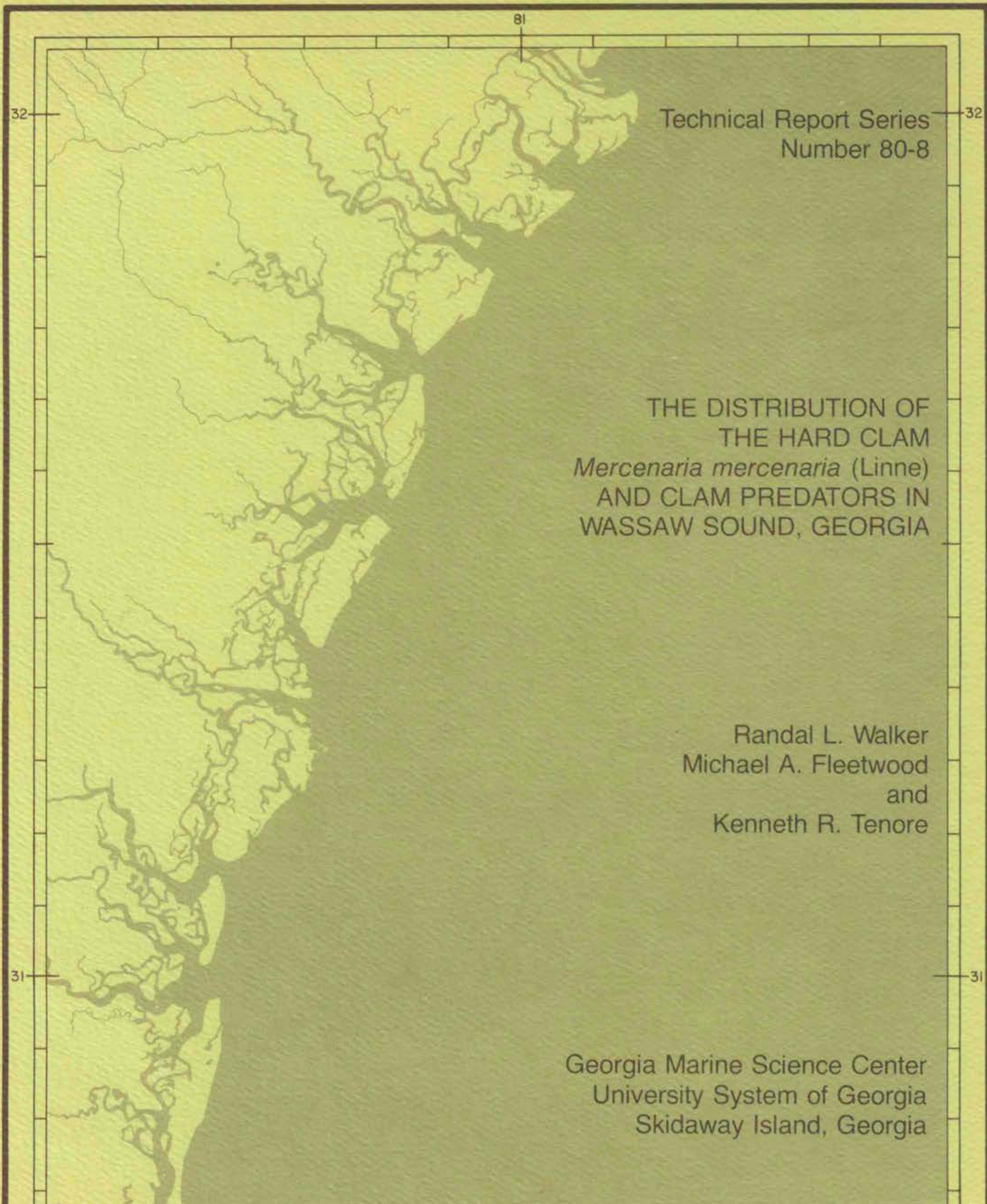

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THE DISTRIBUTION OF THE HARD CLAM *Mercenaria mercenaria* (Linne) AND CLAM PREDATORS IN WASSAW SOUND, GEORGIA

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ABSTRACT

In Wassaw Sound, Georgia, the hard clam *Mercenaria mercenaria* occurred in four habitats at different densitites: live oyster bars ($\bar{X} < 1$ clam/m^2); shell deposits associated with oyster bars ($\bar{X}$ 23 clams/m^2); headwaters of sandy-mud, sand, and mud bottom creeks ($\bar{X}$ 16, 12, 3 clams/m^2, respectively); and small feeder creeks ($\bar{X}$ 36 clams/m^2). In all habitats, clams were most abundant in intertidal areas.

Juvenile clams were noticeably absent from all habitats, possibly due to abnormally low salinities which occurred in spring of 1977 through 1979 or heavy predation.

Clams from creek bottoms were larger ($\bar{X}$ 7.3 cm) than clams from intertidal flats ($\bar{X}$ 4.7 cm). This may be attributed to differences in growth rate, predation pressures, and/or harvesting pressures.

Whelks, drills, rays, and crabs, especially the blue crab, *Callinectes sapidus* preyed upon clams. Whelks migrated seasonally on and off of intertidal flats that contained clams. Whelk densities peaked in fall and spring and were low in winter and summer. The drill, *Urosalpinx cinerea*, occurred at half of the stations and had an average density of 35 drills/m^2. Drills occurred at the base of oyster populations near the mean low water mark. Depressions caused by ray feedings were common throughout the sound. Blue crabs were the main predator on hard clams in Wassaw Sound. Experimental plots seeded with clams were decimated once crabs migrated into the test area.

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INTRODUCTION

The hard clam, *Mercenaria mercenaria*, is a shellfish resource that is a potential commercial crop in coastal Georgia. At present, the clam serves as a recreational resource crop for many coastal residents. Georgia maintained a solid, but modest (ca. 40,000 lbs. annual landing), hard clam industry in the early 1900s. The industry has deteriorated, and today only sporadic harvesting takes place (Lyles, 1966; 1969; 1970) mainly by crab fishermen who clam during winter months when crabbing is slack. Some of the harvest is sold locally, but most is exported to the northeast United States. The demand from northern markets and the instability in the Panaeid shrimp fishery, the mainstay of Georgia's commercial fisheries, has renewed interest among local fish houses in marketing the hard clam.

The hard clam has been commercially exploited in the United States northern waters for many years, and much is known about the resource management and population dynamics of the clam in that region (Belding, 1912; Pratt, 1953; Wells, 1957, Carriker, 1959; Saila *et al*., 1967). In coastal waters of the South Atlantic Bight, this resource is only modestly exploited but could be developed. Knowledge of the ecology of the hard clam in southern waters is limited. Most of the work in the southeast has been done by Menzel, who has investigated the ecology and genetics of *M. mercenaria* and *M. campechiensis* in Florida (Menzel, 1964; Menzel and Sims, 1964; Menzel, 1971; Menzel *et al*., 1976, Nichy and Menzel, 1960). Anderson *et al*. (1978, 1979), and Gracy *et al*. (1978) have investigated the hard clam industry in South Carolina. Godwin (1967, 1968a, 1968b) has studied the feasibility of a hard clam fishery in Georgia.

Because of the paucity of information concerning hard clams in coastal waters of Georgia, a study of hard clam distribution, abundance, and production began in 1977 with support from the Georgia Sea Grant Program. The study was also used to identify potential sites for future development of clam beds and assess problems associated with predation by blue crabs, whelks, and skates. This report summarizes our preliminary findings for Wassaw Sound, Georgia.

AREA OF STUDY

Wassaw Sound (Fig. 1) is a moderately stratified estuary located approximately 15 miles southeast of Savannah, Georgia. The Bull and Wilmington Rivers connect Wassaw Sound to the Savannah River but do not add a significant quantity of fresh water to the sound (Howard and Frey, 1975). Thus, the estuary is essentially a closed salt marsh complex. Numerous tidal creeks that empty into the sound are exposed to relatively low wave energies. The area has a tidal range of approximately 2 m (Johnson *et al*., 1974). Sediments range from silt-clay sediments to fine sand; interbedded sand and mud is the most prevalent (Howard and Frey, 1975). Numerous deposits of oyster shell are present along creek banks and bottoms and sand flats bordering the outer sound.

No comprehensive hydrographic data exist for Wassaw Sound, but data on water temperature and salinity are available for the Skidaway River at the Skidaway Institute dock. The Skidaway River feeds into the Wilmington River. During the past two years, salinity ranged from 13 to 30 o/oo and temperature from 8 to 30°C. (Fig. 3)

I. HARD CLAM DISTRIBUTION AND POPULATION STRUCTURE

Methods

We surveyed Wassaw Sound by time-effort and quadrant sampling to determine hard clam distribution, density, and size-class structure. We sampled 218 stations by hand or by raking in intertidal areas and tonging or dredging in subtidal areas.

Stations with a significant number of clams were further sampled by throwing a 1 m^2 quadrate onto the area and sieving the enclosed substrate through a 1 mm sieve to remove all clams. Shell length (the longest possible measurement, i.e., anterior-posterior) was measured by calipers to the nearest mm.

Results and Discussion

Distribution and relative abundance. Clams occurred only in the outer, more saline region of the sound (Fig. 2). Densities of 0 to 100/m^2 compare to those reported for northern regions (Saila *et al.*, 1967; Wells, 1957), but beds in Wassaw Sound were smaller than those in northern waters.

Unlike populations of the northeast coast, clams in Wassaw sound were limited to intertidal regions, usually the upper reaches of tidal creeks. Some of the intertidal areas in creeks had standing water of up to 2 meters in depth at mean low water. The density of clams varied widely depending on sediment substrate (Table 1). They occurred in four habitats in Wassaw Sound: Among oysters on intertidal oyster bars (Fig. 4); in oyster shell deposits (Fig. 5); in the upper reaches of tidal creeks with mud, sand, or sandy-mud bottoms (Fig. 6); and in small feeder creeks (< 6 meters wide) (Fig. 7).

Clam densities were low (< 1 clam/m^2) on intertidal oyster bars. The clams generally were found on tidal flats or creek banks within the oyster beds where tidal currents prevented build up of shell deposits. On oyster bars with significant shell deposits, densities ranged from 0 to 98 individuals/m^2 and averaged 31/m^2 (Table 2).

In the upper reaches of tidal creeks, clam densities varied depending on substrate. Average densities were greater in sandy-mud (16/m^2) and sand bottoms that contained shell deposits (26/m^2).

Clam densities reached as high as 101/m^2 (average 36 m^2) in small feeder creeks within Wassaw Sound. Large oyster bars at the mouth of the creeks greatly retarded water flow. The mouths were generally less than 6 meters wide at mean high water and, due to the bars, may have been less than one meter wide and only a few centimeters deep at mean low water.

Bottom type. Clams occurred more frequently in sandy-mud substrate and shell substrate than in pure mud or sand. Of all stations sampled, 68% of areas with sandy-mud and 58% of areas with shell deposits had high clam densities, whereas only 20% of stations with pure mud or sand contained clams (Fig. 8).

Of the total clams collected in the time-effort survey, 49% were found in sandy-mud bottoms and 36% in sediments containing shell. Sand and mud bottoms contained 10% and 5% of the total, respectively (Fig. 9). Quantitative quadrate sampling gave different results. The majority (62%) of the total clams harvested was found in shelly substrate, where a density of 22 clams/m^2 occurred. Sandy-mud bottoms accounted for 24% of the total (16 clams/m^2). Sand and mud bottoms represented 13% and 2%, with densities of 12 and 3 clams/m^2, respectively (Fig. 9). Time-effort comparisons are suspect, however, because of the difficulty we had sampling shell environments. Collecting in shelly bottoms took about two to three times the effort required in other bottom types; therefore, the results are difficult to compare with those from other substrates.

Our results agree with other distribution studies of the hard clam in southern waters. Godwin (1968a) found similar patterns in an earlier survey of the Georgia coast reporting a density of 1 clam/m^2 in shelly bottoms and 0.6 and 0.2 clams/m^2 for sand and mud bottoms. However, Anderson et al. (1978) found lowest densities in sand-mud substrates in South Carolina. Wells (1957), in Virginia, and Pratt (1953), in Rhode Island, found the greatest abundance for clams associated with shell and lowest densities with mud or clay bottoms.

Population size structure. The size structure of clam populations of tidal flats in the open sound differed from that of clams inhabiting creek bottoms (Figs. 10 and 11). The mean size of clams from open sound beds was 4.7 ± 1.8 cm versus 7.3 ± 1.6 cm for beds in creek bottoms. This difference may be attributed to different growth rates in the two habitats but not to annual variations in area recruitment. Clams in creek bottoms were generally found near or at the mean low water mark; clams in tidal flats were well above the mean low water mark. Thus, clams of intertidal flats were exposed two or three times longer than creek clams and fed for shorter periods. This difference may also be due to different predation pressures and/or harvesting pressures.

Another characteristic of the size-class histograms we found was the absence of juvenile (< 3.7 cm) clams at most stations, which could have resulted from recruitment failure or juvenile size-selective mortality (due to environmental changes and/or to predation) during the past few years. Larval set of hard clams is naturally sporadic (Haskins, personal communication), but recruitment failure during the past few years might relate to mortality of larvae or juveniles due to stress from low salinities. During the past few years, heavy rains in upstate Georgia produced unusually low salinities in coastal waters during the winter. Salinity at the Skidaway Institute dock, for example, which normally ranges between 18 and 20 o/oo, was depressed to 16 o/oo in January 1977, to 15 o/oo in mid-January through February 1978, and to 13 o/oo in mid-March to mid-May 1979.

Low salinity can affect larval, juvenile, and adult mortality and growth. Clam mortality due to reduced salinity from heavy runoff has been previously reported (Burrell, 1977; Haven *et al.*, 1976; Joyce, 1972). Wells (1957), in Virginia, found no clams in regions where salinities were below 21 o/oo for prolonged periods. Belding (1912) gave the salinity range of the hard clam as 13 to 35 o/oo. Wass (1972) listed *Mercenaria* as a polyhaline (>18 o/oo) species. Castagna and Chanley (1973) reported a low salinity tolerance of 13 o/oo in Virginia waters. Godwin (1968a), in Georgia, found no clams in regions with salinity below 17 o/oo. Davis and Calabrese (1964) cited 27 o/oo, or possibly higher, as the optimum salinity for clam larval growth. Davis (1958) observed growth in larvae at 15 o/oo, but with high mortality.

Commercial size grouping. In terms of commercial size (Table 3), the majority (ca. 50%) of the clams that we found in Wassaw Sound were "chowders" (Figs. 11 and 12). "Littlenecks" and "cherrystones" together comprised less than 46% of the clam population. Juveniles accounted for less than 5%. Godwin (1967) found similar grouping in an earlier survey in Georgia. In South Carolina, Anderson *et al.* (1978) found the highest percentage (57%) of clams to be littlenecks. This difference may reflect temporal variation in recruitment in Georgia and South Carolina clam populations that leads to non-equilibrium of age-class structures. However, in South Carolina, it might also be due to harvesting pressure (Gracy *et al.*, 1978).

II. PREDATORS

The main predators of clams in Georgia waters were whelks, blue crabs, and rays. During the past five years, increased predation pressure, especially size-selective predation of juvenile clams, due to increased predator density, may have caused the observed recruitment failure.

Methods

A total of 2,339 clams from 57 stations were checked for signs of predation. Each clam was measured and the type(s) of damage recorded.

The Atlantic oyster drill, *Urosalpinx cinerea*, produced a smooth hole; the moon snail, *Polinices duplicatus*, produced a larger, more beveled hole. Whelks produced smooth chip(s) along the margin of the hard clam shell, while crabs produced a small, circular chipping or a jagged to roughly serrated breakage along the margin. The boring sponges, *Cliona* spp., produced numerous tunnels (from 0.2 to 2.5 mm diameter) in hard clam shells. Various signs of damage have been described by Krantz and Chamberlin (1978). MacKenzie (1977), Menzel and Nichy (1958), Hopkins (1956), Carriker (1951), and Clench (1939). The results are summarized in Table 4 and are discussed in more detail below.

The presence of predators at each sample site has been monitored since November 1978. Whelks were monitored monthly by hand collecting over a predetermined area (7,440 m^2) at low tide. Oyster drills were sampled at 34 stations at the base and top of oyster bars, at the bottom and top of sloping bank populations, and among sparse oyster populations on intertidal flats. A 0.1 m^2 quadrate was randomly thrown six times per station at both low and high areas. Drills were removed, counted, and measured.

To determine if predation due to crabs could be reduced in Wassaw Sound, we protected beds with combinations of gravel overlay, caging, and crab traps. Sixteen one-meter plots were staked out in each of two areas of Little Tybee Creek on Little Tybee Island, a site well-protected against storms that contained indigenous clam beds. Each plot received 150 seed clams (3 to 12 mm) obtained from Culture Clams, Aquaculture Research Corp., Massachusetts. Each group of four plots in each of the two areas received one of the following treatments: Caging, caging plus gravel overlay, gravel overlay, or no protection (control). The cages consisted of frames (1 x 1 x 0.25 m high) covered with 12 mm mesh netting and buried 20 cm into the sediment. The gravel overlay was a 5 cm layer of crushed stone aggregate (1 to 3 cm). In addition, one area (16 plots) was surrounded with baited crab pots. Nine crab pots were set initially, but this was increased to 18 as the number of trapped crabs increased. Pots were emptied and rebaited three times a week (weather permitting). Crabs were identified, sexed, measured (length of the carapace), and transplanted to another area.

The plots were sampled monthly by taking 16 sediment cores (total of 0.25 m^2 area) in each of the 32 treatment plots--a total of 512 cores/month. The sediment was sieved; and the clams were counted, measured, and returned to their original position. Clam survival and growth was determined.

Results and Discussion

Blue crabs occurred at all stations, regardless of the presence or absence of hard clams. Boring sponges, Cliona spp., occurred at all subtidal stations that possessed shell deposits and on clams and oysters exposed near the mean low water mark. Whelks and drills occurred primarily on intertidal flats in the open sound; however, a few occurred in creek bottoms (Figs. 13 and 14).

Crabs. Studies indicate that the blue crab, Callinectes sapidus, is the most destructive predator of unprotected seed clams in warmer United States coastal waters (Castagna and Kraeuter, 1977; Godwin, 1968b, Menzel and Sims, 1964). One-tenth of the total clams inspected at the 57 stations sampled showed evidence of chipped shells due to crab predation. Clams with evidence of chipping occurred at 87% of the stations sampled.

Clams that exhibited signs of crab chipping ranged in length from 3.9 to 11 cm with an average length of 8.1 ± 1.3 cm. All of the clams, with the exception of one 3.9 cm individual, ranged from 6 to 11 cm. It seems that crab attacks may not be successful on clams greater than 6 cm. Crabs prey successfully upon clams less than 5 cm in length. Blue crabs prey primarily upon seed clams (Castagna and Kraeuter, 1977). The blue crab and possibly the stone crab are probably responsible for predation on larger (4 to 5 cm) clams (Carriker, 1951; 1959).

Predator prevention techniques met with varying results. Many studies have described beds that were protected with penning, caging, or gravel overlay to protect small clams and to insure seed survival. Penning or caging has been used with some success (Godwin, 1968b: Menzel and Sims, 1964). Godwin (1968b) observed clam mortalities ranging from 48 to 100%

in unprotected plots, versus 0 to 60% in caged plots. Stone aggregate increased survival of planted clams, as did the use of baffles in conjunction with the stone aggregate overlay (Castagna and Kraeuter, 1977; Castagna et al., 1970). Castagna et al. (1970) recorded an 80% recovery of clams planted in stone aggregate protected plots, with only 16 to 30% recovery in control plots. However, Menzel et al. (1976) observed only 20% survival using stone aggregate versus 80% in controls that were protected by caging. Castagna (personal communication) suggested that Menzel et al. (1976) might have achieved more favorable results if baffles were used in conjunction with the stone aggregate. Van Engle (1958) indicated that crabs are only serious predators of seed clams and oysters when other food is less available; thus, placing baited crab pots about plots should reduce the threat of crabs.

In our experimental plots, clam densities decreased as crab densities increased, regardless of the type of protection device used. By May 1979, the crab population had increased to the extent that all seeded beds were decimated (Fig. 16). Initially, eight crabs per week were trapped; but by May, the number taken was ten times greater (Fig. 16).

A total of 616 blue crabs and stone crabs were trapped in the pots from February to May 1979. Of these, 99% were blue crabs and 1% was stone crabs. The majority (69%) of the crabs trapped were below legal size (5") until May, when the majority (74%) of the crabs were legal size (Fig. 17). Nine immature blue crabs (size ranging 1.3 to 5.0 cm; $\bar{X}$ = 2.96 ± 1.28 cm) were collected inside the penned plots in March.

Clam mortalities resulted from both tidal currents and crab predation. In the past, washout by tidal currents has been a major problem in clam mariculture (Castagna and Kraeuter, 1977). Many of our experimental pens were either dug up or buried by sediment shifting induced by tidal currents. The tidal currents exposed the clams to crabs, but mortality was due to attack by crabs. Shell fragments produced by crab predation were numerous.

Crabs are the major predators of shellfish in the southeastern United States. The blue crab, Callinectes sapidus, the mud crabs Panopeus herbstii and Eurypanopeus depressus, the stone crab, Menippe mercenaria, and, to a lesser degree, the horseshoe crab, Limulus polyphemus, prey upon hard clams (Whetstone and Eversole, 1978; Castagna and Kraeuter, 1977: MacKenzie, 1977; Eldridge et al., 1976; Menzel et al., 1976; Dow and Wallace, 1951). Crabs feed primarily on juvenile clams, but larger clams (3 to 4 cm) are also taken (Carriker, 1951, 1959).

Boring sponges. We observed signs of the boring sponge, Cliona spp., in hard clam shells at 17 of 57 stations (30%, Table 4). Almost 7% of the hard clams collected were actually infested (Table 9). Boring sponges tended to infest large clams that were only partially buried; only one clam less than 6 cm in length was infested. The low infestation rate (6.7%) was due in part to the burrowing habit of the clam and due in part to the fact that boring sponges only occur below the mean low water line (Dean, 1892; Hopkins, 1956; Linton, 1968; Hoese and Durant, 1969). Hopkins (1962) stated that the boring sponge cannot survive dessication, burial, or depressed salinity. Almost 100% of parasitism by the boring sponge occurs in oysters 0.3 m below mean low water (Linton, 1968).

Studies have noted the boring sponge, Cliona, to be a major oyster parasite in South Carolina and Georgia (Lunz, 1935; Hopkins, 1956; Badger, 1968; Linton, 1968). Although hard clam shells have been reported as a substrate for boring sponges (Old, 1941; Nicol and Reisman, 1976), parasitism has not been cited in the literature.

Whelks. There are four species of whelks native to coastal Georgia's waters: The knobbed whelk, Busycon carica; the lightning whelk, Busycon contrarium; the channeled whelk, Busycon canaliculatum; and Say's pear whelk, Busycon spiratum (Abbott, 1974). Knobbed and lightning whelks are predators of the hard clam (Paine, 1962; Carriker, 1951; Colton, 1908), and in the present study, they dominated the whelk population of the intertidal oyster flats of Wassaw Sound (79% and 20%, respectively). The channeled whelk was rare (1%), and Say's pear whelk was absent.

Densities of whelks were low compared to other areas (Table 5) and varied seasonally (Fig. 15) with the greatest density (680/hectare) in the fall the the lowest density (36/hectare) in the winter. This seasonal fluctuation follows the pattern described by Paine (1962) but differs from that described by Magahlaes (1948), who found greatest density during the summer in Beaufort, North Carolina.

Of the 1,048 whelks collected, 89 (9%) were actively feeding. Of these, 45 were consuming oysters and 44 were consuming hard clams.

Drills. Drills were not found actively preying upon clams during the survey. Several drills were observed on clams, but signs of drilling were not detected. The lack of predation by drills may be due to the absence of juvenile clams (Carriker, 1961).

In our study, the Atlantic oyster drill, Urosalpinx cinerea, was more common in areas of higher salinity than the rough oyster drill, Eupleura caudata (Fig. 14). Studies have shown that where the distribution of two species overlapped, the rough oyster drill comprised only a small percentage of the drill population (Carriker, 1955). Only three shells of the rough oyster drill were collected. These occurred on Williamson Island, away from any oyster beds. The majority (83%) of Atlantic oyster drills were found at the base of oyster bars. Half of the stations yielded drills at the base of the bar, with an average density of $47 \pm 71/m^2$. A small percentage (15%) of the stations possessed drills at the base (low) and top (high) of the bar. At these stations, the average densities varied greatly from low (133 ± 51 m^2) to high areas (27 ± 37 m^2) (Table 6). Drills were always present in low areas if they were found in high areas. Overall density of drills on the bars was $35 \pm 57/m^2$, higher than those cited for other southern areas, but perhaps lower than found in northern areas (Turgeon and Fralick, 1973; Carriker, 1955) (Table 7). The high standard deviations are due to non-random (contiguous) distribution.

Studies have indicated that oyster drills, U. cinerea and E. caudata, are carnivorous gastropods that prey upon bivalves (MacKenzie, 1977; Carriker, 1957; Pratt, 1974) and other gastropods (Federighi, 1931). Little information on drills in Georgia exists (Carriker, 1955). Galtsoff et al. (1937) stated that drills occur infrequently in Georgia. However, Carriker (1955) stated that drills are abundant subtidally off Sapelo Island.

Other carnivorous gastropods encountered during the survey were the moon snail, Polinices duplicatus; the banded tulip, Fasciolaria hunteria; and the Florida rock-shell, Thais haemastoma floridana. We found that live snails of each species inhabited intertidal oyster and clam beds. None were observed actively preying upon clams, although they are considered predators of clams (MacKenzie, 1977; Butler, 1953; Carriker, 1951; Wells, 1958). These snails rarely occurred intertidally in Wassaw Sound.

Starfish. In Wassaw Sound, Asterias forbesi was restricted to deep areas of the sound or to offshore areas. Few starfish appeared in the intertidal areas where prolonged tidal exposure would result in dessication, especially during the summer. MacKenzie (1969) reported that the feeding rate of Asterias in Long Island Sound decreased when they encountered warm water; Asterias died when exposed to 23.5°C water for prolonged periods. If this temperature is critical for southern starfish, the water temperature from May to October would cause mortality (Fig. 3).

Studies have reported that the starfish, Asterias forbesi, preyed upon the hard clam (Belding, 1912; Galtsoff and Loosanoff, 1950; Pratt and Campbell, 1956; Coe, 1972; MacKenzie, 1977), but it was not considered a serious threat due to its inability to burrow after the clam (Belding, 1912). Pratt and Campbell (1956) noted that clams in experimental boxes buried deeper when Asterias was present. Doering (1976) also observed increased burrowing activity by clams when starfish were present.

Rays and Skates. We did not sample for rays during the crab predation test, but numerous ray depressions were observed around the test area. Studies have shown that sediment depressions produced by feeding activities of Dasyatis spp. are numerous in Georgia (Howard et al., 1977). Rays were observed moving with the incoming tides into the headwaters of creeks with intertidal clam beds. Unfortunately, the predation pressure exerted upon the clam population by elasmobranchs is not known. Further studies on predation of commercial shellfish by elasmobranchs and other fish are needed.

It has been shown that elasmobranchs feed on bivalves (Howard et al., 1977; Babel, 1967; Fitz and Daiber, 1963; Hess, 1961; Bigelow and Schroeder, 1953). Studies have also shown the ray to be a major predator upon juvenile and adult hard clams (Castagna and Kraeuter, 1977). Massive destruction of Mya (soft shell clam) beds in Virginia by the cownose ray was reported by Orth (1975). Depressions created by sting rays and the smooth butterfly ray were observed in experimental clam plots in Florida (Menzel et al., 1976).

Elasmobranchs of the families Dasyatidae, Myliobatidae, and Rhinopteridae have been reported to be frequent inhabitants of Wassaw Sound (Howard et al., 1977; Dahlberg, 1972, 1975). The guitarfish, Rhinobatos lentiginosus, commonly found in May and June, occurred primarily offshore but occasionally entered the sound (Dahlberg, 1972). The clearnose skate, Raja eglanteria, has been noted to occur offshore throughout the year, occasionally entering the sound (Howard et al., 1977). The cownose ray, Rhinoptera bonasus, was shown to be common all year inshore, especially during late summer and early fall (Howard et al., 1977). Studies of the smooth butterfly ray, Gymnura micrura, have shown it to be common offshore during warm months and inshore throughout the year (Dahlberg, 1975).

We found that four Dasyatis spp. occurred in Georgia's waters. The Atlantic stingray, D. sabina, was dominant and commonly found inshore year around and occurred offshore during warmer months. The bluntnose stingray, D. sayi, was the second most numerous ray in Georgia. The southern stingray, D. americana, and bluntnose stingray were found to occur commonly inshore April to November. The roughtail stingray, D. centroura, occurred offshore and only rarely (Howard et al., 1977; Dahlberg, 1975).

SUMMARY AND RECOMMENDATIONS

We found that hard clams occurred throughout the creek and sound system of Wassaw Sound. They occurred in decreasing density in shell deposits associated with oyster beds; in small feeder creeks; in sandy-mud, sand, or mud bottom creeks; or among live oysters. High clam densities were associated with shelly substrate. Clam beds were found to be small and patchy. One of the larger and more dense ($50/m^2$) beds in Wassaw Sound measured approximately 90 m , but this size was rare.

Clams from creeks were larger (7.3 ± 1.6 cm length) than clams from intertidal flats (4.7 ± 1.8 cm). Clams from intertidal flats found well above mean low water probably have a slower growth rate than clams in creeks found at mean low water.

Juvenile clams (<3.7 cm) were absent from both intertidal flats and creek populations. This recruitment failure may have resulted from a recent period of high predation or from low salinity or spawning stresses which resulted from heavy runoff of rainwater in upstate Georgia.

We found predation pressure to be exerted by whelks, drills, rays, and crabs, especially the blue crab, Callinectes sapidus. Whelks were found to migrate seasonally on and off of intertidal flats containing clam beds. Desnities of whelks peaked in fall and spring and were low in winter and summer. The drills were primarily Urosalpinx cinerea. These drills occurred at an average density of 35 drills/m^2 at the base of oyster populations. Other drills (Thais, Fasciolaria, Polinices, and Eupleura) were rare on intertidal flats and were absent from creeks. Depressions made by feeding rays were common throughout the Sound. Rays were observed migrating into creeks with the incoming tide and feeding on clam beds. The blue crab was noted to be the main predator on hard clams in Wassaw Sound. Blue crabs decimated experimental plots seeded with clams once the crabs migrated into the creeks.

The results of this study and studies by Godwin (1968a) and Anderson et al. (1978) have shown the same correlation between clam density and substrate. The greatest densities of clams occurred in substrates containing shell. This may well be the key to successfully culturing hard clams in the southeastern United States. The southeast possesses large deposits of wash shell along creeks and rivers of its coastal waters. These deposits may be utilized by turning currently unproductive mud or sandy-mud bottoms into productive clam beds.

FIGURES

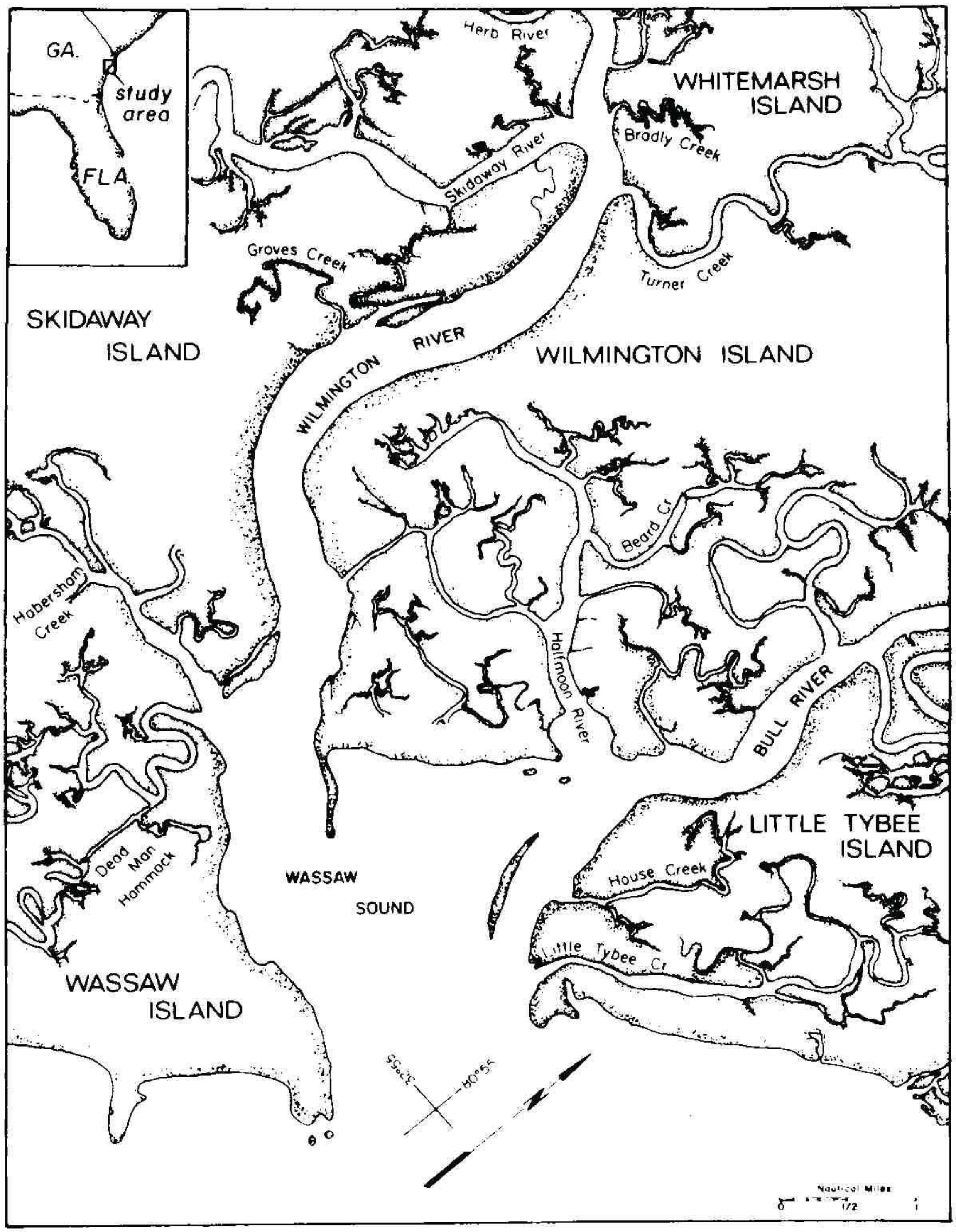

Figure 1. Wassaw Sound, Coast of Georgia.

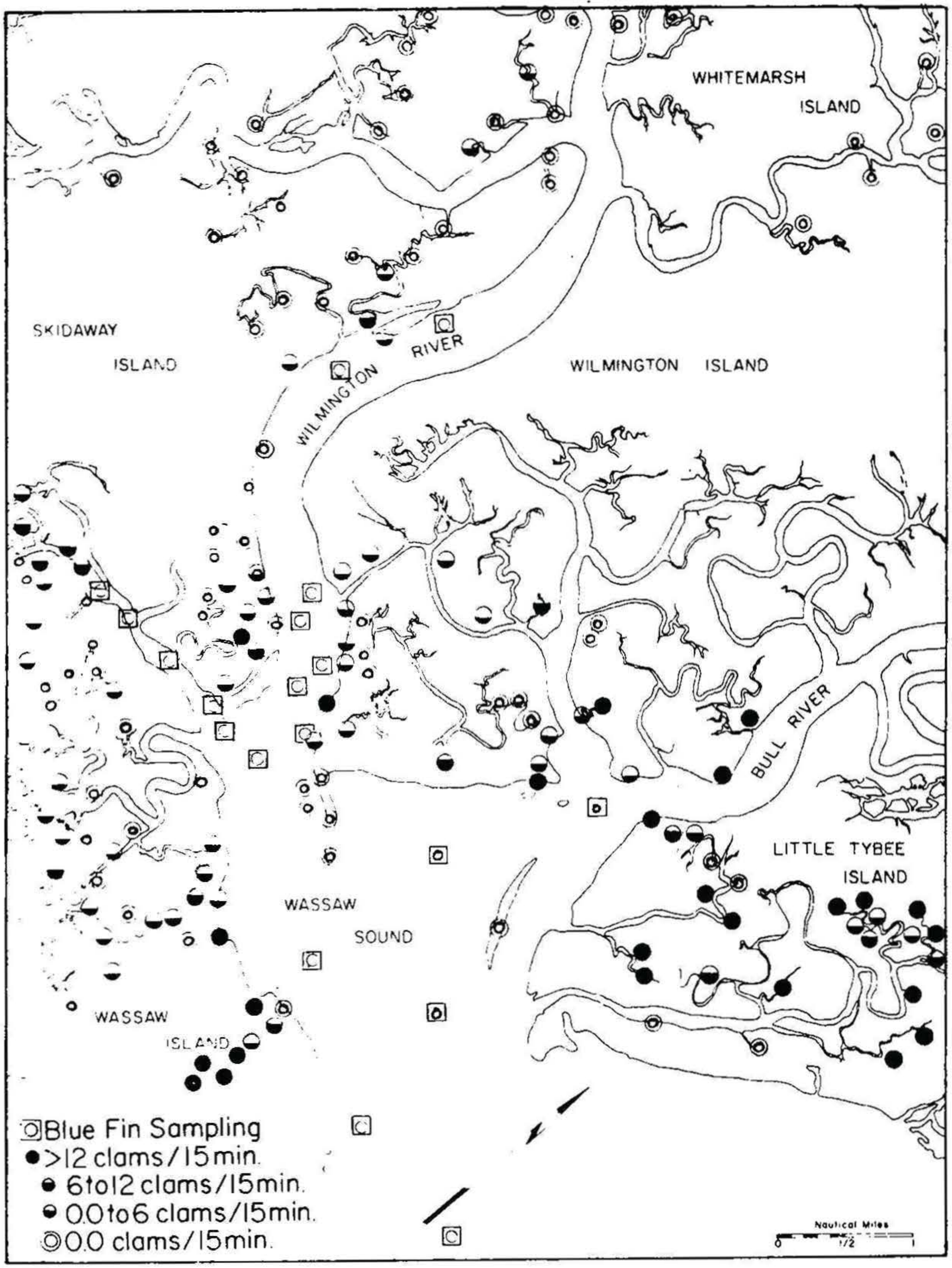

Figure 2. Distribution and density by time-effort of the hard clam, *Mercenaria mercenaria*, in Wassaw Sound.

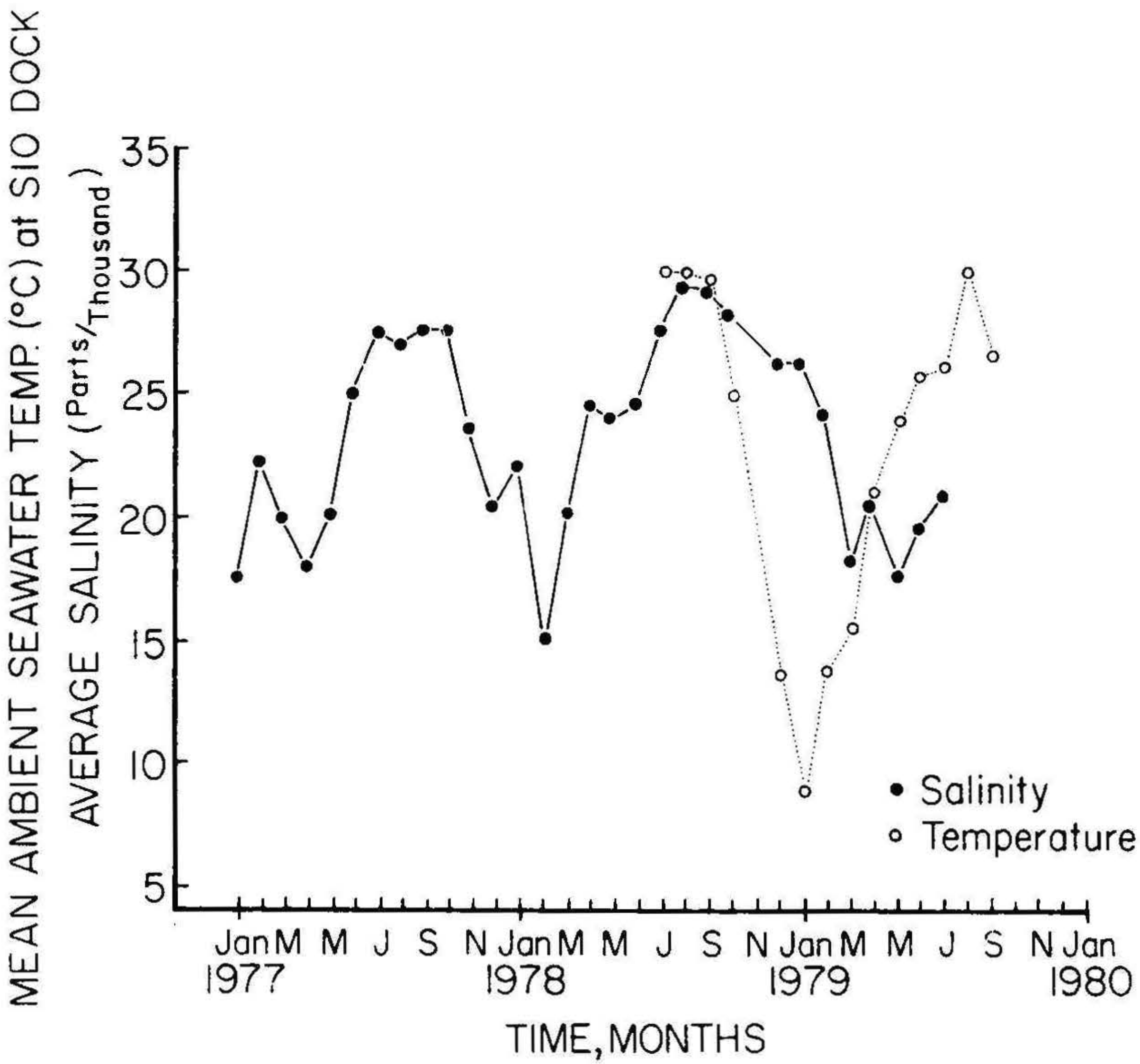

Figure 3. Salinity and temperature variation at Skidaway River, Georgia.

Figure 4. Clams among live oysters along intertidal creek bank.

Figure 5. Shell deposits covering clams.

Figure 6. Mud bottom or sand bottom typical of many of the head water areas of tidal creeks.

Figure 7. Entrance to a small mud or sand bottom feeder creek. Width of mouth at mean low water is approximately two to five feet.

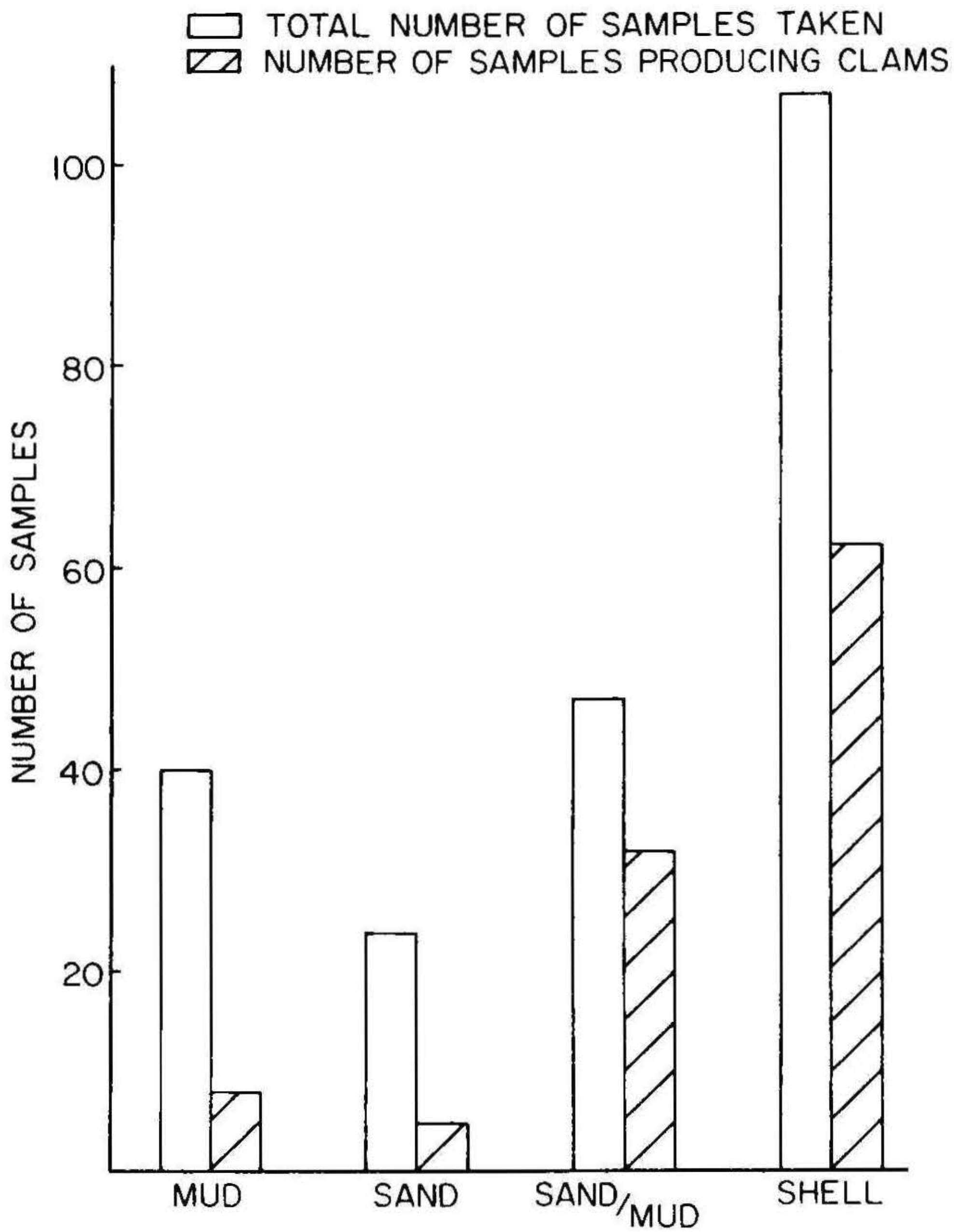

Figure 8. Number of stations yielding clams related to total number of stations sampled per substrate type.

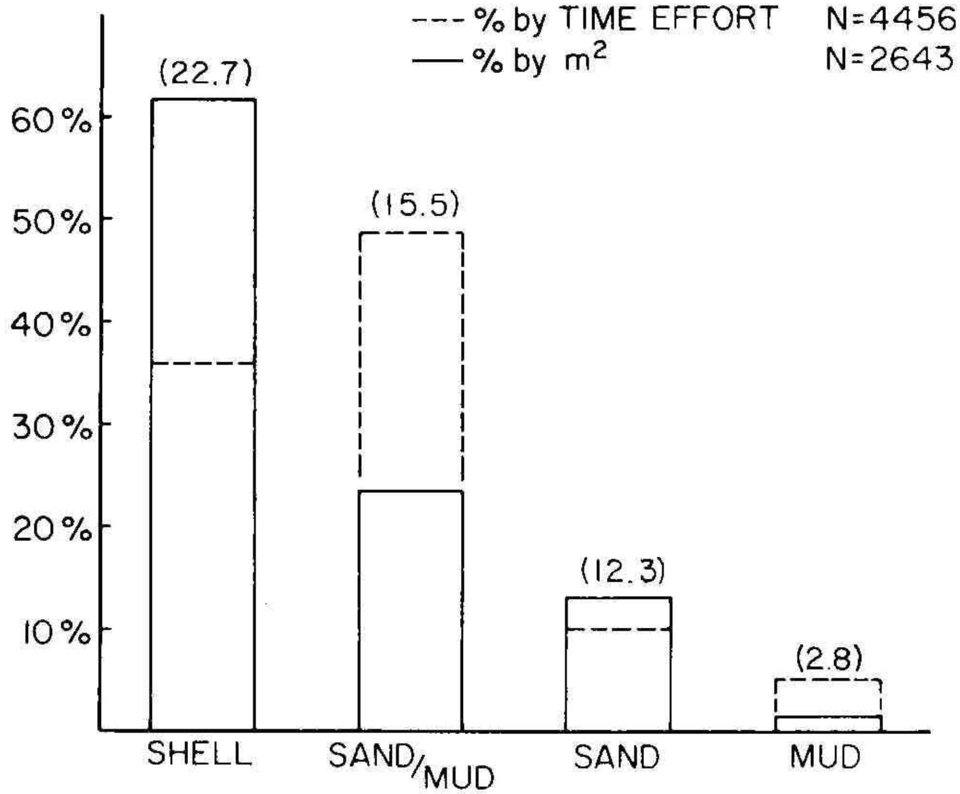

Figure 9. Percentage of total number of clams harvested by time-effort and meter square. The number in parentheses is the average number of clams per meter square per substrate type.

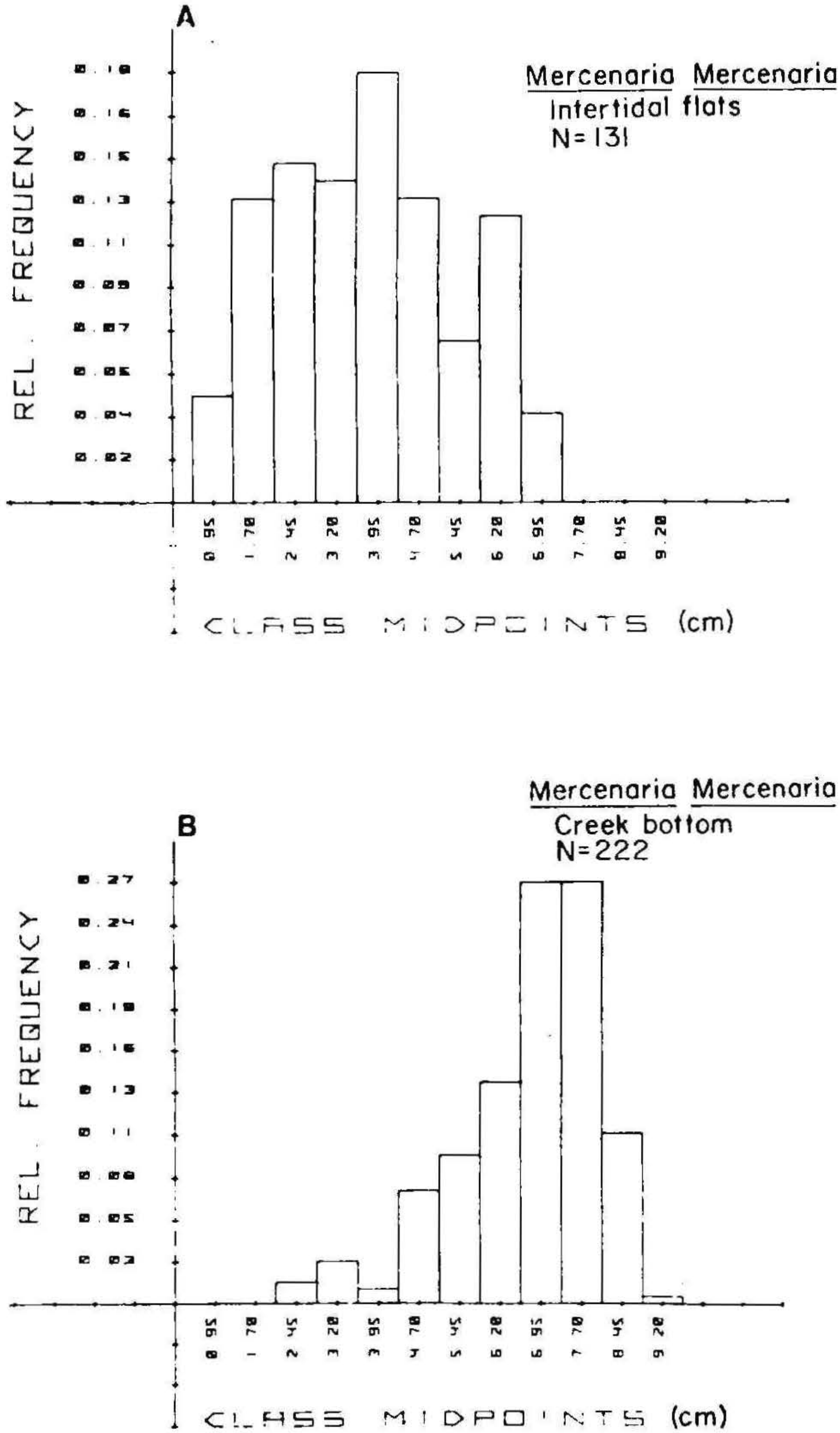

Figure 10. Differences in size classes from (a) intertidal flat and (b) creek bottoms.

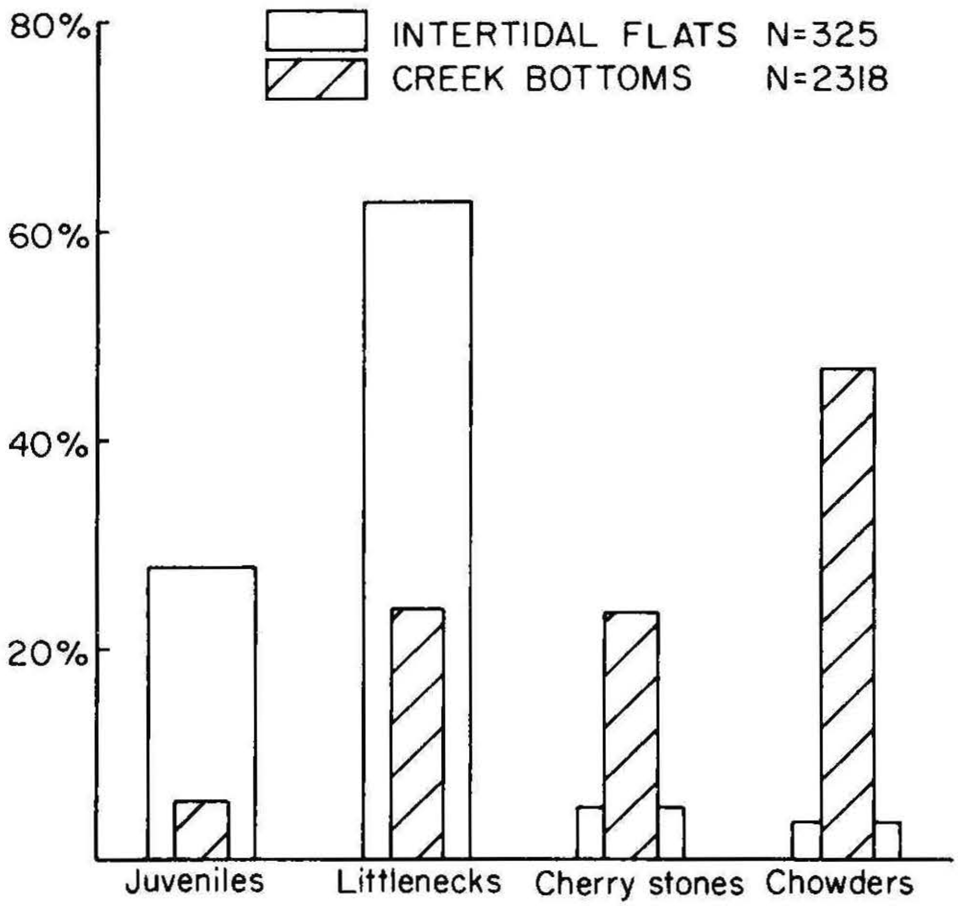

Figure 11. Differences in population size structure between intertidal flat beds and creek bottom beds.

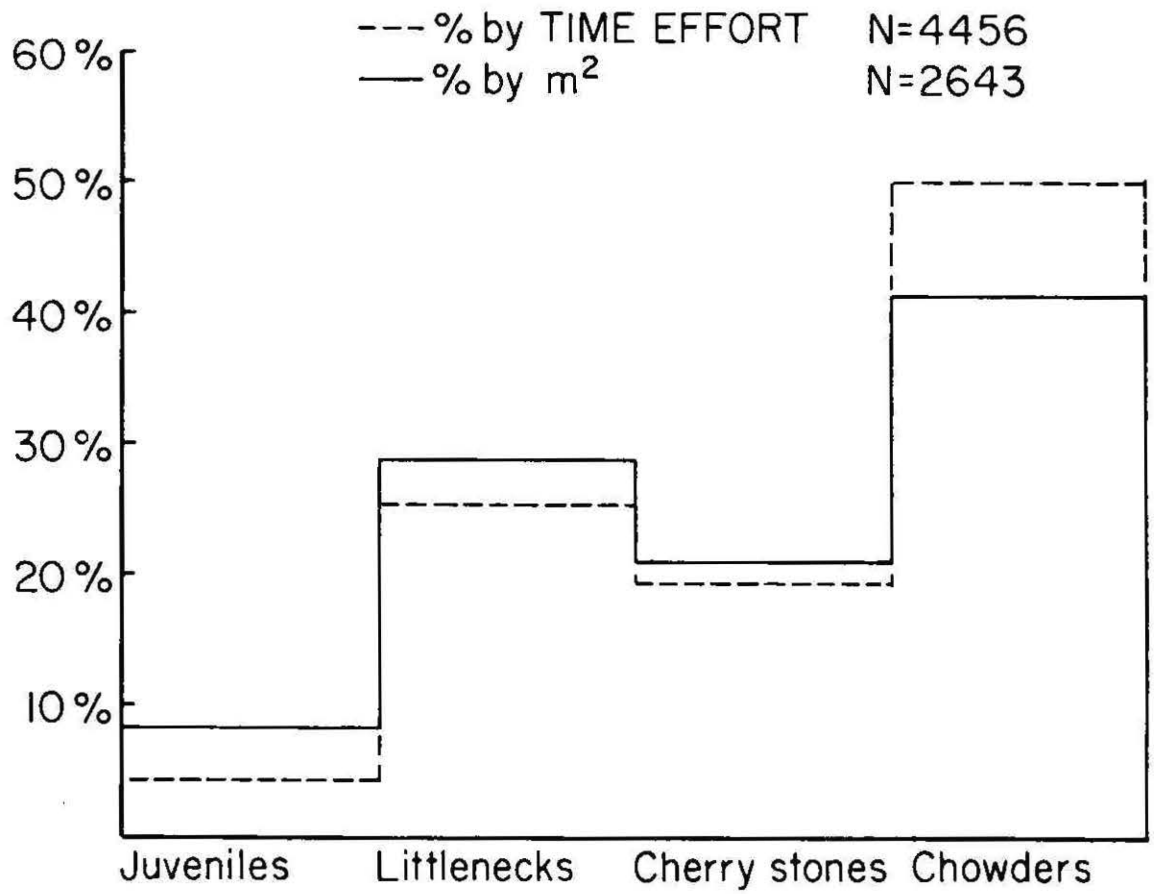

Figure 12. Clams categorized according to commercial size grouping. See Table 2 for size ranges.

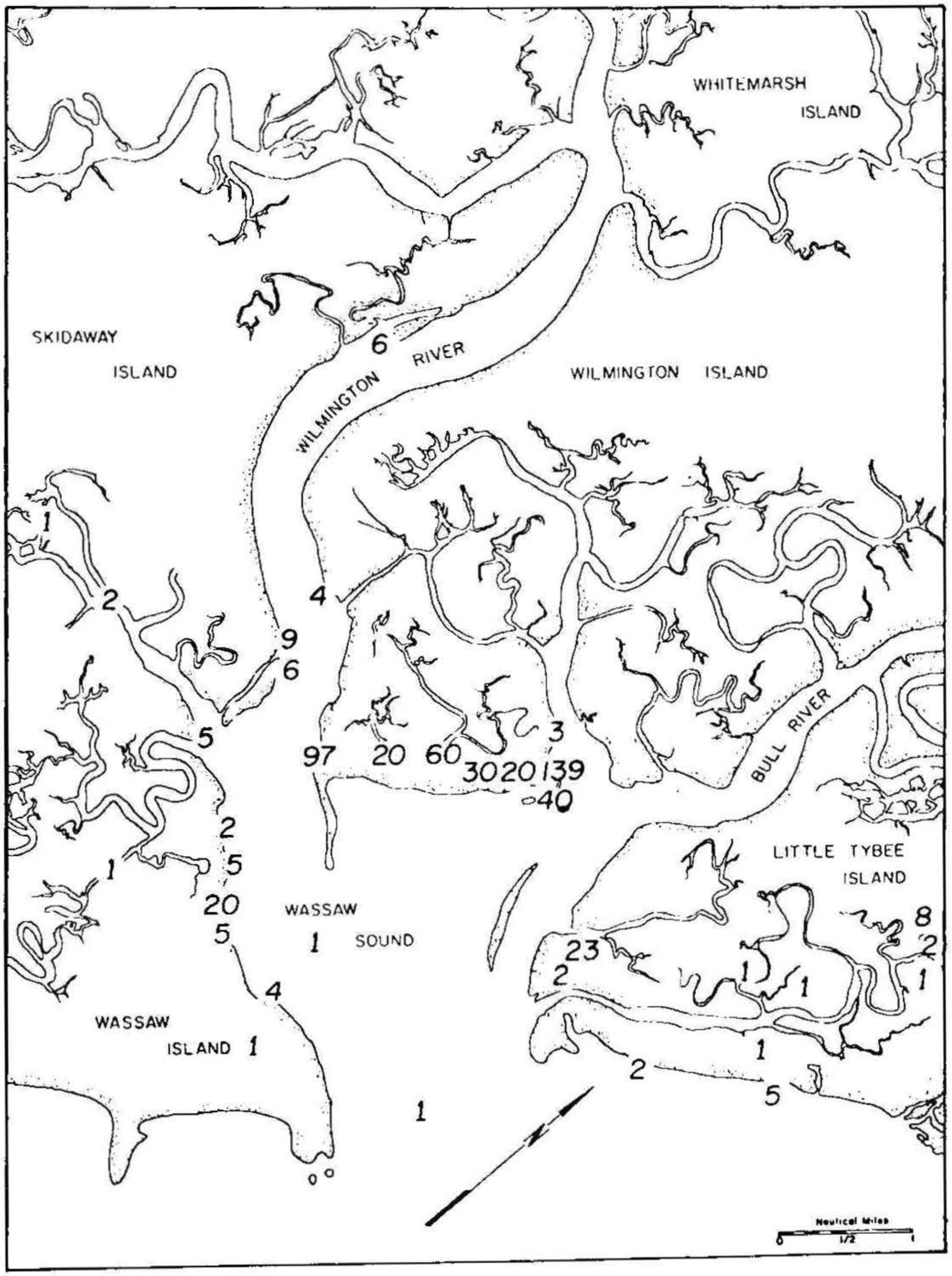

Figure 13. Distribution of whelks, Busycon spp., in Wassaw Sound, Georgia. The number given is the number of whelks obtained per site.

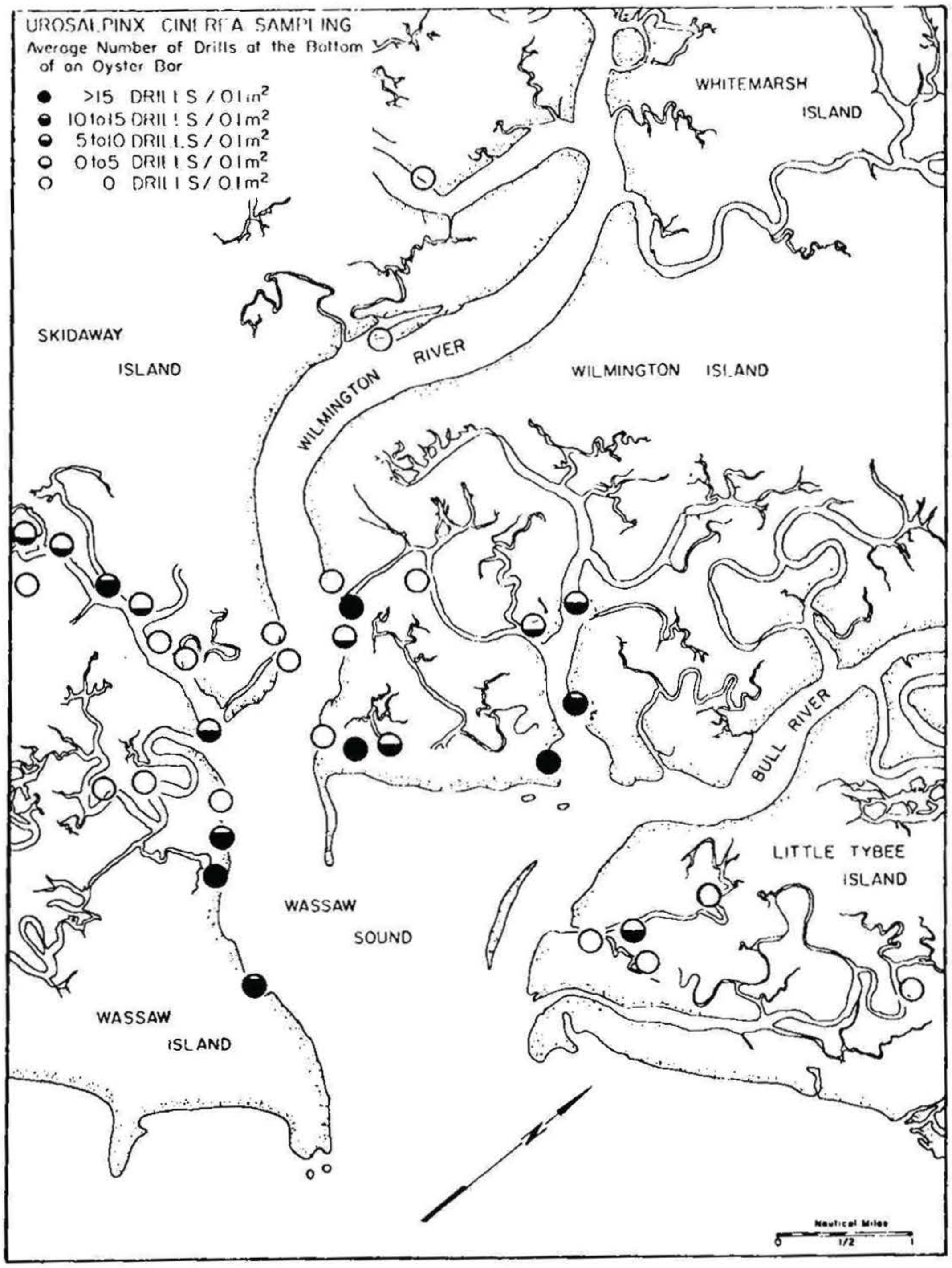

Figure 14. Distribution of drills, Urosalpinx cinerea, in Wassaw Sound, Georgia.

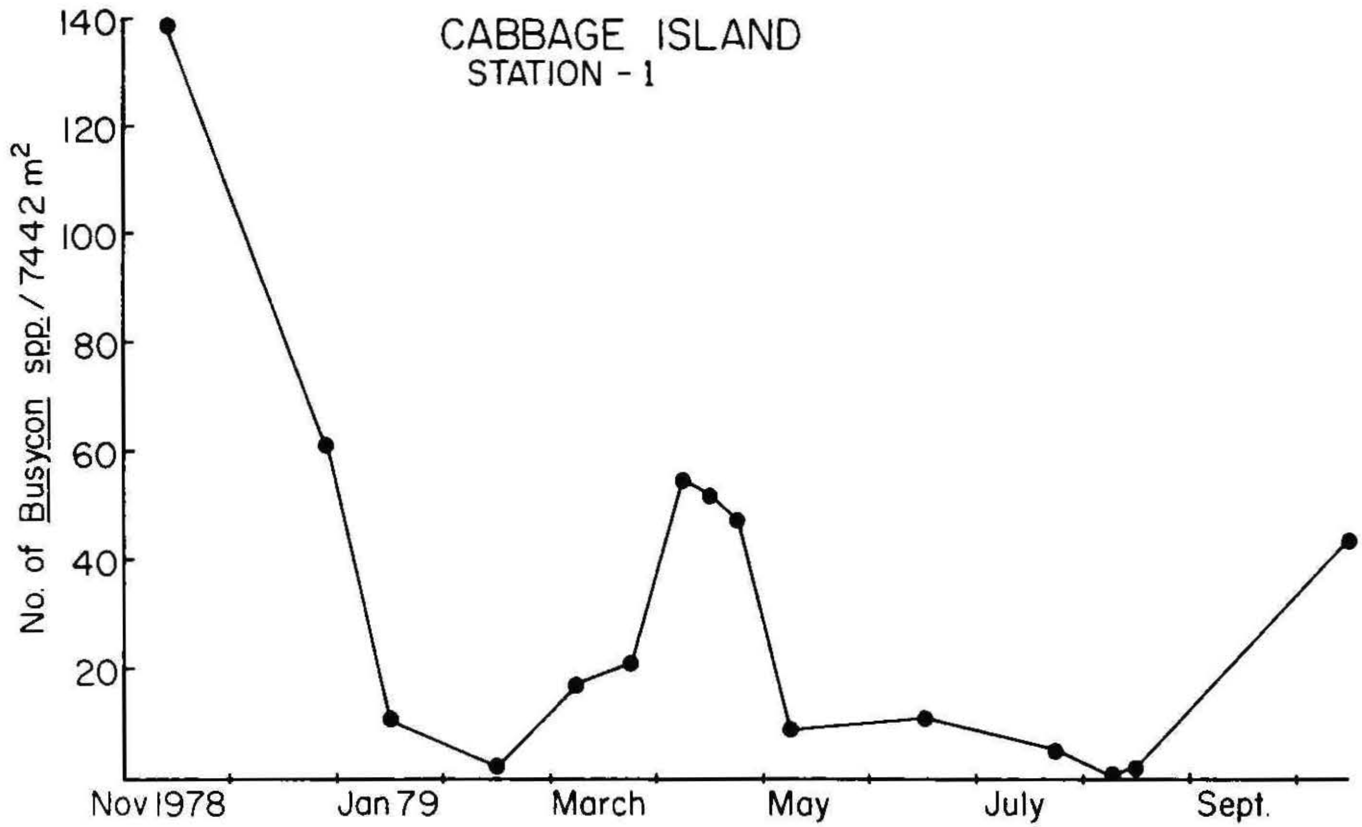

Figure 15. Seasonal changes in whelk densities.

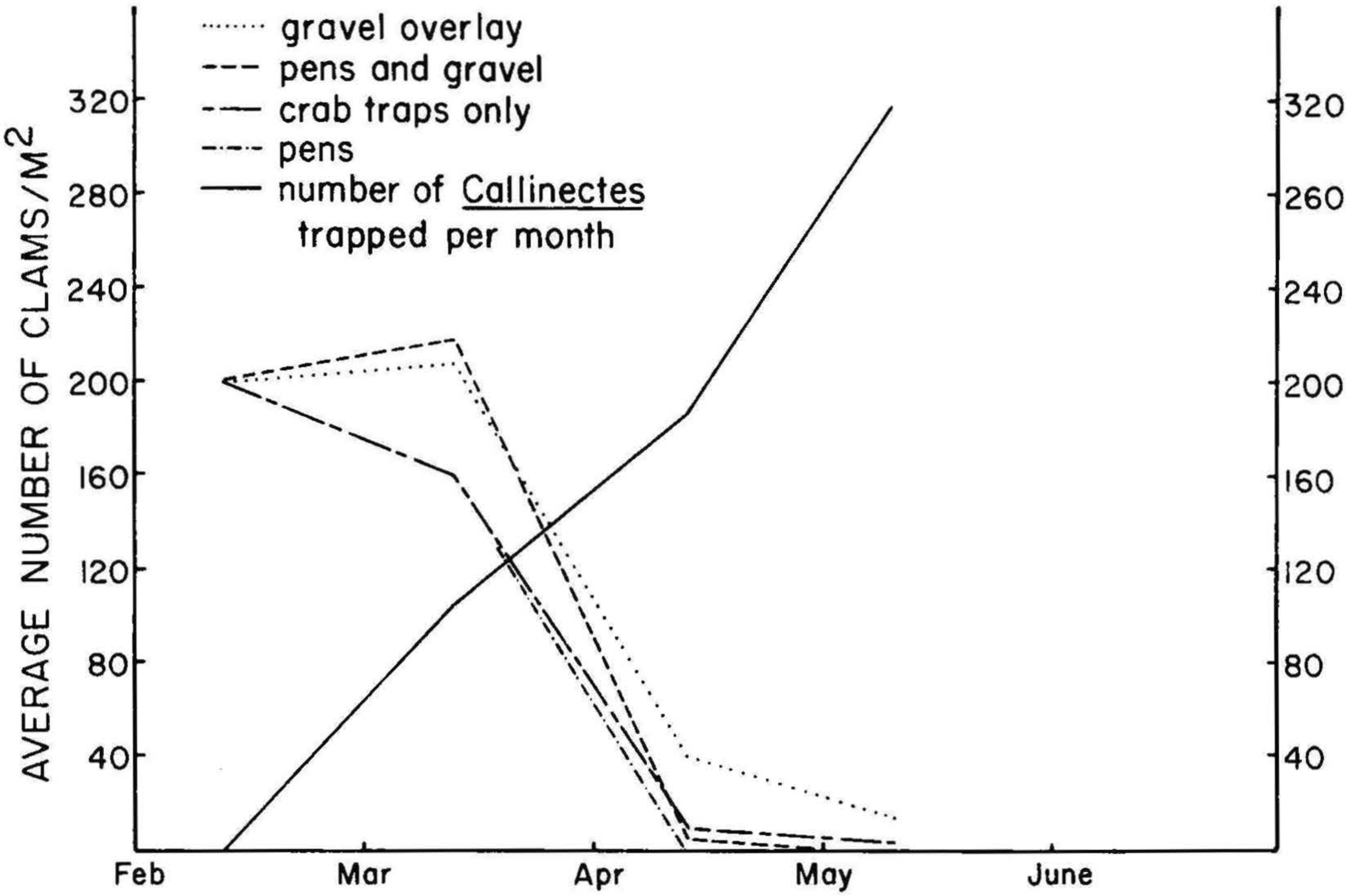

Figure 16. Results of crab experiment testing various means of clam protection.

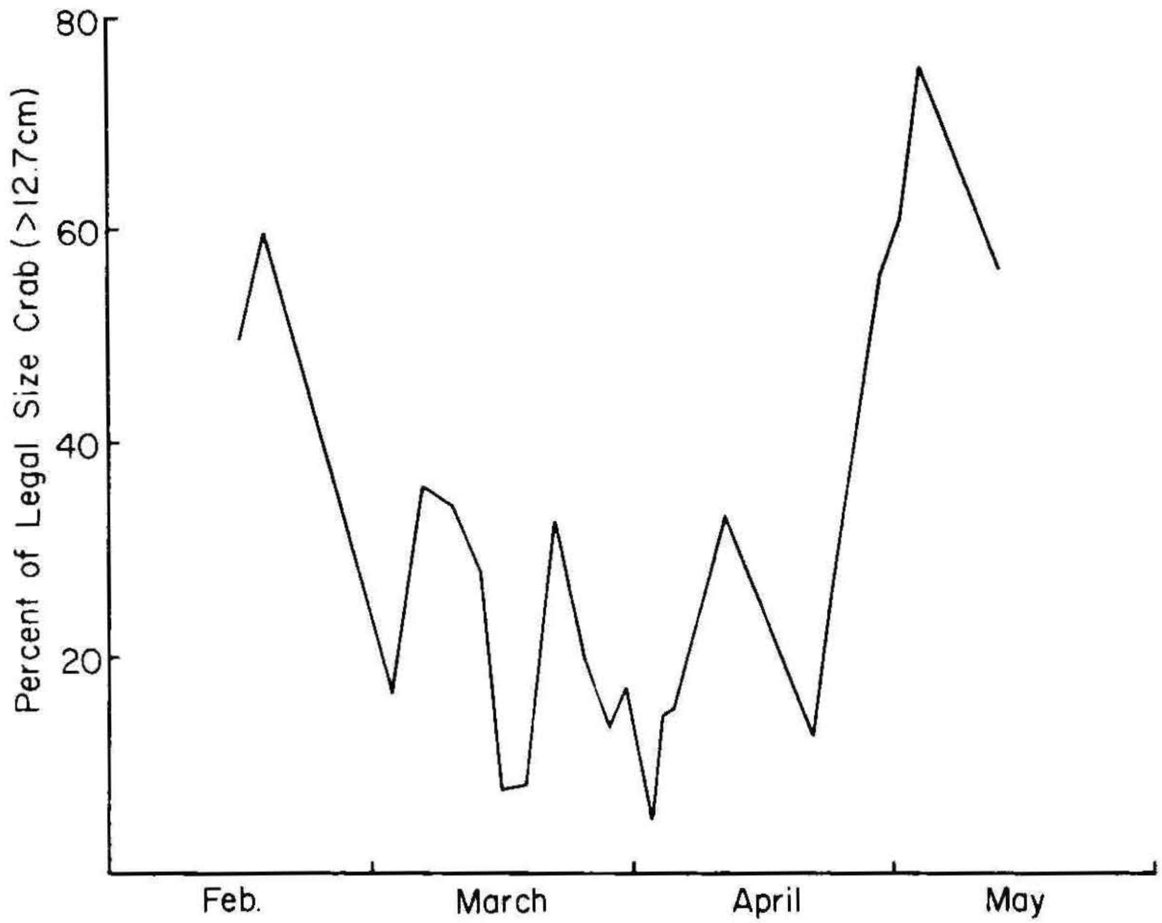

Figure 17. Percentage of legal-size crabs (5") determined from weekly sampling.

TABLES

Table 1. Hard Clam Densities in Wassaw Sound, Georgia

STATION	LOCATION	BOTTOM TYPE	TOTAL COLLECTED	AVERAGE NO. PER m²	AVERAGE LENGTH IN Cm ± SD	RANGE IN Cm	MAP LOCATION NUMBER
105	Wassaw Island	Shell/Mud	189	47.25 ± 30.92	6.27 ± 1.41	1.24 to 9.43	1
1	Cabbage Island	Shell	35	8.75 ± 7.72	4.41 ± 1.16	1.53 to 6.11	2
1	Cabbage Island	Sand	15	3.75 ± 5.19	6.32 ± 1.44	2.88 to 8.135	3
2	Cabbage Island	Shell/Sand	2	0.5 ± .58	8.54 ± 1.04	7.81 to 9.275	4
1	Cabbage Island	Shell/Sand	19	4.75 ± 4.57	5.99 ± 1.99	2.455 to 8.47	5
1	Cabbage Island	Sand	9	2.25 ± 2.22	5.22 ± .72	4.085 to 6.055	6
102	Little Tybee Creek	Sand/Mud	8	2.0 ± 1.83	8.87 ± .93	7.315 to 9.90	7
102	Little Tybee Creek	Sand/Mud	20	5.0 ± 5.23	8.04 ± 1.00	5.25 to 9.275	8
101	Little Tybee Creek	Sand/Mud	30	7.5 ± 4.20	8.55 ± 0.56	7.10 to 9.50	9
104	Little Tybee Creek	Sand/Mud	14	3.5 ± 2.89	8.36 ± 0.84	6.29 to 9.42	10
110	Little Tybee Creek	Sand/Mud	71	17.75 ± 11.87	7.78 ± 0.74	4.55 to 9.17	11
112	Wassaw Island	Sand/Mud	73	18.25 ± 13.94	8.15 ± 1.37	5.085 to 10.42	12
114	Wassaw Island	Sand/Mud	139	34.75 ± 49.01	7.74 ± 1.58	2.645 to 10.19	13
115	Wassaw Island	Sand/Mud	54	13.5 ± 18.41	7.56 ± 0.83	5.575 to 9.465	14
116	Wassaw Island	Sand/Mud	202	101.0 ± 107.48	7.57 ± 1.36	3.025 to 10.04	15
150	Bull River	Shell/Mud	119	29.75 ± 31.53	5.12 ± 1.62	1.45 to 10.41	16
122	Little Tybee Creek	Sand/Mud	10	2.5 ± 3.79	8.07 ± 0.64	6.955 to 8.95	17
123	Little Tybee Creek	Shell/Sand	126	31.5 ± 20.44	8.19 ± 0.97	4.125 to 9.78	18
124	Little Tybee Creek	Shell/Sand	91	22.75 ± 15.45	7.88 ± 1.17	4.415 to 10.775	19
138	Habersham Creek	Mud	3	0.75 ± .96	7.69 ± 1.00	6.99 to 8.83	20
140	Romerly Marsh	Shell/Mud	25	6.25 ± 6.29	8.02 ± 1.34	3.34 to 9.55	21
141	Romerly Marsh	Shell/Mud	27	6.75 ± 4.11	8.12 ± 0.99	6.20 to 10.01	22
158	Blue Bank Creek	Shell/Mud	18	4.5 ± 1.73	5.92 ± 0.57	4.88 to 6.775	23
163	Dead Man Hammock	Shell/Mud	2	0.5 ± .58	6.51 ± 0.09	6.45 to 6.575	24
164	Wassaw Island	Shell/Mud	8	2.0 ± 1.41	6.99 ± 1.40	5.51 to 9.885	25
175	House Creek	Sand	56	14.0 ± 10.23	5.69 ± 1.32	1.77 to 7.615	26
178	House Creek	Sand	144	36.0 ± 45.03	7.07 ± 1.44	2.25 to [illegible]	27
174	House Creek	Mud	18	4.5 ± 2.52	8.76 ± 1.19	4.50 to 10.04	28
174	House Creek	Shell/Mud	51	12.75 ± 17.5	7.72 ± 1.22	3.24 to 10.07	29
1	Cabbage Island	Shell	132	33.0 ± 20.64	3.77 ± 1.69	0.42 to 7.215	30
180	Little Tybee Creek	Sand/Mud	20	5.0 ± 5.23	9.58 ± 1.65	4.58 to 11.235	31
182	House Creek	Shell/Mud	118	29.5 ± 9.47	7.87 ± 1.44	2.38 to 10.08	32
183	House Creek	Shell	197	49.25 ± 21.0	5.96 ± 2.41	1.13 to 9.50	33
184	Little Tybee Creek	Shell	46	11.5 ± 6.95	6.79 ± 1.63	2.90 to 9.04	34
185	Little Tybee Creek	Shell/Sand	36	9.0 ± 9.2	7.97 ± 1.87	2.17 to 10.05	35
16	S. Cabbage Island	Sand	39	9.75 ± 4.99	6.73 ± 1.67	2.76 to 9.46	36
188	Cabbage Island	Shell	81	20.25 ± 8.85	4.88 ± 1.43	1.10 to 7.44	37
187	House Creek	Shell/Mud	392	98.0 ± 88.5	7.48 ± 1.44	2.11 to 10.57	38
196	Cabbage Island	Shell/Mud	4	1.0 ± 1.15	4.61 ± .61	3.82 to 4.90	39

Table 2. Average Clam Density by Location.

A. Among oysters on intertidal oyster bars - LOWEST	Less than $/m^2$
B. On oyster bars with significant shell deposits	$31/m^2$
C. In upper reaches of tidal creeks	
1. Sandy-mud	$16/m^2$
2. Sand	$12/m^2$
3. Mud	$3/m^2$
4. Bottoms with shell deposits	$26/m^2$
D. Small feeder creeks - HIGHEST	$36/m^2$

Table 3. Commercial Hard Clam Size Categories (According to Godwin, 1967).

Commercial Grade	Shell Lengths (cm)
Juveniles	> 3.7
Littlenecks	3.8 to 6.7
Cherrystones	6.8 to 7.7
Chowders	> 7.7

Table 4. Percentage of clams inflicted and percentage of stations exhibiting particular infliction.

	No. of clams examined	No. of clams inflicted	Percentage inflicted	Avg. Length of clam ± S.D. (cm)	Range (cm)	% of Stations (N=57) with inflicted clams
Crab chips	2339	227	9.71	8.07 ± 1.34	3.915 to 11.07	80.70
Busycon chips	2339	63	2.69	7.48 ± 1.56	3.48 to 11.07	19.30
Cliona spp.	2339	93	3.98	8.20 ± .99	3.455 to 10.465	29.82

Table 5: Densities of Busycon spp. for different geographical areas.

SOURCES	AREA	GIVEN DENSITY	DENSITY PER HECTARE
Magalhaes 1948	Beaufort, N.C.	1/89 ft^2	1,200
Nichy and Menzel 1958	Alligator Harbor, Fla.	1/25 m^2	400
Carriker 1951	Little Egg Harbor, N.J.	1/100 ft^2	1,100
Walker *et al.*	Savannah, Georgia	0.54/25 m^2	214

Table 6. Comparison of densities of oyster drills, *Urosalpinx cinerea*, at the base of the oyster bar (LOW) and at the top of the bar (HIGH).

	NUMBER OF STATIONS	NUMBER OF .1m^2 SAMPLES/STATION	NO. OF DRILLS COLLECTED	AVERAGE NO. PER m^2 + SD	RANGE IN AVERAGE NO./ m^2
LOW	5	6	398	133.3 ± 51.2	66.7 to 135.7
HIGH	5	6	65	27.2 ± 36.50	7.7 to 82.5

Table 7. Average densities or range of densities given for different geographical areas by various authors.

INVESTIGATOR	YEAR	LOCATION	TIDAL ZONE	RANGE DRILLS/ UNIT AREA	$\bar{X}$ NO./ UNIT AREA
Stauber*	1943	Del. Bay, New Jersey	Subtidal		$5/m^2$
			Intertidal	237 to $947/m^2$	
Mistakidis*	1951	England	Subtidal	0 to $6/m^2$	$2/m^2$
Nelson*	1922	New Jersey	Intertidal		$29/m^2$
Carriker*	1953	New York		0 to $344/m^2$	
Chesnut*	1954	North Carolina		9 to $106/yd^2$	
Lunz*		South Carolina		0 to $36/yd^2$	
Turgeion and Fralick	1973	New Hampshire	Subtidal	0 to $7/m^2$	
Walker et al.	1980	Georgia	Intertidal	0 to $210/m^2$	$35/m^2$

* From Carriker, 1955

Table 8. Occurrence of crab chipping at various stations.

Station number	Total No. clams	No. clams attached	Percentage	Average Length of clam attached ± S.D. (cm)	Range (cm)
109	33	4	12.12	7.95 ± .35	7.55 to 8.32
110	146	3	2.05	8.565 ± .59	7.90 to 9.03
111	13	4	30.77	8.68 ± 1.28	6.78 to 9.52
112	25	3	12.00	7.94 ± 1.43	6.73 to 9.525
113	281	29	10.32	8.91 ± .92	6.68 to 10.40
114	174	7	4.02	8.37 ± .94	7.45 to 9.71
115	101	7	6.93	8.33 ± .62	7.40 to 9.135
116	294	15	5.10	7.63 ± 1.08	5.48 to 9.055
119	13	3	23.10	9.39 ± .61	8.765 to 9.975
120	23	3	13.04	7.66 ± .71	6.96 to 8.38
121	15	5	33.33	9.47 ± .67	8.67 to 10.21
122	36	14	38.89	9.28 ± .61	8.215 to 10.335
123	61	2	3.28	8.635 ± .67	8.16 to 9.11
124	29	1	3.45	7.77	7.77
125	1	1	100.00	7.935	7.935
137	2	1	50.00	9.46	9.46
140	6	2	33.33	8.59 ± .40	8.31 to 8.87

Table 8. Occurrence of crab chipping at various stations. (Continued)

Station number	Total No. clams	No. clams attached	Percentage	Average Length of clam attaches ± S.D. (cm)	Range (cm)
143	11	2	18.18	7.96 ± .47	7.63 to 8.29
145	11	1	9.09	8.395	8.395
147	4	1	25.00	7.30	7.30
150	125	5	4.00	6.42 ± 2.56	3.915 to 10.41
122m^2	10	1	10.00	8.83	8.83
123m^2	126	6	4.76	8.54 ± .62	7.575 to 9.49
124m^2	91	6	6.59	8.66 ± .63	7.75 to 9.485
138m^2	3	1	33.33	8.83	8.83
158m^2	22	1	4.55	6.885	6.885
159	36	2	5.56	6.63 ± 1.69	5.44 to 7.825
151	1	1	100.00	9.415	9.415
153	5	1	20.00	8.645	8.645
155	4	1	25.00	7.395	7.395
162	6	1	16.62	6.73	6.73
1	82	16	19.51	7.57 ± 1.66	5.63 to 11.07
163	25	7	28.00	6.63 ± 1.18	5.34 to 8.24
164	19	2	10.53	7.21 ± .08	7.15 to 7.26

Table 8. Occurrence of crab chipping at various stations. (Continued)

Station number	Total No. clams	No. clams attached	Percentage	Average Length of clam attached ± S.D. (cm)	Range (cm)
164m[2]	8	5	62.50	7.04 ± 1.62	6.02 to 9.885
165	17	16	94.12	6.88 ± .98	5.60 to 8.12
166	8	3	37.50	9.40 ± 1.72	7.44 to 10.68
167	8	3	37.50	7.56 ± .92	6.54 to 8.315
169	1	1	100.00	9.82	9.82
173	71	11	15.49	7.05 ± 1.55	4.24 to 10.07
174	20	4	20.00	8.44 ± .65	7.75 to 9.31
174m[2]	51	6	11.76	7.98 ± 1.01	6.22 to 9.01
175m[2]	56	2	3.57	6.02 ± .68	5.54 to 6.505
174m[2]	18	1	5.56	8.755	8.755
178m[2]	144	10	6.94	7.68 ± .98	5.36 to 8.92
179	12	6	50.00	9.20 ± .92	8.11 to 10.20
TOTAL	2248	227	10.10	8.06 ± 1.34	3.915 to 11.07

Table 9. Occurrence of Cliona at various stations with percent infestations.

Station Number	Total No. clams	No. Clams Infested	Percent Infestation	Average Length of Clams Infested ± S.D. (cm)	Range (cm)
110	146	30	20.54	7.81 ± 1.10	3.455 to 9.305
113	281	2	0.71	9.68 ± 1.05	8.93 to 10.42
115	101	1	0.99	8.17	8.17
116	294	9	3.06	8.48 ± .54	7.475 to 9.21
120	23	1	4.35	8.81	8.81
122	36	4	11.11	9.77 ± .37	9.565 to 10.32
123	61	1	1.64	10.465	10.465
124	29	1	3.45	9.075	9.075
140	6	1	16.67	8.35	8.35
143	11	1	9.09	7.78	7.78
123m^2	126	3	2.38	7.91 ± .30	7.575 to 8.16
1	82	2	2.44	6.65 ± .90	6.01 to 7.28
166	8	1	12.50	7.44	7.44
169	1	1	100.00	9.82	9.82
178	5	1	20.00	8.12	8.12
178m^2	144	31	21.53	8.04 ± .51	7.01 to 9.68
121	15	3	20.00	9.68 ± .37	9.34 to 10.08
Total	1369	93	6.79%	8.20 ± .99	3.455 to 10.465

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APPENDIX A: TABLE A

TABLE A. Time-Effort Sample Station Data 1977-1979.

Station Number	Substrate	No. Clams Collected	Average Length ± S.D. in cm	Range in cm	No. of clams per 15 min.
1	Sand/Shell	100	5.57 ± 2.46	1.93 to 7.96	2.1
2	Sand/Shell	200	4.87 ± 1.96	1.61 to 7.52	12.5
3	Shell/Mud	0			0
4	Mud	0			0
5	Mud	0			0
6	Mud/Shell	3	7.72 ± 1.61	6.52 to 9.55	9
7	Mud/Shell	49	6.245 ± 1.20	2.695 to 8.29	12.25
8	Sand	0			0
9	Shell/Mud	0			0
10	Shell/Mud	0			0
11	Shell/Mud	0			0
12	Shell/Mud	4	7.01 ± 8.23	6.18 to 8.12	2
13	Mud/Clay	5	5.38 ± .564	4.69 to 6.08	2.5
14	Sand/Mud	0			0
15	Shell/Sand	59	7.47 ± .87	5.48 to 8.79	14.25
16	Sand/Shell	3	7.26 ± .64	6.85 to 8.00	1.5
17	Sand	2	5.79 ± 4.29	2.75 to 8.83	1
18	Mud/Clay	36	8.14 ± 1.04	5.50 to 10.11	18

TABLE A. Time-Effort Sample Station Data 1977-1979. (Continued)

Station Number	Substrate	No. Clams Collected	Average Length ± S.D. in cm	Range in cm	No. of clams per 15 min.
19	Mud/Clay	0			0
20	Mud/Shell	0			0
21	Mud/Shell	25	8.06 ± 1.10	5.51 to 10.33	6.25
22	Shell/Mud	0			0
23	Mud	5	8.26 ± .32	7.90 to 8.58	5
24	Mud	4	7.41 ± 2.41	3.815 to 8.895	6
25	Sand/Shell	1	10.45 ± 0.00		1
26	Mud/Clay	0			0
27	Mud	0			0
28	Mud	0			0
29	Mud/Shell	0			0
30	Shell/Mud	0			0
31	Sand/Mud	0			0
32	Mud	0			0
33	Mud	0			0
34	Sand/Mud	3	10.02 ± .73	9.32 to 10.78	1.5
35	Mud/Shell	2	8.44 ± 1.31	7.52 to 9.365	1
36	Shell/Mud	3	7.655 ± .86	6.70 to 8.335	1.5

TABLE A. Time-Effort Sample Station Data 1977-1979. (Continued)

Station Number	Substrate	No. Clams Collected	Average Length ± S.D. in cm	Range in cm	No. of clams per 15 min.
37	Mud/Shell	14	8.04 ± 1.21	5.88 to 10.12	3.5
38	Mud/Shell	1	4.875		
39	Mud/Shell	0			0
40	Mud/Shell	7	7.75 ± .93	6.55 to 8.99	3.5
41	Shell/Mud	0			0
42	Shell	13	9.50 ± .81	8.22 to 11.00	13
43	Shell/Mud	31	7.43 ± 1.10	4.91 to 9.35	15.5
44	Mud/Shell	0			0
45	Mud/Shell	0			0
46	Shell/Mud	13	7.42 ± 1.54	3.88 to 9.22	6.5
47	Shell/Mud	21	7.40 ± 1.55	2.965 to 8.895	10.5
48	Mud/Shell	0			0
49	Mud/Shell	2	7.60 ± .41	7.315 to 7.885	2
50	Mud/Shell	1	8.845		1
51	Shell/Mud	3	7.72 ± 1.60	5.88 to 8.795	3
52	Shell/Mud	8	8.61 ± 1.57	5.945 to 10.335	4
53	Shell/Mud	7	7.67 ± 1.044	6.40 to 9.22	3.5

TABLE A. Time-Effort Sample Station Data 1977-1979. (Continued)

Station Number	Substrate	No. Clams Collected	Average Length ± S.D. in cm	Range in cm	No. of clams per 15 min.
54	Shell/Mud	2	7.36 ± .22	7.20 to 7.515	1
55	Mud/Shell	0			0
56	Sand	0			0
57	Sand	0			0
58	Sand	0			0
59	Sand	0			0
60	Sand	0			0
61	Mud	0			0
62	Mud	0			0
63	Shell/Mud/Sand	2	5.82 ± 3.15	3.595 to 8.05	1
64	Shell/Mud	0			0
65	Mud/Shell	0			0
66	Shell/Mud	1	8.12		0.5
67	Mud/Sand/Shell	0			0
68	Mud/Shell	0			0
69	Mud/Shell	0			0
70	Mud	0			0

TABLE A. Time-Effort Sample Station Data 1977-1979. (Continued)

Station Number	Substrate	No. Clams Collected	Average Length ± S.D. in cm	Range in cm	No. of clams per 15 min.
71	Mud/Shell	0			0
72	Clay/Mud	0			0
73	Clay/Mud	0			0
74	Mud/Shell	0			0
75	Mud/Sand/Shell	0			0
76	Shell/Sand/Mud	0			0
77	Mud/Shell	0			0
78	Mud/Shell	0			0
79	Sand/Shell	0			0
80	Shell/Mud	0			0
81	Sand/Mud	0			0
82	Sand/Mud	0			0
83	Mud	0			0
84	Sand/Mud	0			0
85	Mud	0			0
86	Mud/Sand/Shell	1	5.74		5
87	Clay/Mud	0			0

TABLE A. Time-Effort Sample Station Data 1977-1979. (Continued)

Station Number	Substrate	No. Clams Collected	Average Length ± S.D. in cm	Range in cm	No. of clams per 15 min.
88	Clay/Mud	0			0
89	Mud	0			0
90	Mud	0			0
91	Mud	0			0
92	Clay/Mud	0			0
93	Mud	0			0
94	Sand/Mud	0			0
95	Clay/Mud	0			0
96	Sand/Mud	0			0
97	Mud/Shell	0			0
98	Mud	0			0
99	Mud/Snad	114	9.44 ± .80	7.23 to 11.15	9.5
100	Sand/Mud	208	8.99 ± .82	5.00 to 10.67	17.3
101	Sand.Mud	94	8.96 ± .94	5.00 to 10.64	10.4
102	Sand/Mud	93	8.05 ± 1.19	4.06 to 10.28	10.3
103	Sand/Mud	318	8.85 ± .92	4.485 to 12.83	8.83
104	Sand/Mud	87	8.46 ± .96	3.42 to 10.36	4.83
105	Shell/Mud	189	6.27 ± 1.41	1.24 to 9.43	23.65

TABLE A. Time-Effort Sample Station Data 1977-1979. (Continued)

Station Number	Substrate	No. Clams Collected	Average Length ± S.D. in cm	Range in cm	No. of clams per 15 min.
106	Shell/Mud	2	10.85 ± .73	10.33 to 11.37	1
107	Shell/Mud	2	6.22 ± 1.65	5.055 to 7.39	1
108	Shell/Mud	13	7.44 ± 1.74	3.85 to 9.64	13
109	Sand/Mud	33	8.00 ± 1.17	5.05 to 9.62	16.5
110	Sand/Mud	146	7.84 ± .83	3.455 to 9.52	24.3
111	Sand/Mud	13	8.27 ± 1.50	5.08 to 9.88	6.5
112	Sand/Mud	35	7.20 ± 1.35	4.10 to 9.665	2.8
113	Sand/Mud	281	8.05 ± 1.30	3.75 to 10.665	3.1
114	Sand/Mud	174	7.32 ± 1.91	2.625 to 10.25	14.5
115	Sand/Mud	101	7.61 ± .99	3.35 to 9.465	26.8
116	Sand/Mud	294	7.60 ± 1.28	3.025 to 10.04	24.5
117	Sand	0			0
118	Sand/Mud	7	9.29 ± .55	8.52 to 10.315	5.25
119	Sand/Mud	13	8.81 ± 1.09	7.06 to 10.47	9.75
120	Sand/Mud	23	8.11 ± .89	5.32 to 9.835	17.25
121	Sand/Mud/Shell	15	8.90 ± 1.20	5.805 to 10.21	5.6
122	Sand/Mud	36	8.77 ± 1.01	6.015 to 10.335	18
123	Mud	61	9.27 ± .70	6.81 to 10.81	6.75

TABLE A. Time-Effort Sample Station Data 1977-1979. (Continued)

Station Number	Substrate	No. Clams Collected	Average Length ± S.D. in cm	Range in cm	No. of clams per 15 min.
124	Shell/Mud	29	7.33 ± 1.31	5.01 to 9.645	2.9
125	Shell/Mud	1	7.935		1
126	Mud	0			0
127	Shell/Mud	0			0
128	Mud	0			0
129	Mud	0			0
130	Shell/Mud	0			0
131	Mud	0			0
132	Shell/Mud	5	7.90 ± .95	7.165 to 9.53	5
133	Shell/Mud	0			0
134	Mud	5	6.08 ± 1.99	2.65 to 7.59	5
135	Sand/Mud	4	5.18 ± 3.78	1.38 to 9.195	3
136	Sand/Mud	0			0
137	Mud	2	8.29 ± 1.65	7.12 to 9.46	2
138	Mud	3	7.93 ± .99	6.965 to 8.95	3
139	Mud	0			0
140	Mud/Sand/Shell	6	8.31 ± .62	7.15 to 8.82	9
141	Mud/Sand	5	7.91 ± 2.00	4.39 to 9.17	7.5

TABLE A. Time-Effort Sample Station Data 1977-1979. (Continued)

Station Number	Substrate	No. Clams Collected	Average Length ± S.D. in cm	Range in cm	No. of clams per 15 min.
142	Mud/Sand	3	7.37 ± 1.30	5.895 to 8.35	4.5
143	Mud/Sand/Shell	11	6.88 ± 1.42	4.18 to 8.29	8.25
145	Mud/Sand/Shell	11	7.05 ± 1.59	4.365 to 8.85	11
147	Sand/Mud	4	6.86 ± 2.29	3.50 to 8.455	4
148	Shell/Mud	8	7.00 ± .90	5.16 to 7.715	4
149	Shell	11	6.16 ± 1.24	4.40 to 7.78	8.25
150	Shell/Mud	125	5.11 ± 1.45	1.45 to 10.41	20.83
151	Clay/Mud	1	9.415		1
152	Shell/Mud	1	7.365		1
153	Sand	5	8.55 ± .98	7.31 to 9.635	5
154	Sand/Mud	0			0
155	Sand/Mud	4	8.31 ± 1.09	7.395 to 9.88	4
156	Sand/Mud	2	7.87 ± .35	7.62 to 8.12	2
158	Shell/Sand/Mud	22	6.18 ± .90	4.965 to 9.075	11
159	Shell/Sand/Mud	36	5.46 ± 1.04	3.09 to 7.97	18
160	Shell/Sand/Mud	1	5.63 ± .00		0.5
161	Sand	4	7.41 ± 1.86	5.06 to 9.46	2
162	Shell/Sand	6	5.83 ± .80	4.69 to 6.73	3

TABLE A. Time-Effort Sample Station Data 1977-1979. (Continued)

Station Number	Substrate	No. Clams Collected	Average Length ± S.D. in cm	Range in cm	No. of clams per 15 min.
163	Shell/Sand	25	6.69 ± 1.23	2.825 to 8.36	7.5
164	Shell/Sand/Mud	19	6.62 ± .69	4.95 to 7.89	5.7
165	Shell/Sand/Mud	17	6.84 ± .97	4.77 to 8.12	4.25
166	Mud/Sand	8	8.42 ± 1.34	7.01 to 10.65	4.8
167	Mud/Sand	8	7.59 ± 1.52	4.28 to 8.875	8
168	Mud/Sand	0			0
169	Shell/Mud/Sand	1	9.82	-	1.5
170	Sand/Mud	0			0
171	Sand/Mud	0			0
172	Shell/Mud	0			0
173	Shell	71	7.26 ± 1.14	4.24 to 10.07	5.9
174	Shell/Mud/Sand	20	7.20 ± 1.36	4.14 to 9.31	20
175	Sand	56	5.69 ± 1.32	1.77 to 7.615	56
176	Sand	0			0
177	Shell/Mud	0			0
178	Sand/Mud	5	6.95 ± 1.30	5.525 to 8.37	75
179	Shell/Sand	12	8.63 ± 1.41	4.915 to 10.20	18
180	Sand/Mud	20	9.58 ± 1.65	4.58 to 11.235	20

TABLE A. Time-Effort Sample Station Data 1977-1979. (Continued)

Station Number	Substrate	No. Clams Collected	Average Length ± S.D. in cm	Range in cm	No. of clams per 15 min.
181	Sand	0			0
182	Shell/Mud	118	7.87 ± 1.44	2.38 to 10.08	20
183	Shell	197	5.96 ± 2.41	1.13 to 9.50	32.8
184	Sand/Shell	46	6.79 ± 1.63	2.90 to 9.04	11.5
185	Sand/Shell	36	7.97 ± 1.87	2.17 to 10.05	9
186	Sand	0			0
187	Shell/Mud	392	7.48 ± 1.44	2.11 to 10.57	2.18
188	Shell	81	4.88 ± 1.43	1.10 to 7.44	0.45
189	Sand	0			0
190	Shell/Mud	16	6.04 ± 1.92	2.20 to 8.53	3.2
191	Mud/Shell	0			0
192	Shell/Mud	6	7.50 ± 1.41	5.37 to 9.00	1.2
193	Shell/Mud	2	8.05 ± .37	7.79 to 8.31	0.4
194	Shell/Mud	7	7.13 ± 1.87	4.66 to 9.61	1.4
195	Shell/Mud	1	7.53 ± 0.00	-	0.2
196	Shell/Mud	4	4.61 ± .61	3.82 to 4.90	0.8