each type in a set were randomly assigned a "fished" and "unfished" treatment. Fished traps were hauled and emptied approximately every three hours for 18 hours with the trapped crabs not returned to the water. Traps not-fished were also hauled approximately every three hours for 18 hours, but golden and jonah crabs were counted, marked, replaced in the traps and returned to the water. Marking was used to determine whether escapement of crabs occurred. Traps were freshly baited at each observation period. Catch data by species for fished traps were calculated as the accumulated catch for the observation time, while data from unfished traps were the observed number of crabs in a trap at each observation.

Size and Sex Composition

Golden and jonah crabs were 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 between the rostal 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 as was molt condition and presence of chitinolysis and poecilasmatid barnacles, Trilasmis inaequilaterale, on the exoskeleton. Molt condition of G. fenneri was classified by stages described by Wenner et al. (in press). Molt condition of C. borealis followed stages defined by Carpenter (1978).

Female G. fenneri and C. borealis were examined for presence of eggs or remnants and evidence of mating. Descriptions given by Haefner (1977a) for G. quinquedens were used in categorizing G. fenneri by ovarian color, ovarian size and the physical condition of the vulvae. Cancer borealis were assigned ovarian stages based on descriptions from Carpenter (1978). Seminal receptacles were examined for presence of sperm or spermatophores and for relative size. A representative sample of ovaries and seminal receptacles were prepared for histological examination. Following fixation in 10% sea water formalin, samples were dehydrated in alcohol, cleared, and embedded in paraffin. Sections were cut at 7 μm, stained with hematoxylin and counterstained with eosin-Y. Oocytes were measured using an ocular micrometer.

Abdomens were ablated in toto from 12 of the 19 ovigerous females collected and were fixed in 10% seawater buffered formalin. After fixation, the abdomens were transferred to isopropanol. Individual abdomens were then weighed to the nearest gram, and the eggs were removed from each. Eggs were placed in a separatory funnel and suspended in a one liter mixture of isopropanol and water by aeration. Three 1-ml aliquots (representing three subsamples of the entire volume of eggs and solution) were obtained using a 1-ml pipette, and the total number of eggs in each subsample was counted. The mean number of eggs for the three aliquot samples was used to calculate the number of eggs for each crab. A random number of eggs, from each sample, were measured to determine average egg diameter. Regression analyses (Sokal and Rolhf 1981) were performed in an effort to determine relationships between the number of eggs per crab and carapace width, total body weight, and abdomen weight.

RESULTS

Gear Assessment

Sampling gear used during the second year of the project was the same as that described in the Year I report. No significant losses of gear occurred, and the major problem encountered was the drifting of trap strings when strong surface currents were present. When strong currents precluded fishing in a particular area or depth strata, we would usually move to an alternate sampling location. The use of longer strings of gear in a commercial type operation would eliminate the problem of gear drift, but a corresponding problem of the submergence of buoys by the current drag would then be likely. In such cases, the time consuming use of a grappling device to snag the submerged buoy line or ground line would be necessary.

One of the most important questions raised during the first year about the gear used was: what was the actual configuration of the trap string once it had settled to the bottom? In situ observations made from the Johnson Sea Link research submersible provided information on this question during August 1986. Trap strings were deployed by the R/V Lady Lisa and observed 1-3 h and 5 h after deployment. The most important finding concerning the deployed gear was that traps generally settled closer together on the bottom than their spacing on the groundline (200 ft. apart). In the sets observed, the groundline was not sufficiently stretched out and large bights of line floated off the bottom with only 100 feet between some traps. In most cases, the traps landed on the bottom in proper fishing position. Only two traps had entrance ports occluded because they landed on a side or upside down. Maintaining more tension on the groundline while deploying or setting at a slightly greater boat speed may eliminate the bunching up of traps. Additionally, it would be advisable to increase the spacing of traps on the groundline to reduce the potential for competition between adjacent traps.

Distribution and Relative Abundance

The 60 valid sets (354 individual trap observations) caught 1235 G. fenneri (1274.2 kg) at sampled depths between 293 and 859 m. The red crab, Geryon quinquedens, was collected only from stratum 6 (Appendix I). The only other numerically important species collected was the jonah crab, Cancer borealis (1190 individuals, 339.1 kg). Better catches of golden crab were associated with oozes, consisting predominantly of globigerina with a mixture of pteropod fragments and silt-clay (Figure 2). At depths >550 m large coral mounds were encountered, and gear set in stratum 4 was regularly lost or retrieved with few crabs.

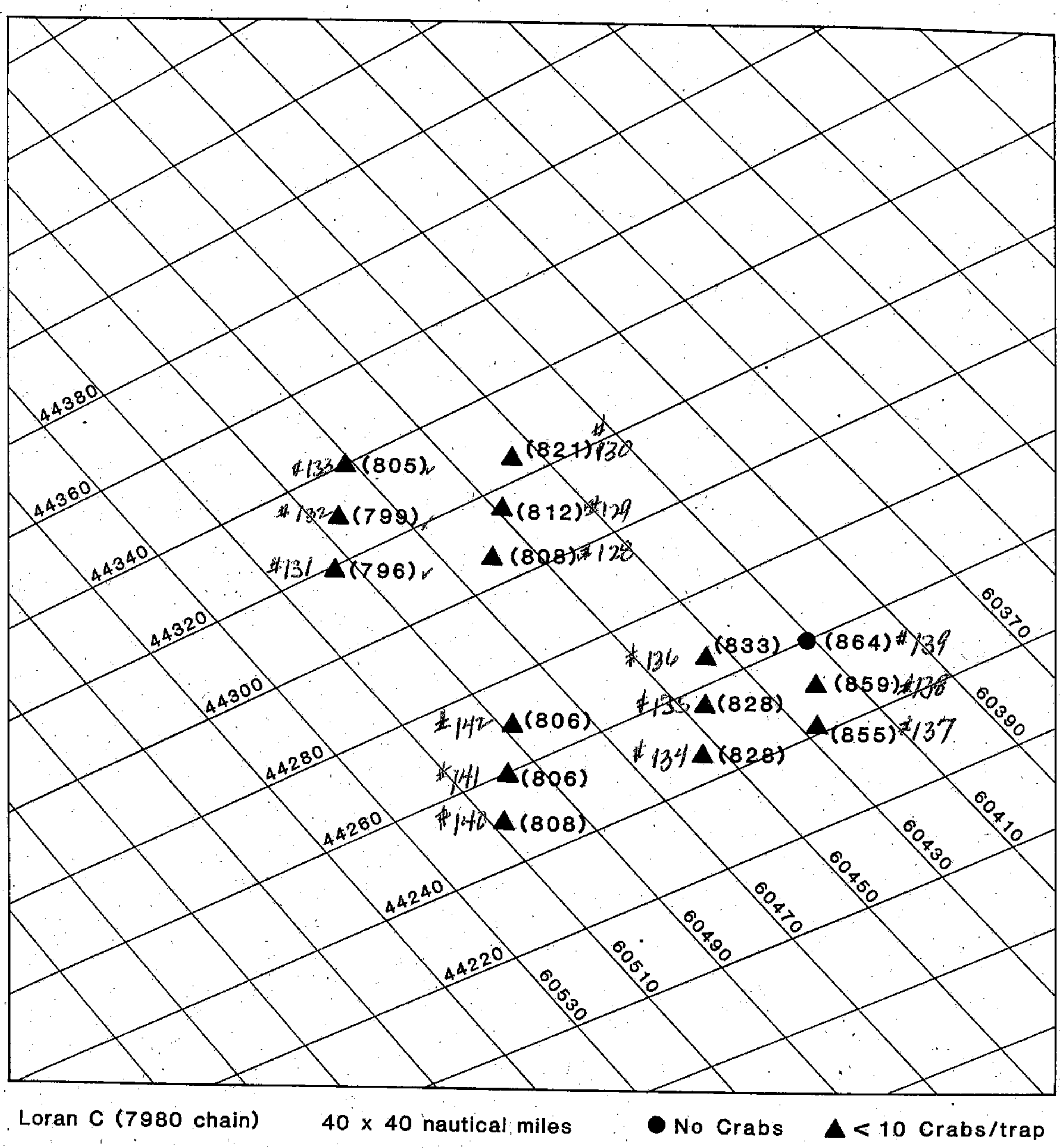
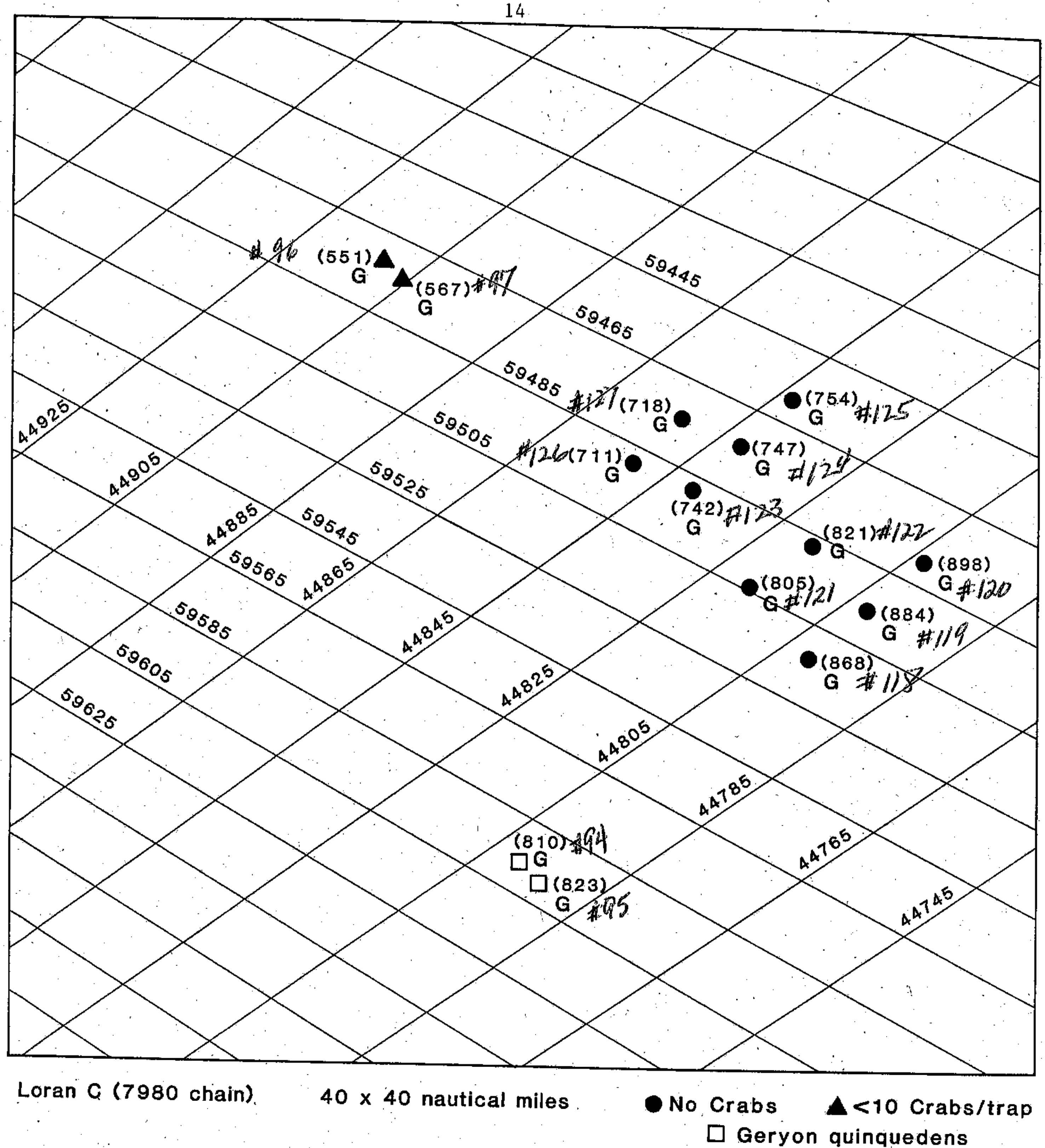


Figure 2. Station locations sampled during Year 2. Depth (m) is noted in parentheses and sediment type (G = globigerina ooze; S = shell hash; C = coral fragments) where available.



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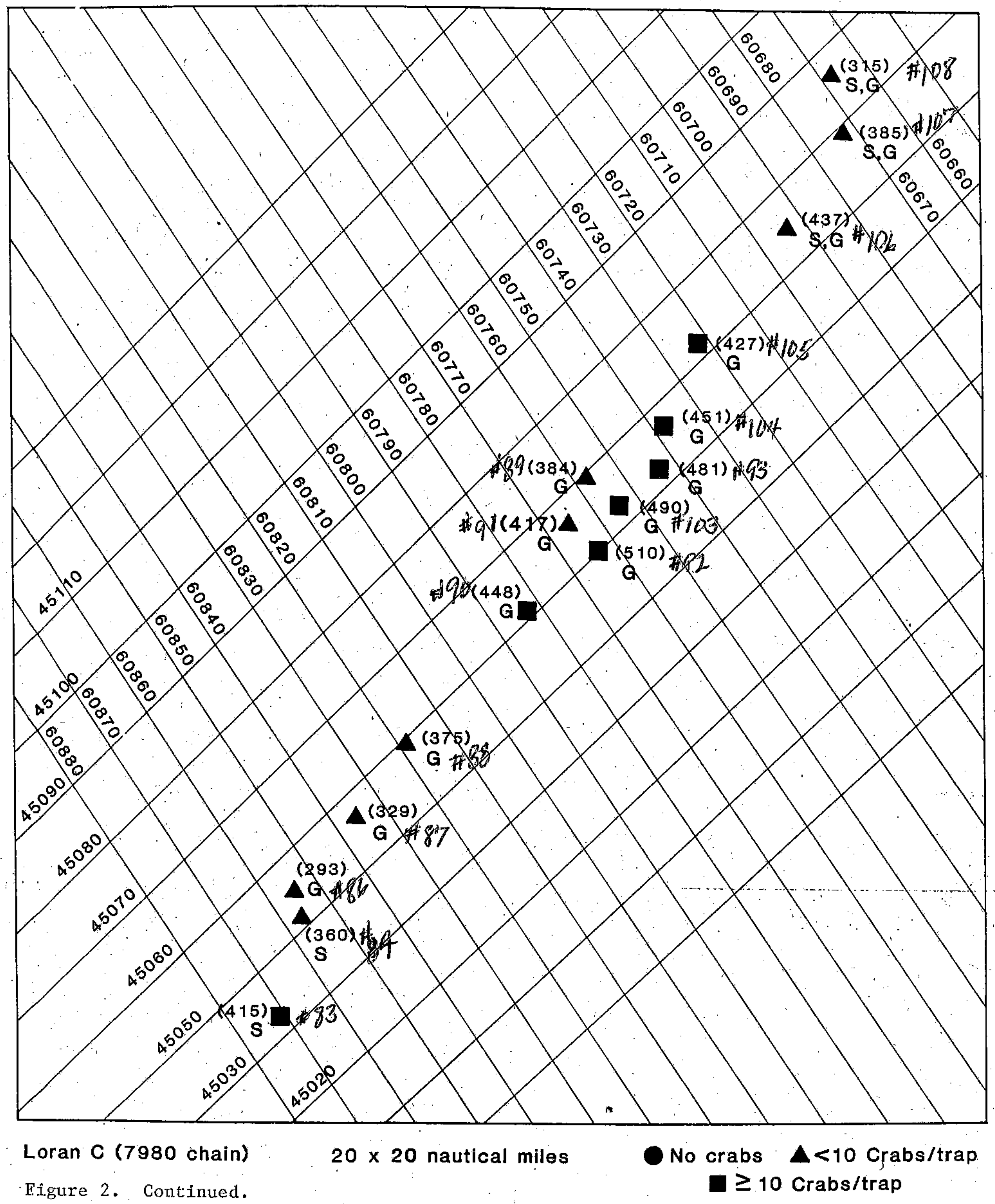

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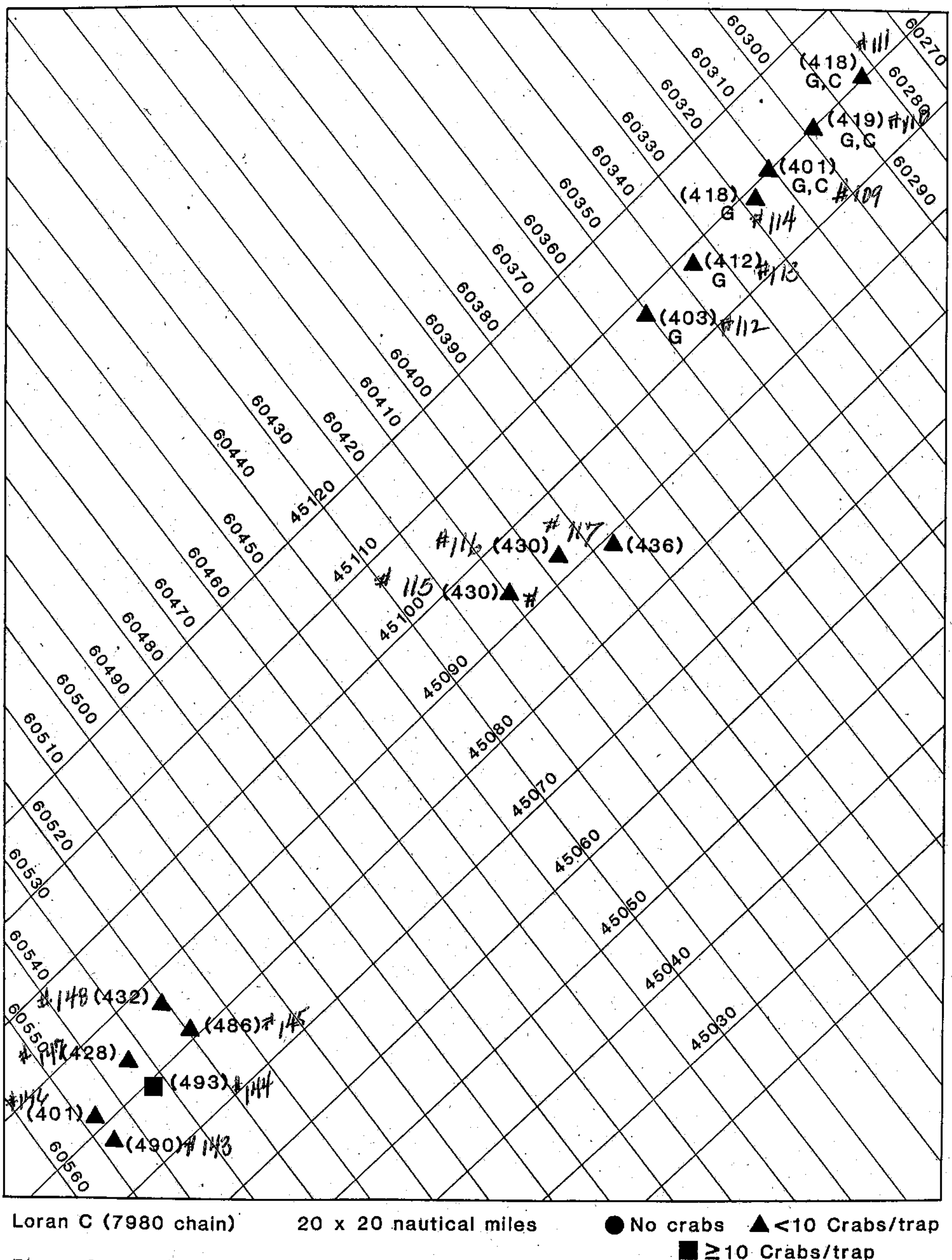

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Catch per trap of golden crab and jonah crab was related to depth. Catches of golden crab increased from 3.6 crabs/trap (4.49 kg/trap) in the shallowest stratum to a maximum abundance of 10.0 crabs/trap (9.6 kg/trap) in the 458-549 m depth zone. Catches then declined to <1 individual/trap in deeper strata (Table 3). This trend was similar to that noted in Year 1; however, catch per trap of golden crab was lower in Year 2 for all strata.

Cancer borealis was collected at depths from 293-567 m. Greatest catches of 15.9 crabs per trap (4.36 kg/trap) were in stratum 1 where jonah crab were present in every set (n = 4). Abundance declined with depth so that ≤1.0 crab per trap were collected in strata 3 and 4.

Comparisons of catches between trap type for each stratum showed that more individuals and greater weight of golden crab were collected by the Florida trap in every stratum except 7; however, statistical tests of mean catch between the two trap types revealed a significant difference in number and weight in stratum 3 only (Table 4). When catches for both Year 1 and Year 2 were compared between trap types, the Florida trap caught more crabs than the Fathoms Plus trap in strata 2 and 3 where golden crab were most numerous (Figure 3).

Catches of C. borealis from both years showed a different trend with mean number and weight greatest in the Fathoms Plus trap (Figure 4). A statistically significant difference in catches of the two trap types during Year II was noted in stratum 2 (Table 4).

Visual Assessment

A total of 18 transects was completed at three sites between 472-555 m (Table 5). Bottom type at sites 1 and 2 was fairly uniform, consisting of fine silt-clay, molluscan fragments and foraminiferan tests. The bottom topography at both sites was characterized by ripple marks, shallow depressions, and low

Table 3. Number of individuals and weight per trap for *Geryon fenneri* and *Cancer borealis* from the seven depth strata sampled in Year II.

G. fenneri

Stratum	No. Traps	No./Trap	Wgt./Trap (kg)
1	24	3.6	4.49
2	124	5.8	6.26
3	36	10.0	9.62
4	11	0.4	0.07
5	12	0	0
6	93	0.4	0.31
7	54	0.4	0.25

C. borealis

Stratum	No. Traps	No./Trap	Wgt./Trap (kg)
1	24	15.9	4.36
2	124	6.3	1.84
3	36	0.5	0.09
4	11	1.0	0.19
5	12	0	0
6	93	0	0
7	54	0	0

Table 4. 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 and Cancer borealis. Standard deviation is noted in parentheses; * indicates significance at 0.05 level.

G. fenneri

Stratum	Number/trap			Weight/trap		
	Fm+	FLA	T_s	Fm+	FLA	T_s
1	3.2(2.43)	3.9(3.64)	0.32	4.1(2.92)	4.9(4.52)	0.29
2	5.3(4.06)	6.2(4.28)	0.76	5.7(4.15)	6.7(4.35)	0.77
3	6.9(4.05)	13.2(5.04)	2.38*	6.6(2.72)	12.6(3.02)	3.64*
4	0.8(0.71)	0	--	0.1(0.08)	0	--
5	0	0	--	0	0	--
6	0.3(0.41)	0.5(0.74)	0.67	0.2(0.32)	0.4(0.54)	0.50
7	0.4(0.56)	0.4(0.78)	0.23	0.3(0.31)	0.3(0.43)	0.19
Total	3.6(5.54)	4.1(5.12)	0.50	3.1(3.86)	4.2(5.06)	1.29

C. borealis

Stratum	Number/trap			Weight/trap		
	Fm+	FLA	T_s	Fm+	FLA	T_s
1	17.8(9.24)	12.5(9.16)	0.81	4.6(1.77)	3.9(2.59)	0.46
2	8.4(8.55)	4.0(3.84)	2.12*	2.9(2.64)	1.6(1.34)	1.84
3	0.7(0.95)	0.3(0.29)	0.96	0.2(0.30)	0.1(0.10)	0.77*
4	1.2(0.21)	0.9(0.84)	0.41	0.2(0.08)	0.2(0.13)	0.87
Total	7.7(8.86)	7.0(8.26)	0.30	2.6(2.58)	1.6(1.79)	1.60

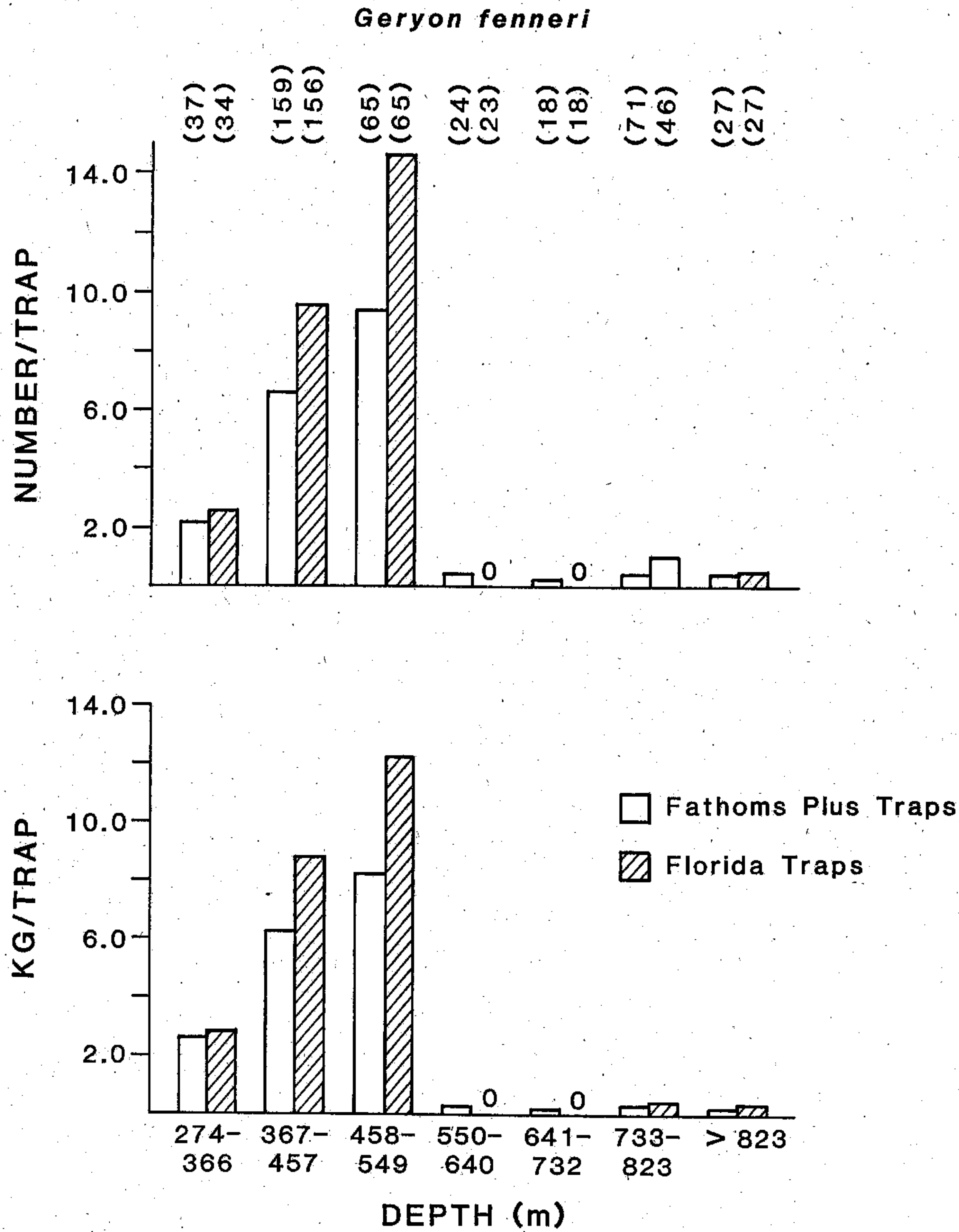

Figure 3. Comparison of catches of Geryon fenneri between two trap types for depth strata sampled in Years 1 and 2. Effort (number of traps) is shown in parentheses.

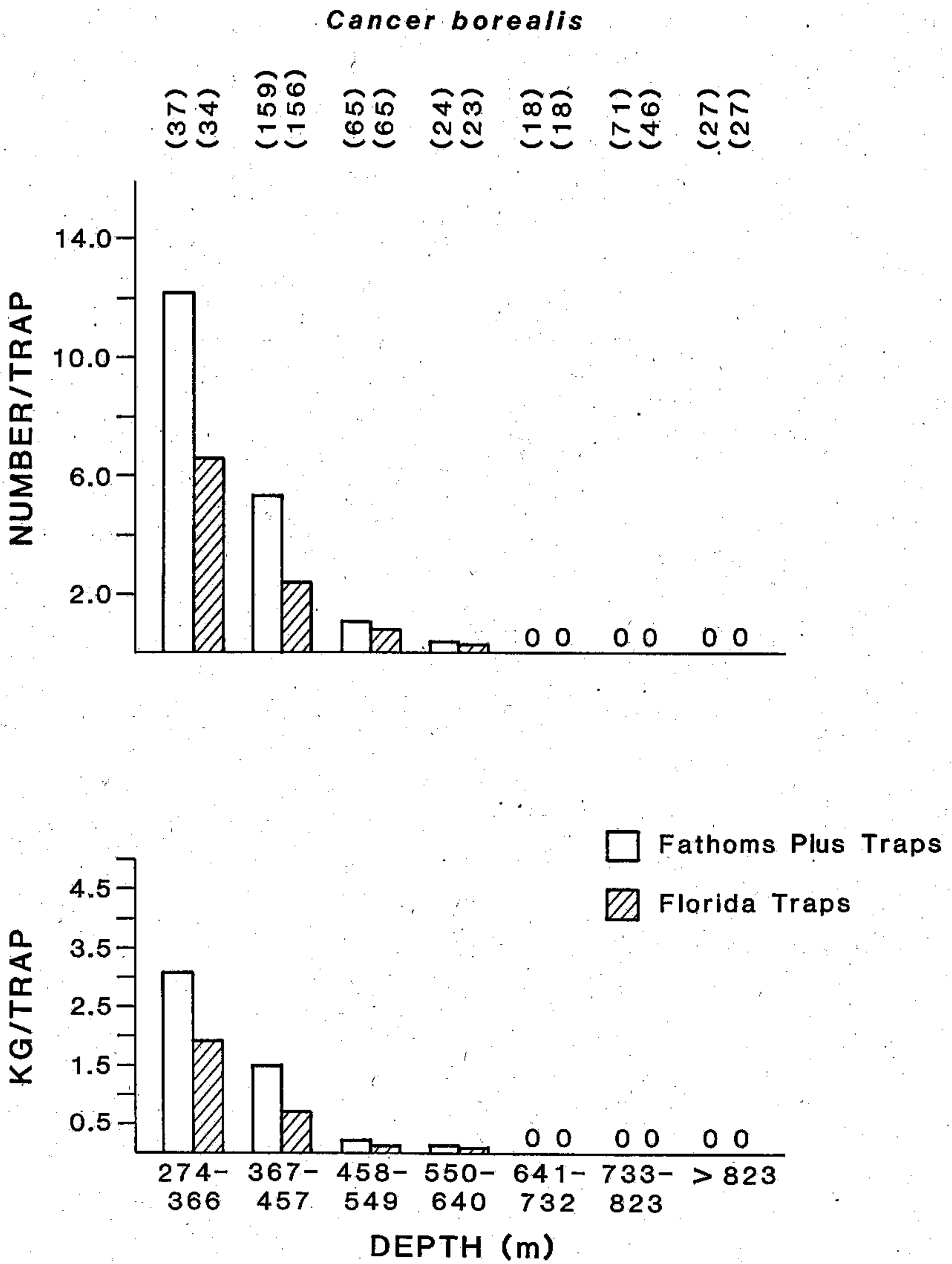

Figure 4. Comparison of catches of Cancer borealis between two trap types for depth strata sampled in Years 1 and 2. Effort (number of traps) is shown in parentheses.

Table 5. Number of golden crab, G. *fenneri*, and jonah crab, C. *borealis*, counted on transects.

Location	Depth (m)	Transect No.	No. of C. *borealis*	No. of G. *fenneri*	Total Area (m^2)
Area A, Site 1	495-497	1- 5	212	5	7100
Area A, Site 2	472-475	6-11	363	7	8500
Area A, Site 4	521-555	12-18	19	16	9900

mounds. At site 4, however, sediment and topography were more variable since transects were made near coral "mounds", some which possessed slopes of ~ 100 ft. Sediment near the base of the mounds consisted of silt-clay and molluscan fragments, whereas that on the crests consisted mostly of coral fragments.

At all sites, counts for Cancer borealis greatly exceeded those for golden crab. An additional 8 and 55 C. borealis were observed ventral side up at sites 1 and 2, respectively, suggesting that these were exuvia or dead crabs.

Both species of crabs were highly visible and were not partially or otherwise buried. Jonah crab was the most active of the two species, with individuals usually moving rapidly away from the approaching submersible. In contrast, golden crab seldom moved and appeared unaffected by the lights or turbulence caused by the submersible. No meral spread was observed for this species as reported by Wigley et al. (1975) for red crab, G quinquedens.

The density of golden crabs for the three sites surveyed ranged from 0.7/1000 m^2 to 1.6/1000 m^2 (Table 5). Density was highest for G. fenneri at site 3, whereas density of C. borealis was lowest there. Based on a total of 12 G. Fenneri and 575 C. borealis observed on 15,600 m^2 of bottom at sites 1 and 2, the in situ density would be 0.8 G. fenneri/1000 m^2 and 37 C. borealis/1000 m^2.

Observations made at six traps that had been deployed 1-3 hours earlier confirmed that crabs were attracted to the bait within a short time after settling on the bottom. Several crabs were already inside the traps while others (mainly C. borealis) approached and gathered around the base of the traps (Table 6).

Traps that had soaked for five hours yielded substantially more crabs than those that had soaked 1-3 hours. When retrieved, all traps contained G. fenneri (Table 7). Several C. borealis were observed around the base or in the

Table 6. Summary of observations at six traps for 1-3 h soak duration.

#	Trap Type	Observation Order	Number Approaches	Agonistic Encounter	Other	Escape	Catch Bottom	Catch Surface
6	Fm+	1	0	-----	Hetercarpus sp. & Ueophysis sp. w/in trap vicinity	-----	0	1 G. Fenneri
5	Fla	2	2 G. fenneri 1 C. borealis	-----	--------	-----	2 G. fenneri	4 G. fenneri
4	Fla	3	2 C. borealis	-----	--------	-----	1 G. fenneri	1 G. fenneri
3	Fm+	4	1 C. borealis	-----	--------	-----	0	0
2	Fm+	5	3 C. borealis	-----	--------	-----	1 G. fenneri	3 G. fenneri 1 C. borealis
1	Fla	6	1 C. borealis 1 G. fenneri	-----	--------	-----	0	2 G. fenneri

Table 7. Summary of observations at six traps after 5 h soak duration.

#	Trap Type	Observation Order	Number Approaches	Agonistic Encounter	Other	Escape	Catch Bottom	Catch Surface
6	Fla	1	3 _C._ _Borealis_	noted 2 _C. Borealis_ confronting each other at area around trap	Large six-gilled shark entered trap area & consumed several _C. borealis_	-----	3 _G._ fenneri	7 _G._ _Fenneri_
5	Fm+	2	2 _G._ _fenneri_ w/in vicinity of trap	-----	--------	-----	4 _G._ _fenneri_	5 _G._ _fenneri_ 3 _C._ _borealis_
4	Fm+	3	2 _C._ _borealis_	-----	Another (poss.the same) shark at this trap consuming _C. borealis_	-----	undeter. no. of _C._ _borealis_ present w/in the trap	5 _G._ _fenneri_ 2 _C._ _borealis_
3	Fla	4	0	-----	sharks (2) again seen w/in trap vicinity	-----	undeter. no.of crabs/none seen to enter	6 _G._ _fenneri_
2	Fla	5	0	-----	--------	-----	undeter.no. of crabs w/in trap/none seen to enter	1 _G._ _fenneri_ 2 _C._ _borealis_
1	Fm+	6	0	-----	One shark picked up & shook trap	-----	crabs in trap not counted/ none seen entering	9 _G._ _fenneri_ 4 _C._ _borealis_

vicinity of traps. Large six-gill sharks were observed to be actively preying on jonah crab that were approaching the traps.

Gear Saturation

Trap catches from gear saturation experiments did not yield enough G. fenneri to determine whether catch per trap was asymptotic with soak time. Correlation analysis from sets made in stratum 3 over the past year (includes sets listed in Appendix I, as well as those having short soak duration from experimental cruises) indicates a positive relationship ($r^2 = 0.91$) between catch per unit of effort and soak duration (Figure 5). This relationship is inconclusive, however, because data were from sets that were not made at the same time or location.

Comparisons of catches of C. borealis for fished (accumulated catch over 18 hour period) and not-fished (observed catch at each observation) traps suggested that saturation of the Florida trap may occur after 6 hours. For the two replicate sets, catches from not-fished Florida traps over the observation period were similar and appeared to be asymptotic after 6 hours (Figure 6). By contrast, CPUE of Florida traps from which crabs were removed (fished treatments) was nearly identical from 12 to 18 hours, and the cumulative catch of not-fished Florida traps was 20 crabs/trap at 18 hours. Chi-square analysis indicated that the catch ratio was significantly different for the two treatments at $\geq$12 h. For the Fathoms Plus trap, no significant difference in catch was observed for sets 1 or 2, although catches from the unfished traps in set 1 reached an asymptote at $\geq$6 hours. These limited data suggest that unfished traps may become saturated at <20 hours and, therefore, may catch only a small fraction of the crabs potentially available to the traps.

Over the 12 observations made on both sets of traps during the 18 h period, escapement of C. borealis was greater from the Fathoms Plus trap. A total of

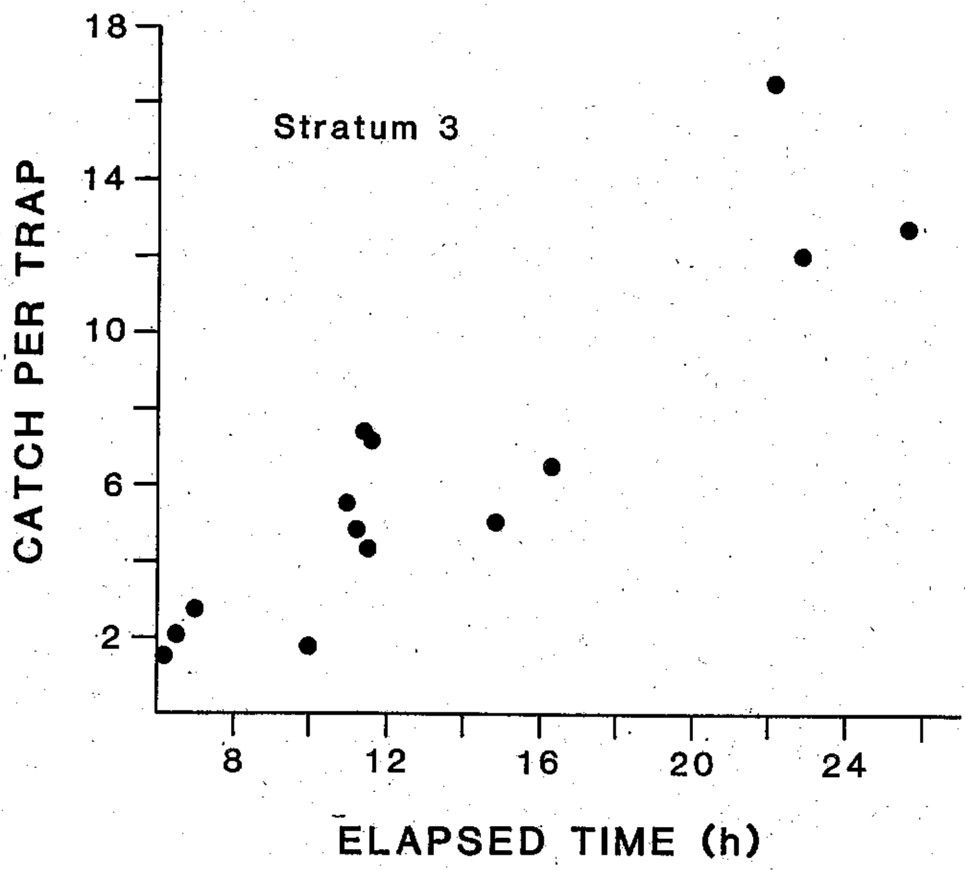

Figure 5. Relationship between catch per trap of golden crab and elapsed soak time for sets made in stratum 3 during Year II.

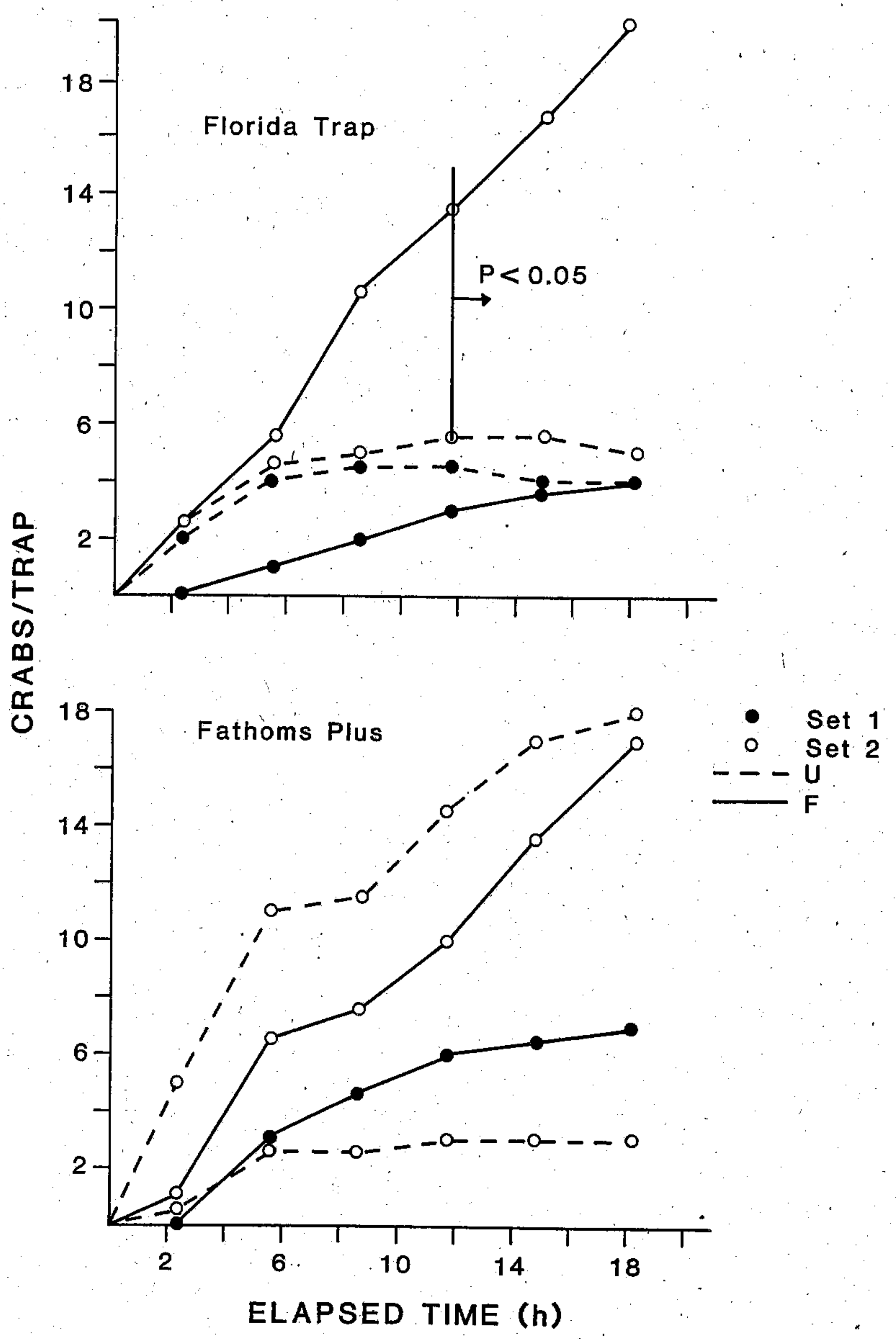

Figure 6. A comparison between catches of C. borealis from the Florida trap and Fathoms Plus trap using a fished strategy (F) in which crabs are removed at ~3 h intervals and a not-fished (U) treatment in which gear is allowed to fish for ~18 h.

13 jonah crabs escaped from this trap type, while 8 individuals escaped from the Florida trap. There was no apparent relationship between soak duration and escapement.

Size and Sex Composition

G. fenneri - Analysis of sex ratios by chi-square analysis indicated male golden crab were significantly more numerous than females, outnumbering them by 13:1 ($P<0.001$). Overwhelming dominance of male crabs was also noted in Year I. Of the 75 females collected, 19 were ovigerous. Dominance of males was statistically significant for strata 1-3 (Table 8). In strata 4, 6 and 7, females outnumbered males; but sex ratios for these strata were not significantly different from 1:1. No significant difference in the number of female crabs was found between the two trap types ($X^2 = 1.29$, $P>0.05$); however, significantly more males were collected by the Florida trap than the Fathoms Plus trap ($X^2 = 1.68$, $P<0.01$).

The 1153 golden crab that were measured in Year II ranged from 71 to 195 mm in carapace width and weighed from 91 g to 1876 g. The largest crab collected measured 195 mm and weighed 1765 g. Average weight of male golden crab collected was 840 g ($s = 391.3$, $n = 590$). Non-ovigerous females averaged 349 g ($s = 140.2$, $n = 70$), while average weight of ovigerous females was 503 g ($s = 161.6$, $n = 19$). Carapace width-frequency distributions showed a skewed distribution for male crabs with a modal group from 160-170 mm (Figure 7). Non-ovigerous and ovigerous females had modes at 115 mm and 135 mm, respectively.

Linear least-squares and functional regression equations (Ricker 1973; Sokal and Rohlf 1981) calculated for the relationships of carapace length and live wet body weight with width in ovigerous females are in Table 9.

Table 8. Frequency of male and female Geryon fenneri and Cancer borealis within each depth stratum. Number of females that were ovigerous is indicated. Asterisks denote significant deviation ($P<0.05$) of M:F from 1:1 by Chi-square analysis.

Sex	STRATA (M) 274-366	367-457	458-549	550-640	641-732	733-823	>823
G. fenneri							
Male	84*	642*	500*	2	---	16	10
Female	2	40	12	3	---	25	12
Ovigerous	0	1	1	0	---	12	5
C. borealis							
Male	334*	928*	112*	11*	---	---	---
Female	61	16	1	0	---	---	---

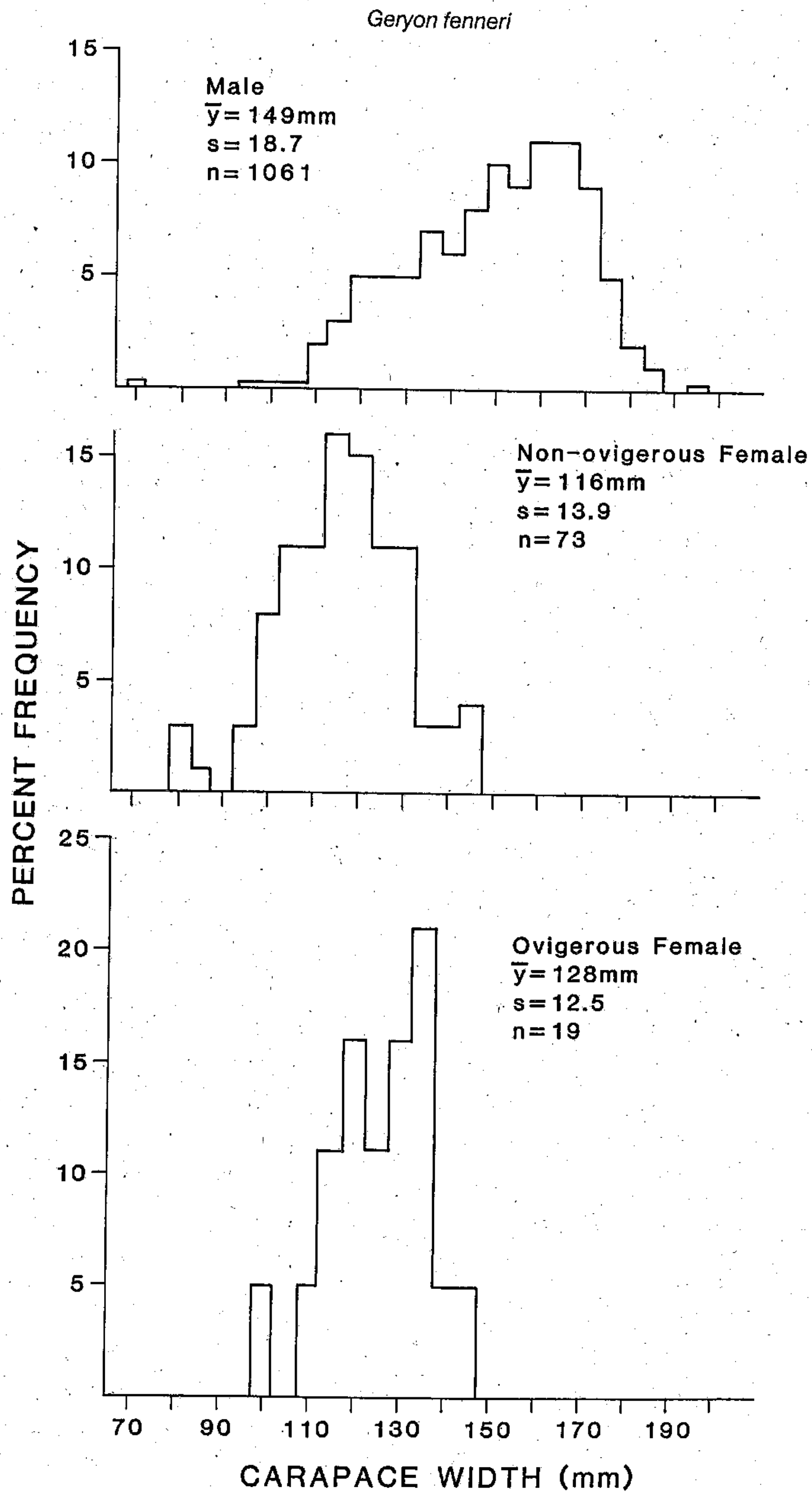

Figure 7. Width-frequency distributions of male, female and ovigerous G. fenneri caught with experimental traps.

Table 9. Least-square linear and geometric mean functional regression equations of carapace length (CL) and live body weight (WT) on carapace width (CW) for ovigerous female *Geryon fenneri*. Length and width units are millimeters while weight units are grams.

Least-square equation	n	r^2	GM functional equation
$CL = -3.52 + 0.83\ CW$	18	0.93	$CL = -7.71 + 0.86\ CW$
$\log_{10}WT = -4.13 + 3.23\ \log_{10}CW$	18	0.89	$\log_{10}WT = -4.53 + 3.42\ \log_{10}CW$

Width-weight relationships were calculated from data on individuals that were not missing appendages.

Of the 1237 golden crab examined for missing appendages, 2.7% were missing one or both chelae. Pereopods were missing from 155 individuals (12.5%). Most (78%) were missing only one pereopod.

Mean size of G. fenneri was variable between depth strata (Table 10). In strata 1-3 where abundance was greatest, analysis of variance showed a significant difference in mean carapace width (F = 26.8, $P<0.001$) and weight (F = 13.8, $P<0.001$) between strata. Mean carapace width ($\bar{y}$ = 156 mm) and weight ($\bar{y}$ = 1085.1 g) were significantly greater for crabs from stratum 1 than those from strata 2 or 3.

Mean carapace width of golden crabs from the Fathoms Plus traps ($\bar{y}$ = 148 mm, s = 20.3, n = 496) was not significantly different from mean width of crabs from the Florida trap ($\bar{y}$ = 146, s = 20.1, n = 660). No statistically significant difference was noted for mean weight either (Fathoms Plus: $\bar{y}$ = 870 g, s = 423.6, n = 290; Florida: $\bar{y}$ = 817 g, s = 398.7, n = 390).

C. borealis - A total of 1385 male jonah crab and 78 females were collected during the study. Sex ratios deviated significantly from 1:1 in strata 1-4 where C. borealis were collected (Table 8). A significantly greater number of male (X^2 = 114, $P<0.001$) and female (X^2 = 54, $P<0.001$) jonah crab were collected in the Fathoms Plus trap than in the Florida trap.

Male jonah crab which averaged 129 mm CW (s = 9.1, n = 338) were larger than females ($\bar{y}$ = 103 mm, s = 8.2, n = 76) and weighed more (male: $\bar{y}$ = 277 g, s = 73.9, n = 208; Female: $\bar{y}$ = 94 g, s = 42.2, n = 75). No jonah crab smaller than 87 mm was collected and maximum carapace width recorded was 155 mm. A

Table 10. Size and weight statistics of male, female and ovigerous female <u>Geryon fenneri</u> 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	157	115	184	14.8	84	1126	300.2	33
	367-457	152	95	195	17.1	595	953	379.3	348
	458-549	143	94	183	20.1	354	784	397.9	181
	550-640	86	71	101	21.2	2	148	79.9	2
	641-732	---	---	---	----	0	---	-----	0
	733-823	155	118	175	16.1	16	1022	328.9	16
	>823	148	117	170	17.5	10	905	314.2	10
Female	274-366	121	113	129	11.3	2	416	123.7	2
	367-457	115	97	135	9.2	37	325	101.9	34
	458-549	118	95	130	10.8	11	346	86.9	11
	550-640	89	80	102	11.5	3	147	52.8	3
	641-732	---	---	---	----	0	---	-----	0
	733-823	130	110	146	12.8	13	508	152.7	13
	>823	105	78	127	14.9	7	245	116.4	7
Ovig. Female	274-366	---	---	---	---	0	----	-----	0
	367-457	112	112	112	---	1	292	-----	1
	458-549	101	101	101	---	1	207	-----	1
	550-640	---	---	---	---	0	----	-----	0
	641-732	---	---	---	---	0	----	-----	0
	733-823	130	115	143	8.9	12	523	121.4	12
	>823	131	115	154	14.9	5	555	198.3	5

modal group of 130 mm was observed for male C. borealis, while the modal group for females was 105 mm (Figure 8).

Mean carapace width was similar for male C. borealis from strata 1-3. The average size and weight of crabs collected in stratum 4 was smaller than for other strata (Table 11). For the two strata in which females were captured, average size was smallest in Stratum 1.

Jonah crab collected in the Florida trap were larger ($\bar{y}$ = 128 mm, s = 10.3, n = 151) than those collected in the Fathoms Plus trap ($\bar{y}$ = 123 mm, s = 15.0, n = 265). Mean body weight was also greater in the Florida trap ($\bar{y}$ = 265 g, s = 79.1, n = 95) than in the Fathoms Plus trap ($\bar{y}$ = 211 g, s = 111.9, n = 188).

The relationship between carapace width and length for 61 female C. borealis was expressed by the following equations:

Linear: $CL = -4.23 + 0.67\ CW,\ r^2 = 0.76$

Functional: $CL = -14.55 + 0.78\ CW$

No predictive equation is presented for the relationship between logarithmically ($\log_{10}$) transformed variables of carapace width and body weight for female crabs not missing appendages because the coefficient of determination indicated that only 48% of the variation was explained by the regression.

Chelae were missing from 7% of the 624 C. borealis examined. Of this total, 108 individuals (17%) were missing 1-3 pereopods.

REPRODUCTIVE BIOLOGY

G. fenneri - Of the 94 female G. fenneri collected, 77 were dissected for determination of gonadal condition. Among non-ovigerous females, 21 of the 62 individuals examined had early stage ovaries (for a complete description of ovarian developmental stages, see Year I report). The carapace width of crabs in early ovarian development ranged from 78 to 128 mm ($\bar{y}$ = 108 mm), and most

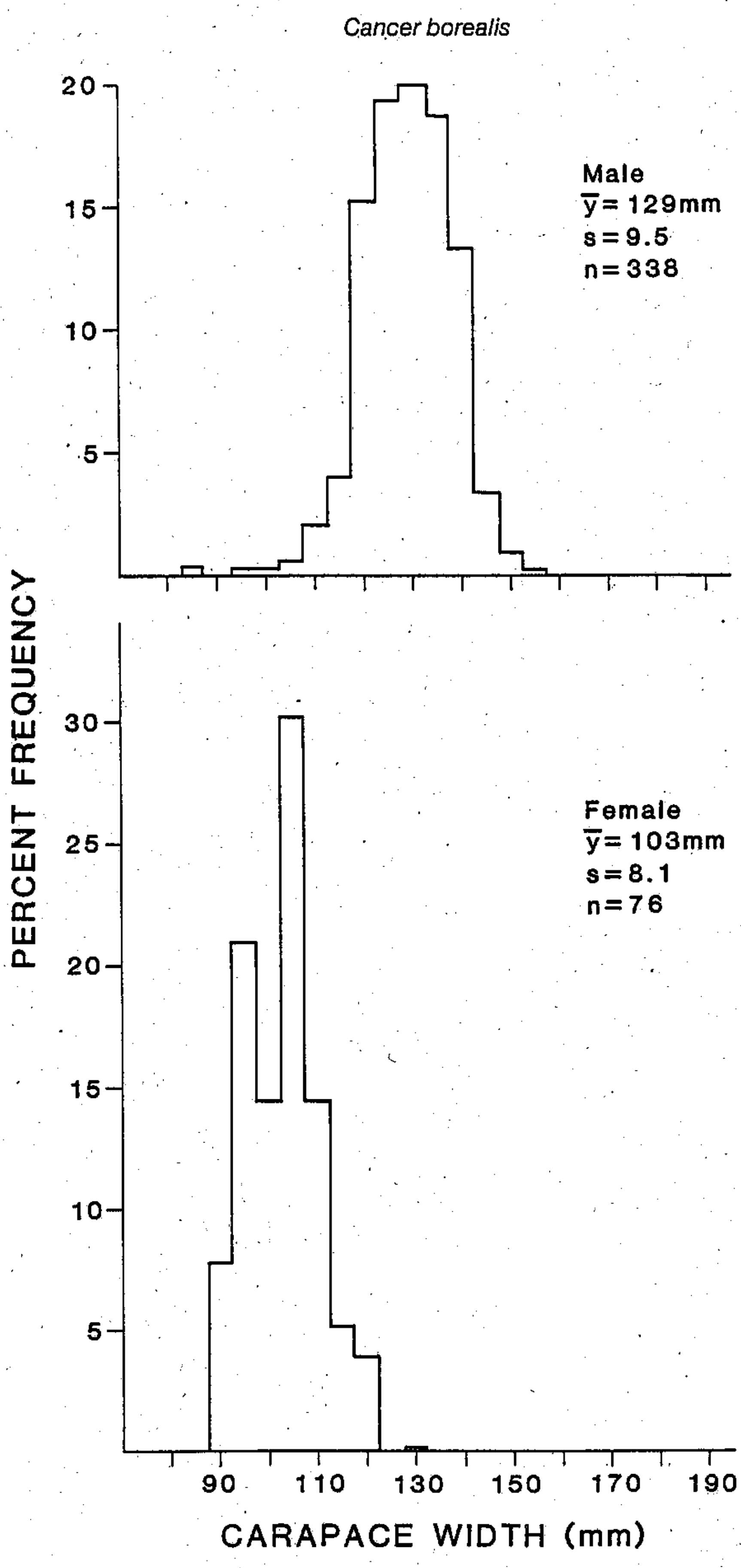

Figure 8. Width-frequency distributions of male and female *Cancer borealis* caught with experimental traps.

Table 11. Size and weight statistics of male and female Cancer borealis for depth strata where they occurred.

Sex	Stratum (m)	Carapace width (mm)					Weight (g)		
		Mean	Min.	Max.	s	n	Mean	s	n
Male	274-366	129	87	155	9.1	253	277	74.9	111
	367-457	130	111	145	9.8	59	287	67.8	58
	458-549	128	112	138	9.3	15	290	53.9	28
	550-640	120	97	150	14.7	11	198	97.7	11
Female	274-366	102	89	132	7.8	61	86	36.9	61
	367-457	109	99	121	43.8	15	127	49.1	14

(62%) had immature vulvae (types a and b) suggesting that these crabs had not mated (Table 12). Seminal receptacles taken from six individuals contained no sperm or spermatophores.

Intermediate stage ovaries were found in 14 non-ovigerous females measuring 107-130 mm CW ($\bar{y}$ = 121 mm). Only two individuals had no seminal products in the seminal receptacle and all, except one individual, had vulval types e or f indicative of past copulation (Table 12).

The advanced ovarian condition was found in 15 non-ovigerous females ranging from 101-146 mm CW ($\bar{y}$ = 122 mm). All had either type e or f vulvae (Table 12) and of those (n = 10) whose seminal receptacles were examined, seven had sperm or spermatophores present.

Individuals with mature gonads measured 110-141 mm CW ($\bar{y}$ = 127 mm CW, n = 12) and had either type e or f vulvae (Table 12). Seminal products were found in eight of the ten individuals whose seminal receptacles were sectioned for histological examination.

The 19 ovigerous _G. fenneri_ collected ranged in carapace width from 112-154 mm ($\bar{y}$ = 129 mm) and all had either type e or f vulvae indicative of previous copulation (Table 12). Of the nine seminal receptacles examined, all contained spermatophores. Most of the ovigerous females had redeveloping ovaries, as evidenced by presence of relatively large ova (150-500 μm) interspersed with numerous small ova (35-50 μm) and a large amount of connective tissue. All but two of the berried females carried late stage eggs, as denoted by their purple black color and presence of eyes. All ovigerous females were collected from May-August and 16 individuals were collected in August at depths from 796-833 m.

Estimated fecundity of 12 _G. fenneri_ ranged from 170,000-429,000 eggs (Table 13. Average diameter of preserved eggs was 570-608 μm. The regression

Table 12. Incidence of vulval type (after Haefner 1977a) in relation to carapace width and gonadal condition of non-ovigerous and ovigerous *Geryon fenneri*. n = number of individuals examined

Vulval Type	n	Carapace Width (mm)	n	Gonadal Condition
Non-Ovigerous				
a	14	78-114	6	early
b	7	99-111	7	early
c	3	104-115	2	early
			1	intermediate
e	25	104-146	4	early
			5	intermediate
			7	advanced
			6	mature
f	25	101-146	2	early
			8	intermediate
			8	advanced
			6	mature
Ovigerous				
e	2	115-124	1	intermediate (redeveloping)
			1	advanced
f	17	112-154	1	early (redeveloping)
			7	intermediate (redeveloping)
			2	advanced
			1	mature (redeveloping)

Table 13. Fecundity estimates and mean egg diameter for ovigerous *Geryon fenneri*.

Carapace Width (mm)	Body Weight (G)	Abdomen Weight (G)	$\bar{y}$ no. of eggs (x 10^3)	$\bar{y}$ egg diameter (μm)
115	357	58.620	175	600
128	503	71.152	184	608
132	520	94.038	348	585
137	621	103.332	297	595
121	436	69.008	261	570
134	602	70.531	199	577
137	556	79.130	212	572
121	451	74.817	238	588
137	652	108.927	368	573
170	353	59.007	170	573
132	556	111.276	357	600
154	887	154.333	429	586

relationships between number of eggs and carapace width, body weight, and abdomen weight are found in Table 14. All least-square regressions were significant at $\alpha = 0.05$.

C. borealis - Of the 78 female C. borealis collected, 47 were sacrificed for gross and histological examination of the ovaries. Seminal receptacles from 38 females were also examined histologically for presence of sperm. Most of the individuals examined had mature ovaries, indicative of imminent spawning (Table 15). While only two females had sperm plugs in the gonopore, 37 of the 38 seminal receptacles examined contained spermatophores.

MOLT CONDITION AND FOULING

Most (83%) of the 1239 G. fenneri examined were in the intermolt (hard) stage. Seventeen percent were classified as hard-old which is a premolt stage and only one individual was in post-molt condition (hard-new). All of the 623 C. borealis examined were in the intermolt stage of ecdysis.

Blackened abraded areas of the exoskeleton, indicative of damage by chitinolytic bacteria, were present on 99% of the 1240 G. fenneri examined.

DISCUSSION

Golden Crab

Results from this two-year study show that depths of maximum abundance occur between 367-549 m within the latitudinal extent of our study area. Sediment type at these depths is mainly a mixture of silt-clay and foraminiferan tests (globigerina ooze). In situ observations revealed that golden crab are not restricted to this sediment type, since they were observed on coral rubble at depths of 521-555 m. The difficulty in successfully

Table 14. Least-square linear and geometric mean functional regression equations of egg number on carapace width, body weight, and abdominal weight for ovigerous *Geryon fenneri*. Width units are millimeters while weight units are grams.

Least-squares equation	n	r^2	GM functional equation
Egg No. = 5921 CW - 503,814	12	0.51	Egg No. = 8314 CW - 816,482
Egg No. = 455 Body Wgt.+ 23,697	12	0.57	Egg No. = 605 Body Wgt- 57,536
Egg No. = 2921 Abd. Wgt.+ 13,238	12	0.86	Egg No. = 3155 Abd. Wgt- 7,369

Table 15. Ovarian condition and size statistics for female *Cancer borealis*.

Gonad Condition	Carapace Width min.	max.	$\bar{y}$	n
Slight	109	109	109	1
Advanced	91	110	101	6
Mature	89	132	105	40

recovering gear within the 458-549 m depth stratum where coral mounds ooccur limits the feasibility of commercial effort at these depths, however.

There is evidence which suggests that the depth of maximum abundance changes with latitude. Commercial efforts off southeastern Florida occur in a narrow and comparatively shallow depth zone of 118-128 fathoms (W. Lindberg, 1987, pers. comm.), whereas in our study area at these depths, catches are dominated by jonah crab, *Cancer borealis*. In the Gulf of Mexico, golden crab occur in greatest numbers at depths of 210-350 fm (W. Lindberg, 1987, pers. comm.) which is comparable to our results. The abundance of golden crab at shallower depths off southeastern Florida is somewhat anomalous and needs further study to ascertain the physical and biological factors affecting bathymetric distribution of golden crab there.

Although catch per trap of golden crab from our survey compares favorably with catch rates reported by Otwell et al. (1984) in the Gulf of Mexico, our study area may be approaching the northern limit of the geographic range of golden crab. Exploration off Onslow Bay as part of the South Atlantic SEAMAP effort produced only two golden crab in sets made at 145-243 fms (Wenner and Beatty 1987). The most abundant species collected were *C. borealis* and *C. irroratus*, the latter occurring only from depths <177 fms. Red crab, *G. quinquedens*, apparently replaces *G. fenneri* as the dominant species further north (Haefner and Musick 1974; Wigley et al. 1975).

The density of golden crabs calculated from *in situ* counts along transects was surprisingly low (0.8 crabs/1000 m^2). Using photographic methods to estimate density, Wigley et al. (1975) calculated that red crab densities could be as high as 258-282/ha in 320-640 m depths off southern New England. They estimated 182 million red crab inhabit the entire study area from Maryland to Corsair Canyon off Georges Bank at depths from 229-1646 m. Although our density estimate was based on limited data, we think it does suggest that golden crab stocks may be substantially less than those of red crab and that some caution in commercially exploiting the species is advisable. Furthermore, using our density value (0.8 crabs/1000 m^2) and an average catch of 2.9 crabs/trap for the sites fished near transect locations, an effective fishing area (EFA) of 3625 m^2/trap is calculated using Miller's (1975) equation. This value is fairly similar to the EFA of 2922.5 m^2/trap which was used to estimate the population size of G. fenneri for the study area sampled in Year I. Those estimates were based on the assumption of McElman and Elner (1982) that each trap fished a circular area with radius of half the distance between adjacent traps. [In situ observations on deployed traps indicated that this is not the usual situation since traps generally settled much closer together than their maximum possible distance on the groundline and may, therefore, be competing.] Although the effective area fished per trap is limited in terms of accuracy and precision (Miller 1975) and will vary with trap fishing time (Rothschild et al. 1970), trap design (Watson and Simpson 1969), seasonality and area fished (Miller 1975), this value can be used to make a crude estimate of the size of the golden crab resource for the 367–549 m depth strata within our study area (Table 16). The density of crabs was calculated using Miller's (1975) equation:

$$\text{crab density} = \frac{\text{crabs/trap}}{3625\ \text{m}^2/\text{trap}} \times \frac{10^6\ \text{m}^2}{\text{km}^2}$$

Values obtained from this expansion were much lower than the highest density estimate (22,400/km^2 for a 37.34 km^2 area in 360–540 m) suggested for G. quinquedens on the Scotian shelf (Stone and Bailey 1980). The total estimated population size (1.7 x 10^6 crabs) for the estimated 822 km^2 area encompassed by strata 2 and 3 is comparable, however, to values on the trapable

Table 16. Estimation of number of golden crab at depths between 367-549.

Depth (m)	No. Traps	Approx Area (km^2)	Catch Crab/Trap	Density Crabs/km^2	No. Crabs in Depth Zone
367-457	124	411.14	5.8	1600	657,824
458-549	36	411.14	10.0	2759	1,134,335

* Estimate assumes an average width of each strata of 3.70 km and length of sampled area of 111.12 km.

7.4 Km

60200 - 60900 - 70 nm
60900 - CC - 160 nm
230 nm = 426 Km

$426 \times 7.4 = 3152.4\ Km^2$

$\frac{7.9 \text{ crabs/trap}}{.0003625} \times 3152.4 = 6,870,058$ crabs   20:1 ♂:♀

6,526,555 crabs

$\bar{X}$ wt ≈ .895 Kg

$B_o = 5,841,267$ Kg

$MSY = \frac{1}{2} m B_o$

MSY = 438,095 Kg = 963,809 #s

number of crabs (3.8×10^6 for a 2186 km^2 between 183-732 m) estimated by McElman and Elner (1982).

The comparison of catches (no./trap) between the two trap types over the two-year study indicated that the Florida trap caught more golden crab than the Fathoms Plus trap in strata 2 and 3 where abundance was greatest. Mean size and weight differences of individuals caught in the two traps were not noted for Year II data, however. Observations of traps in situ were limited and unfortunately did not provide much insight into the apparent differences in trap performance. Both G. fenneri and C. borealis were attracted to the traps within 1.5 h after deployment; however, more C. borealis were observed approaching the traps than were actually caught. Five hours after deployment, however, the number of C. borealis captured had increased and most were from the Fathoms Plus traps. Although inconclusive, these data suggest that golden crab have no difficulty entering either trap, whereas C. borealis may have difficulty scaling the vertical sides of the Florida trap. The ability to carry more Fathoms Plus traps because of its nesting configuration may outweigh the disadvantage of lower catch per trap, however.

Soak duration and trap saturation are factors which still need to be evaluated. Our attempts at determining the relationship between these factors were less than satisfactory for golden crab. Data gleaned on Cancer borealis suggest that the commercial strategy of leaving gear for a 24-h period may catch only a fraction of the crabs potentially available to the traps. Furthermore, in three of the four unfished treatments, catch per trap was asymptotic with soak, appearing to level off after ~6 hr. Catches of Geryon, however, may increase with soak duration (Figure 6) but experiments that examine catch rates over time within one area will be necessary before any conclusions can be reached.

The dominance of male crabs for strata 1-3 suggests a segregation of the sexes with depth. Most of the females collected during the two-year study were taken in deeper strata. Because seasonal cruises were not undertaken, there are no data to support seasonal migrations as have been suggested for G. quinquedens (Wigley et al. 1975). Information taken from commercially caught golden crab in the eastern Gulf of Mexico also suggests that crabs may segregate by depth and come together during the mating season which occurs in March and April (Hinsch, unpublished ms.). The deeper occurrence of females in the South Atlantic Bight will likely preserve the spawning stock, while males will be targeted by commercial efforts in shallower, more accessible areas.

As with the first year study, the small number of females collected precludes any definitive statements regarding ovarian cycles or spawning patterns. Based on our interpretations of ovarian development, vulval condition and presence of seminal products, it appears that female G. fenneri reach sexual maturity at sizes between 90-110 mm CW. This agrees with findings of Hinsch (unpublished ms.) who found mature G. fenneri ranged from 94-144 mm in the eastern Gulf of Mexico.

Although ovigerous G. fenneri were collected only from May-August, these data do not substantiate a spawning season in the South Atlantic Bight because we were unable to obtain seasonal coverage of all depth strata. These data do, however, agree fairly well with observations by Hinsch (unpublished ms.) that G fenneri from the eastern Gulf of Mexico are ovigerous during September-October. The red crab, G. quinquedens, appears to be ovigerous over much of the year, with greatest incidence of spawning in November (Haefner 1977a).

The size composition of golden crab from our study clearly indicates that the average size of golden crab exceeds that reported for red crab along the eastern U.S. and Canada. Over 90% of the 4370 individuals measured during the two-year study exceeded the minimum size of 114 mm CW that is acceptable for commercial utilization of red crab (Wigley et al. 1975). Based on growth data for G. quinquedens, entry to the red crab fishery (114 mm CW) occurs at 5.3 yr. of age for 15 C or 6.0 yr. at 9-12 C (Van Heukelem et al. 1981). Although we did not determine growth rates of G. fenneri, it is highly likely that molting frequency is low and that the species is slow-growing. As a result, the sustained exploitation of old male crabs could exert a considerable mortality on market-size crabs.

Jonah Crab

The jonah crab which constitutes a by-catch of the lobster fishery along the Maine coast (Krouse 1980) is an unexploited resource in the South Atlantic Bight. Greatest catches (16 crabs per trap) occur at 274-366 m, and density estimates of 37 crabs/1000 m^2 from in situ counts at 472-555 m are much higher than for G. fenneri. Since depths <274 m were not sampled during our two-year effort, abundance at shoaler depths can only be inferred from data in the Middle Atlantic Bight. Haefner (1977b) found abundance was highest at 151-338 m in the a trawl survey of the Norfolk Canyon and adjacent continental shelf and slope. Carpenter (1978) reported low abundance at depths <150 m from the same area. Maximum abundance in this study occurred between 250-350 m. These results are consistent with our observations on bathymetric distribution and abundance.

As found during the first year of sampling, male C. borealis dominated the catch in all strata. Unequal sex ratios have been noted for C. borealis along the Maine coast (Krouse 1980) and in the Norfolk Canyon and adjacent slope (Carpenter 1978). The tendency for increasing number of females with decreasing depth in our study area supports similar observations by Carpenter (1978) of increased female abundance at depths <150 m. Whether an inshore migration to spawn occurs in the South Atlantic Bight, as has been suggested for populations near Boothbay Harbor, Maine (Krouse 1980) and those from the Norfolk Canyon area (Carpenter 1978), remains to be determined.

The size of C. borealis did not change appreciably between depth strata, as has been reported for jonah crabs from other areas. Haefner (1977) and Carpenter (1978) reported that smaller crabs (30-40 mm) were most abundant in depths <150 m, while the maximum abundance of larger crabs (>40 mm) occurred in 150-400 m. The smallest C. borealis collected in our study was 85 mm. The traps used were probably biased for capture of larger individuals so that any size-depth trends would be difficult to detect.

In areas where jonah crab are fished, sale of claws are used to offset operational costs (Krouse 1980). In New York's marine waters, however, most lobster fishermen avoid concentrations of jonah crab and, with few exceptions, discard the crabs they catch (Briggs and Mushacke 1982). In the period from 1975-1979, a processor handled 129 metric tons of jonah crabs a year but since suspension of his operation the reported landings have fallen to 10 metric tons (Briggs and Mushacke 1980). Although palatable and of good texture, the major criticism of jonah crab as a product lies in the difficulty of cracking the claws and removing the meat. Since there is currently no market for jonah crab in the South Atlantic Bight, avoidance of shallower strata should maximize catches of golden crab relative to those of jonah crab in commercial operations.

COMMERCIAL DEVELOPMENT ACTIVITIES

One of the objectives of this study was to assess the commercial development potential of the Geryon resource off South Carolina and Georgia and to provide current information on catch rates, gear, and abundance by area to commercial fishermen interested in diversifying their fishing operations. The Seafood Marketing Services Section of SCWMRD has also been involved in identifying potential markets for golden crabs. There has been a strong commitment throughout the two years of this study to foster commercial development of the resource at an appropriate level.

When the commercial fishing operation that was initiated early in the first year of this study failed, there was a considerable reduction in interest among local fishermen who were considering entering the fishery. The primary reason for the business failure was not crab availability since the vessel demonstrated consistent ability to catch in excess of 4000 pounds per trip. Insufficient operating capital and lack of suitable marketing outlets were the major problems encountered. The Seafood Marketing Services Section of SCWMRD advised the company to start on a small scale, concentrating on consistently supplying local markets until the extent of the resource could be better defined. An attempt at developing a large scale regional market for picked meat put the operation into direct competition with established crab products and businesses and proved to be unsuccessful. No commercial effort occurred during the remainder of the first project year and throughout most of Year II.

In order to assess the economic potential of this fishery, a projected income statement was developed by Raymond J. Rhodes, SCWMRD Industry Economist as part of his Marine Business Assistance Project for Clemson/Sea Grant Marine Extension Service (Table 17). The operating expenses and catch rates used in this projection were those generated from the previously described,

Table 17. Projected Income Statement for a Hypothetical Golden Crab Commercial Fishing Operation based in South Carolina, 1987-91. Data Source: Division of Marine Resources, S.C. Wildl. & Mar. Res. Dept., Charleston, S.C. Prepared by: Ray Rhodes, DMR Industry Economist for the Clemson/Sea Grant Marine Extension Program, Charelston, S.C., Nov., 1986.

	1987	1988	1989	1990	1991
Assumptions:					
Average Catch (Live Pounds)/Trap/Day:	15				
Traps Used per Trip:	200				
Fishing Days per Trip:	3				
Total Trap Days per Trip:	600				
Total Catch per Trip:	9,000				
Total Trips per year:	30				
Replacement Traps/Year:	100				
Exvessel Price per live pound:	$0.700				
(In Thousnads) YEARS PROJECTED:	1987	1988	1989	1990	1991
Gross Sales and poundage:					
Total Catch (Pounds) Per Year:	270.0				
Total Gross Sales per Year:	$189.0				
Annual Operating Expenses (In Thousands):					
1. Fuel, 150 g/day @ 0.55/g	$ 49.5				
2. Ice, 30 bk/trip @ 7.75/bk	7.0				
3. Bait, 2500 lb/trip @ 0.24/lb	18.0				
4. Groceries, gloves, etc.	4.5				
5. Oil 5.0 g/trip @ 26.0/5-gallon	0.8				
Crew Share: 35% after exp. above	38.2				
Traps, 200 Traps @ $40 per trap	8.0				
Misc. Fishing Gear (e.g. flyers, etc.)	1.0				
Vessel and Gear Maintenance	5.0				
Total Operating Expenses:	$132.0				
Depreciation:	$ 1.4				
Total Annual Expenses:	$133.4				
Net Income (Loss) Before Taxes:	$ 55.6				
Estimated Income Taxes @ 32.0%	17.8				
Net Income (Loss) After Taxes:	$ 37.8				

Depreciation Schedule		1987	1988	1989	1990	1991
Vessell and Gear Depreciation:						
Vessel	0					
Engine	0					
Electronics	0					
Hydraulic Reel System	$4,900					
3.16" Cable @ 0.10/ft.:	4,500					
5-Year ACRS Percent:		15.0%	22.0%	21.0%	21.0%	21.0%
Total Depreciation:		$1,410	$2,068	$1,974	$1,974	$1,974

unsuccessful commercial operations. A live-weight price of $0.70/lb. is assumed. Although each fishing operation is different in terms of operating expenses and catch rates and crab prices may fluctuate substantially, this example illustrates that given what we feel are conservative inputs, a net income of $37.8 thousand dollars can be generated. This hypothetical case may be useful to an individual in deciding whether to begin fishing for golden crabs or if other alternative fisheries would prove to be more profitable.

Recent Commercial Development - In May 1987 an offshore, lobster fisherman from the Northeast, contacted the principal investigators to discuss the potential for establishing a Charleston-based, commercial venture on golden crabs. The background of the previous commercial venture on golden crabs and the problems associated with this type of fishery (i.e., strong currents on the fishing grounds and the importance of establishing local markets, particularly during the initial stages of a fishery) were discussed. The fisherman was reasonably confident that these problems could be surmounted and in June moved his vessel to Charleston and began fishing.

The gear presently used are offshore lobster traps (wooden or wire) fished in 50 trap "trawls" attached to 5/8 inch polypropylene ground line. Spacing between traps is about 240 ft. Four 50-trap trawls are being used. Traps are allowed to fish between trips with resulting bottom time of 6-7 days on some sets and as little as 24 hours on those set and pulled during a trip. No problems have been experienced with the gear dragging across the bottom when affected by strong surface currents on the buoy line. The major problem encountered has been the surface current pulling the buoys under water, resulting in considerable time being spent on grappling for the buoy lines. Refinements in the buoying technique need to be made to increase effective fishing time on each trip.

Crabs are held in an ice-chilled hold, and survival rates at unloading have been less than anticipated. Better handling methods are being worked on to insure maximum survival rates for live marketing of the crabs. The present marketing strategy is to market as many crabs as possible alive. On-board butchering and cooking is a labor intensive process and adequate cooking facilities are not presently available on the boat. Installation of such equipment would represent a considerable capital investment and the uncertainties of resource sustainability and market stability preclude making this expenditure at present. Negotiations with a local crab company to butcher, cook and freeze golden crab clusters for sale to restaurants unequipped or unwilling to market live crabs are currently underway.

A marketing arrangement has been developed with a local seafood company specializing in sale of live lobsters to restaurants and seafood markets. This company uses holding tanks with recirculating water for live lobsters and found that it works well for golden crabs. Survival of crabs that appeared healthy when unloaded from the vessel has been good in the holding facility and in live tanks at restaurants. This company has been actively promoting golden crabs in their market accounts and have met with considerable interest and good consumer response. In addition, we have supplied two local restaurants with crab so that they could determine yield and meat quality. They achieved a yield of 15% and felt that the quality of picked meat was superior. The success of the marketing effort is not assured but indications are favorable for further market development.

Insuring a consistent supply of crabs sufficient to maintain restaurant and consumer interest may become a problem during the winter months when storm fronts make fishing difficult and sporadic. We are encouraged by the present developments in commercial utilization of this resource and believe that the cautious approach being taken in expansion is appropriate to what is presently known about the magnitude of the resource. We envision a relatively small scale fishery becoming established, targeting local specialty markets such as gourmet restaurants and retail purveyors of high quality fresh seafood. Major expansion and entry of a large number of boats into the fishery with the objective of making golden crab a mass market substitute for snow crab could very likely result in rapid reductions of fishable stocks to levels at which it would no longer be economically feasible to harvest them. This fishery needs to be monitored closely for signs of significant declines in catch rates and reduced average size of crabs. If it were possible under the Management Council framework, it would be beneficial to issue a limited number of permits for this fishery in its initial development. As more information became available on the extent of fishing grounds and sustainability of harvests on known grounds, the number of permits could be adjusted up or down as necessary.

Potential entrants to this fishery should do so with the awareness that the known grounds supporting fishable concentrations of these crabs are not extensive and initial estimates of crab density from submersible observations are lower than we had anticipated. Additionally, without a management framework to limit effort any evidence of profitability would probably result in a rapid influx of new boats into the fishery and subsequent stock declines as occurred with the tilefish resources off South Carolina and Georgia.

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Appendix I. Depth, location, soak time, fishing effort and catch per trap for each valid set during Year II.

Set No.	Date 1986	Position	Depth (m)	Stratum	Soak Time	No. Traps FM+	No. Traps FLA	Geryon Number FM+	Geryon Number FLA	Geryon Weight FM+	Geryon Weight FLA	Cancer Number FM+	Cancer Number FLA	Cancer Weight FM+	Cancer Weight FLA
83	05/19	31°25.2'/79°32.4'	415	2	22.5	3	3	38	42	39.000	44.000	6	4	1.524	1.077
84	05/19	31°25.8'/79°32.5'	360	1	20.6	3	3	17	26	21.081	32.000	25	23	6.921	6.933
86	05/19	31°23.2'/79°33.6'	293	1	22.1	3	3	7	8	10.148	9.286	61	78	19.000	22.889
87	05/19	31°26.6'/79°32.2'	329	1	23.8	3	3	14	13	16.764	17.257	39	18	12.885	5.918
88	05/19	31°28.0'/79°33.1'	375	2	25.0	3	3	21	21	23.500	21.501	5	2	1.317	.471
89	05/20	31°33.2'/79°26.9'	384	2	23.7	3	3	28	20	33.500	24.506	19	2	6.302	.599
90	05/20	31°30.6'/79°28.4'	448	2	21.8	3	3	17	35	19.760	36.000	3	1	.737	.232
91	05/20	31°32.2'/79°27.4'	417	2	23.7	3	3	27	29	27.941	35.000	8	2	2.350	.546
92	05/21	31°31.8'/79°27.1'	510	3	22.3	3	3	42	57	34.000	38.500	–	–	–	–
93	05/21	31°33.5'/79°25.3'	481	3	25.7	3	3	23	53	22.500	43.500	–	2	–	.425
94	06/16	32°21.4'/76°59.4'	810	6	20.2	3	3	4*	2*	2.140	.989	–	–	–	–
95	06/16	32°20.8'/76°58.4'	823	6	20.6	3	3	12*	13*	7.473	8.624	–	–	–	–
96	06/18	32°43.1'/77°05.3'	551	4	18.6	3	2	1	–	.207	–	3	3	.558	.506
97	06/18	32°42.5'/77°04.5'	567	4	19.6	3	3	4	–	.528	–	4	1	.919	.191
103	06/25	31°32.6'/79°26.3'	490	3	22.9	3	3	24	48	21.000	52.000	–	1	–	not avail
104	06/25	31°34.1'/79°25.3'	451	2	23.8	3	3	38	50	37.000	44.000	–	1	–	not avail
105	06/25	31°35.7'/79°24.4'	427	2	24.8	3	3	40	31	39.500	36.500	17	9	6.000	4.500
106	06/25	31°37.9'/79°22.6'	437	2	20.2	3	3	14	17	19.500	23.500	25	23	7.800	6.750
107	06/25	31°39.5'/79°21.8'	385	2	20.8	3	3	1	6	1.579	7.582	89	21	25.500	7.250
108	06/25	31°40.9'/79°21.5'	315	1	21.5	4	2	1	–	1.240	–	118	21	22.500	7.500
109	07/07	32°07.8'/78°57.1'	401	2	20.5	3	3	2	1	1.839	1.283	56	20	14.500	7.000
110	07/07	32°08.6'/78°56.0'	419	2	21.7	3	3	5	5	5.905	4.176	79	18	24.800	7.300
111	07/07	32°09.6'/78°54.9'	418	2	22.6	3	3	9	18	6.887	15.890	22	35	7.200	12.500
112	07/08	32°05.1'/78°59.7'	403	2	21.1	3	3	5	6	5.483	5.949	49	31	15.200	9.500
113	07/08	32°05.9'/78°58.8'	412	2	23.2	3	2	5	4	5.276	4.711	32	5	11.000	2.000
114	07/08	32°07.2'/78°57.3'	418	2	21.4	3	3	3	14	3.902	15.840	51	34	15.600	11.300
115	07/08	31°59.5'/79°03.0'	430	2	17.7	3	3	18	19	16.34	18.994	6	–	2.000	–
116	07/08	32°00.3'/79°01.9'	430	2	18.9	3	3	8	15	9.386	13.790	21	14	5.800	15.000
117	07/08	32°00.6'/79°00.6'	436	2	20.2	3	3	9	8	9.000	9.500	3	15	1.100	4.600
118	07/22	32°29.8'/76°46.2'	868	7	19.7	3	3	–	–	–	–	–	–	–	–
119	07/22	32°31.0'/76°44.4'	884	7	21.1	3	3	–	–	–	–	–	–	–	–
120	07/22	32°32.8'/76°42.0'	898	7	21.9	3	3	–	–	–	–	–	–	–	–
121	07/22	32°31.8'/76°49.5'	805	6	22.2	3	3	–	–	–	–	–	–	–	–
122	07/22	32°33.3'/76°46.8'	821	6	20.4	3	3	–	–	–	–	–	–	–	–
123	07/23	32°35.2'/76°52.1'	742	6	18.8	3	3	–	–	–	–	–	–	–	–
124	07/23	32°36.9'/76°50.0'	747	6	19.6	3	3	–	–	–	–	–	–	–	–
125	07/23	32°38.6'/76°47.7'	754	6	20.4	3	3	–	–	–	–	–	–	–	–
126	07/23	32°36.3'/76°54.6'	711	5	18.7	3	3	–	–	–	–	–	–	–	–
127	07/23	32°37.9'/76°52.5'	718	5	19.8	3	3	–	–	–	–	–	–	–	–
128	08/07	30°29.8'/77°39.9'	808	6	19.4	3	3	2	1	.874	.379	–	–	–	–
129	08/07	30°31.5'/77°39.5'	812	6	20.1	3	3	–	3	–	1.750	–	–	–	–
130	08/07	30°33.3'/77°39.1'	821	6	20.6	3	2	1	–	.653	–	–	–	–	–
131	08/07	30°29.4'/77°46.4'	796	6	21.2	3	3	3	4	2.730	3.460	–	–	–	–
132	08/07	30°31.2'/77°46.2'	799	6	22.3	3	3	2	3	1.626	1.394	–	–	–	–
133	08/07	30°33.9'/77°45.9'	805	6	22.5	3	3	3	2	2.357	2.099	–	–	–	–

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Appendix I. Continued:

Set No.	Date 1986	Position	Depth (m)	Stratum	Soak Time	No. Traps FM+	No. Traps FLA	Geryon Number FM+	Geryon Number FLA	Geryon Weight FM+	Geryon Weight FLA	Cancer Number FM+	Cancer Number FLA	Cancer Weight FM+	Cancer Weight FLA
134	08/08	30°23.0'/77°31.3'	828	7	19.7	3	3	4	3	2.180	1.730	–	–	–	–
135	08/08	30°24.7'/77°31.2'	828	7	20.4	3	3	1	0	1.046	–	–	–	–	–
136	08/08	30°26.4'/77°31.2'	833	7	21.1	3	3	4	7	2.254	3.825	–	–	–	–
137	08/08	30°23.9'/77°26.5'	855	7	18.5	3	3	0	1	–	1.270	–	–	–	–
138	08/08	30°25.3'/77°26.5'	859	7	18.2	3	3	1	1	.355	.885	–	–	–	–
139	08/08	30°26.9'/77°26.9'	864	7	18.8	3	3	0	0	–	–	–	–	–	–
140	08/09	30°20.4'/77°39.4'	808	6	19.3	2	2	1	0	.769	–	–	–	–	–
141	08/09	30°22.1'/77°39.1'	806	6	19.8	3	3	1	5	.469	3.357	–	–	–	–
142	08/09	30°23.8'/77°39.0'	806	6	20.5	3	3	3	7	2.150	5.168	–	–	–	–
143	08/11	31°49.0'/79°11.9'	490	3	11.5	3	3	15	28	16.800	33.600	2	2	.579	.601
144	08/11	31°50.1'/79°11.0'	493	3	11.6	3	3	12	31	12.800	34.200	7	0	1.929	–
145	08/11	31°51.2'/79°10.1'	486	3	11.2	3	3	8	20	11.700	25.700	4	1	–	–
146	08/11	31°49.5'/79°12.4'	401	2	10.2	2	3	10	15	11.600	17.500	2	5	–	–
147	08/11	31°50.5'/79°11.6'	428	2	11.2	3	3	17	25	20.300	29.200	23	5	–	–
148	08/11	31°51.7'/79°10.8'	432	2	11.9	4	2	17	7	22.200	7.800	12	2	–	–

* Numbers are for Geryon quinquedens.

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