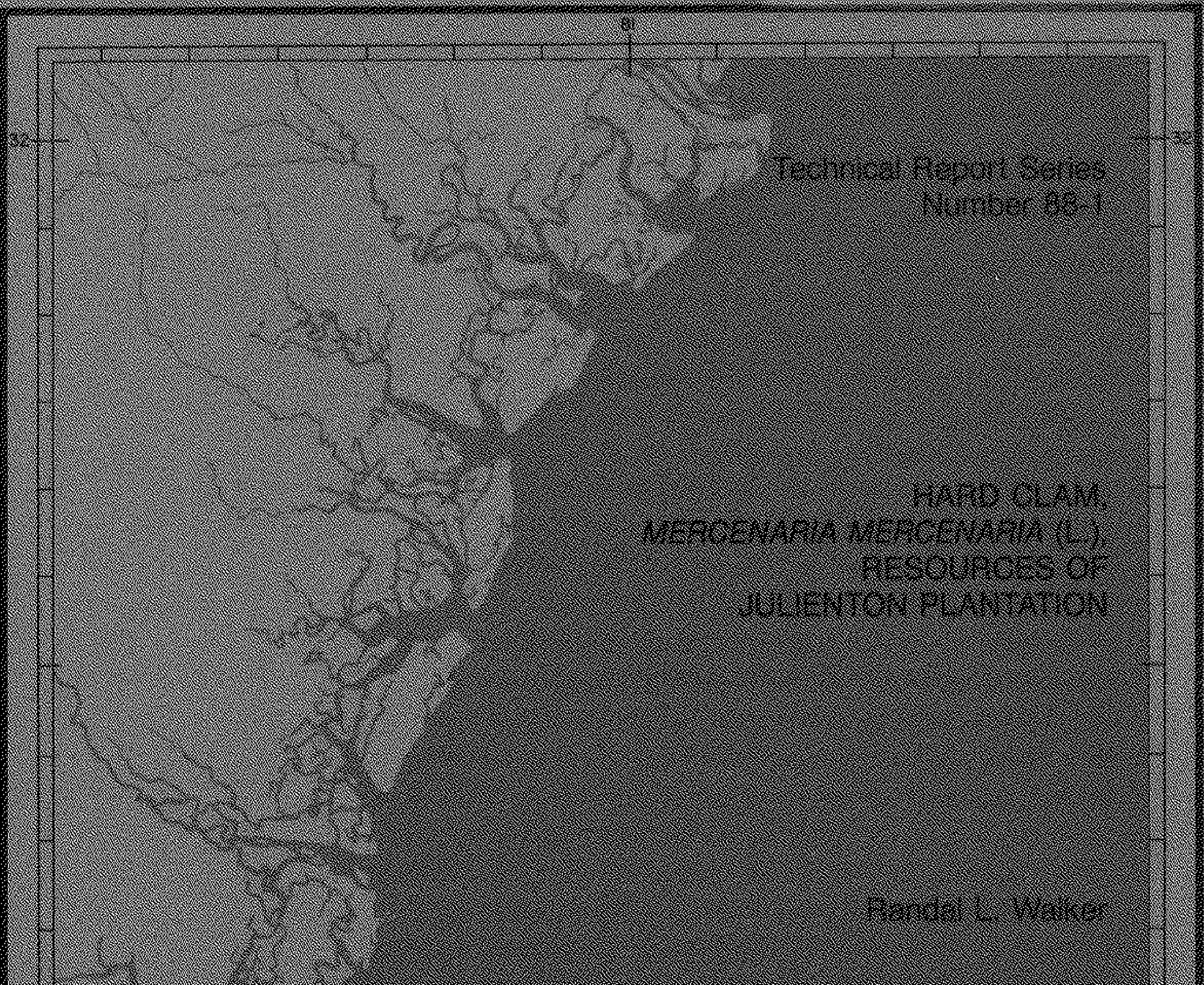

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HARD CLAM, *MERCENARIA MERCENARIA* (L.), RESOURCES OF JULIENTON PLANTATION

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Hard Clam, *Mercenaria mercenaria* (L.), Resources of Julienton Plantation

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Abstract

Forty-nine sites were surveyed in the Julienton Plantation, Harris Neck, Georgia, area to determine if commercial quantities of hard clams, *Mercenaria mercenaria*, occurred. Clams occurred at 19 stations with densities ranging from less than 1 to 50 clam^{-2}. Population growth curve, age structure, size structure, and commercial size groupings were determined for 15 stations. Native clams were up to 10 cm in shell length and 38 years of age with the commercial size littlenecks dominant. Replicate (N = 2) test cages seeded with clams at a mean shell length of 19.5 mm (N = 70 clams per cage) were set up at 8 sites within the area to determine the feasibility of clam mariculture. In general, native clams grow to marketable size in 2 to 3 years, whereas, cultured clams reach marketable size in 2 years.

Keywords: Aquaculture, bivalve, clam, coast, estuary, fishery, mollusc, recruitment, resource, saltmarsh, stock, survey

List of Figures

List of Tables

Table of Contents

Introduction

In response to a meeting of Georgia Sea Grant personnel and Mr. Gene Slivka of the Julienton Plantation on 7 June 1985, the following report is put forth to Mr. Slivka in response to his request for aid in developing his shellfish resources and expanding into the Georgia shellfish industry. This report describes the distribution, densities, growth rates, population age, and size-class structure, as well as the commercial size structure for various clam populations in the Julienton Plantation area. In addition, seed clams were planted at various sites to determine their relative growth rates. Finally, a survey of clam predators was undertaken in the test area. The results of these studies are reported herein.

Background

The molluscan shellfishery in Georgia consists of the American oyster, *Crassostrea virginica* Gmelin, the hard clam, *Mercenaria mercenaria* (L.), the calico scallop, *Argopecten gibbus* (L.), and four species of whelks: the knobbed whelk, *Busycon carica* (Gmelin), the lightning whelk, *Busycon contrarium* (Conrad), channeled whelk, *Busycotypus canaliculatum* (L.), and the pear whelk, *Busycotypus spiratum*. In the past, the oyster industry was the mainstay of the molluscan fishery (Harris, 1980), but today the oyster industry is in decline (Table 1). Commercial harvesting of hard clams has occurred sporadically since 1880 (Walker, 1984b), however, recently local and out-of-state fishermen have expressed considerable interest in expanding into the Georgia hard clam fishery. The scallop industry in Georgia began in 1965 and, as with the hard clam fishery, has had sporadic landings (Table 1). Scallops are harvested mainly by Florida fishermen and are processed at plants in Darien and St. Mary's, Georgia. Whelk harvesting began in 1981 and became the dominant molluscan fishery in 1982 (Table 1).

One way to re-establish a significant shellfish industry in Georgia is through diversification. Hard clams, soft-shell clams, surf clams, and scallops, in addition to oysters, offer good industry potential. Market demand for all five shellfish is well established and often exceeds supply. Growth of these shellfish is greater in warm southern waters than in the cooler waters of northern states. The result is that shellfish attain a marketable size quicker at lower latitudes (Ansell, 1968; Eldridge *et al.*, 1979; Walker, 1984a).

Oyster and clam harvesting in Georgia is now limited to manual gathering from intertidal beds, which is often done by blue crab fishermen during slack periods in their principal fishery. Despite the potential for increased production, harvest is constrained by the inefficient and sporadically employed harvesting methods, which preclude the availability of dependable and affordable supplies of shellfish for processing in Georgia.

One means of increasing shellfish production is to develop shellfish populations in underutilized areas. Georgia has a considerable expanse

Table 1. Landings and dockside value of molluscan species in Georgia. Data from Department of Natural Resources (1976-1986) and Lyles (1966, 1976).

Year	Oysters		Clams		Scallops		Whelks	
	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
1964	195,800	68,536	0	0	0	0	0	0
1965	247,700	86,696	0	0	1,200	787	0	0
1966	181,900	63,563	0	0	0	0	0	0
1967	203,100	114,007	0	0	0	0	0	0
1968	190,600	106,619	0	0	53,200	25,564	0	0
1969	255,500	144,376	0	0	3,000	1,000	0	0
1970	195,400	107,007	0	0	63,300	34,375	0	0
1971	138,500	72,870	0	0	0	0	0	0
1972	152,100	86,812	0	0	0	0	0	0
1973	105,900	65,122	5,800	4,510	0	0	0	0
1974	64,664	36,040	0	0	0	0	0	0
1975	44,962	25,613	0	0	0	0	0	0
1976	71,839	49,240	10,885	16,397	0	0	0	0
1977	87,221	75,009	0	0	0	0	0	0
1978	20,938	18,792	0	0	86,848	117,718	0	0
1979	11,375	11,459	0	0	32,760	45,209	0	0
1980	33,117	42,113	0	0	0	0	0	0
1981	24,898	35,716	5,855	21,014	*	*	6,842	4,334
1982	18,292	24,016	9,725	36,498	*	*	94,644	44,940
1983**	4,427	6,014	3,482	13,964	0	0	200,182	88,273
1984	5,916	9,208	3,474	11,866	*	*	494,231	238,027
1985	36,898	67,832	6,966	25,431	*	*	282,099	130,499
1986	3,941	7,878	17,220	52,398	0	0	74,959	28,005
1987	4,377	6,820	31,047	123,339	0	0	319,965	137,418

*Confidential data.
**Low landing for oysters and clams is due to the closure of waters to shellfish gathering for water quality reasons.

(450,000 acres) of essentially unpopulated and unpolluted coastal marsh. Undoubtedly, a substantial portion of these wetlands offer the optimal salinity, temperature, and turbidity regimes conducive to shellfish culture.

In 1983, 14.2 million pounds of hard clam meat valued at $42.4 million were landed in the United States (National Marine Fisheries Service, 1984). The south Atlantic states accounted for 13% of the landings. Of that, Georgia accounted for less than 1%. Most of the landings occurred in the New England and mid-Atlantic states, where clam growth is slow. At Bluepoints Co., Inc, W. Sayville, New York, 4 to 5 years are required for hard clams to grow to a marketable size of 25.4 mm in shell thickness (Craig Strong, personal communications). By comparison, it requires less than two years for hard clams to grow to a marketable size in the warmer coastal waters of Georgia (Walker, 1984a). Accordingly, there is an excellent potential for increasing hard clam production in Georgia through mariculture.

Although the coastal waters of Georgia contain unexploited populations of hard clams (Godwin, 1967, 1968; Walker *et al.*, 1980; Walker and Tenore, 1984; Walker and Rawson, 1985), most of these occupy small areas and are difficult to locate and harvest. They are, however, indicative of extensive pollution-free marshes suitable for shellfish production and culture. Hard clams grow year-round in southeastern U.S. waters (Eldridge *et al.*, 1979; Walker, 1984a), and clam densities above 25 m^{-2} are common in Georgia (Walker and Tenore, 1984). Densities up to 100 m^{-2} have been observed in intertidal regions of small creeks, headwaters of major creeks, and in shell deposits associated with oyster bars (Walker *et al.*, 1980; Walker and Tenore, 1984; Walker and Rawson, 1985).

As greater numbers of people have become interested in the hard clam fishery in Georgia, the Department of Natural Resources has begun to assign leases that give preferential treatment to individuals involved in developing and exploiting the clam resource. One means of increasing clam production in an area is to reseed after harvesting. Studies to date have shown that seeding with conventional size seed clams (2 to 10 mm) results in low recovery (Walker, 1983). This may be due to the high level of predation activity, heavy silt load of Georgia's coastal waters, or strong tidal currents. Clams planted at 6 mm within experimental predator-free cages grew to commercial size (44.4 mm in shell length) within 17 months with a greater than 80% survival rate (Walker, 1984a). If this can be duplicated on a commercial scale, it should be possible to increase hard clam landings in Georgia appreciably.

Since most natural clam populations in Georgia consist of 50% chowders (Walker *et al.*, 1980; Walker and Tenore, 1984; Walker and Rawson, 1985; Walker, 1987), mariculture is seen as the best method for increasing clam production, since it can produce large numbers of the more valuable littleneck clam. According to the current "Green Sheets" (price listing for fish and shellfish published by the National Marine Fisheries Service), littlenecks are now being sold at $0.15 each (as high as $0.30 last year) as compared to $0.03

for the chowder clam. Furthermore, chowders are not readily marketable; whereas there is always a market for littlenecks.

Methodology

Clams were collected from 49 populations around Julienton Plantation, Harris Neck, Georgia, by taking three 0.44 m^2 quadrat samples per site. A 66 x 66 cm square PVC frame was randomly thrown on the creek bottom. Clams occurring within the frame were dug by hand, placed in field sampling bags, and marked as to locality. Clams were then returned to the laboratory, where they were counted and measured for shell length (longest possible measurement, i.e., anterior-posterior). Clams from 15 of the 49 populations were also aged by shell sectioning techniques (see Rhoads and Lutz, 1980; Rhoads and Panella, 1970). Growth curves for each clam were constructed by measuring shell length at each summer annual ring increment.

The clams at each station were categorized according to the following commercial size groups: juveniles, less than 38 mm; pre-legal littlenecks, 38 to 44.4 mm; littlenecks, 44.4 to 67.0 mm; cherrystones, 68 to 77 mm; and chowders greater than 78 mm in shell lengths. This classification scheme is similar to Godwin's (1967) scheme except that his littleneck size class (38 to 68 mm) was divided into legal littlenecks, those greater than 44.4 mm and pre-legal littlenecks, those less than 44.4 mm (Walker 1984b).

To determine optimum hard clam mariculture sites, sixteen test cages were set up around the Julienton Plantation area (Figure 20). Two cages (30 x 30 x 30 cm, constructed of 13 mm mesh vinyl-coated wire) were buried at each site (N = 8 sites) 15 cm into the sediment with stakes attached at two corners of each cage. The cages were seeded with 70 clams (average shell length of 19.5 mm ± 0.2 S.E.) and the tops were attached. Cages were sampled in Summer 1987 to determine the relative growth rate of clams planted at the various sites.

Oyster drills, *Urosalpinx cinerea*, were collected from 22 stations by taking six 0.02 m^2 quadrat samples per site. A 10 x 20 mm square PVC frame was randomly thrown at the base of oyster bars. Drills found within the frame were picked from oysters and shells by hand, placed in field sampling bags, and marked as to locality. Drills were returned to the laboratory, where they were counted and measured for shell length (longest possible measurement, i.e., apex to the end of the siphonal canal).

The presence of other clam and oyster predators or parasites was noted, but no estimates of density or size were determined.

Results

Natural Hard Clam Populations

A total of 49 stations in the Julienton Plantation area were sampled for the presence of hard clams (Figure 1). Clams occurred at 19 stations and ranged in densities from less than 1 to 50 clams m^{-2} (Table 2). The majority of the clams occurred in creeks (83%) and within a shelly substrate (94%) (i.e., mud and shell, shell, or sandy-mud and shell).

Mean clam densities ranged from less than 1 to 50 clams per square meter (Table 2). Overall average density of the 15 clam populations sampled was 15 clams per square meter.

The growth curves of 15 clam populations (Figure 2) are given in Figures 3 - 17. In 93% of populations sampled, clams reached a mean marketable size (44.4 mm in shell length or 25.4 mm in shell thickness) in 2 to 3 years, while individual clams obtain this size in from under 2 to 7 years. Furthermore, average commercial size was obtained in less than 2 years for 33% of the populations and in less than 3 years for 93% of the populations. The exception to this is Sapelo Sound Station number 9, in which 5 years of growth were required before commercial size was obtained.

Population shell size and age structures are given in Figures 3 - 17. Clams were aged to 38 years with an overall mean age of 10.2 years. Overall, clams less than 10 years accounted for 65% of the harvested animals; whereas, clams 11 to 20, 20 to 30 and those greater than 30 years old accounted for 20%, 12% and 3% respectively. Most populations appear to be healthy as exhibited by the presence of individuals in the younger year classes. In terms of shell lengths, clams were recorded up to 10.10 cm with an overall mean shell length of 6.20 ± 1.23 S.D. cm.

In terms of commercial size grouping (Figures 18, 19 and 20), juveniles accounted for 3% of the overall population with pre-littlenecks, littlenecks, cherrystones and chowders accounting for 4%, 39%, 28% and 26% respectively. Chowders, cherrystones and littlenecks each dominated at 33% of the clam populations respectively.

Seed Hard Clams

The growth and survival rates of seed hard clams planted at the eight sites in the Julienton Plantation area are given in Table 3. Of the 16 test cages planted (two per 8 sites) 9 cages were recovered. No cages or stakes were recovered from Stations 1, 3, and 6. Cages were found as they were planted within the sediment only at Stations 5 and 2. At all other sites, cages were void of sediment, but were held in place by the stakes. Both cages were recovered at Station 8, but one damaged cage contained no clams.

Significant differences in growth were recorded at the 3 stations in which both test cages were recovered, as determined by Analysis of Variance

Table 2. The distribution and density (i.e., total number collected and number per m^2) of hard clams, *Mercenaria mercenaria*, collected at all stations (with substrate type given) about the Julienton Plantation area

Station	Area	Substrate	No. of Clams Collected	No. of Clams per m^2
1	Julienton River	Sandy-mud	0	0
2	Julienton River	Sand	1	<1
3	Julienton River	Sand	0	0
4	Dike Creek	Shell-sand	0	0
5	Julienton River	Sandy-mud	0	0
6	Julienton River	Shell-mud	0	0
7	Julienton River	Shell-mud	0	0
8	Gut Creek	Shell-mud	18	4
9	Julienton River	Shell-mud	0	0
10	Julienton River	Shell-mud	0	0
11	Major Creek	Shell-mud	2	<1
12	Major Creek	Shell-mud	40	10
13	Major Creek	Shell-mud	8	2
14	Major Creek	Mud	8	2
15	Major Creek	Shell-mud	13	5
16	Major Creek	Shell-mud	50	23
17	Major Creek	Sandy-mud	11	1
18	Julienton River	Shell-mud	0	0
19	Gut Creek	Shell-mud	40	8
20	Julienton River	Shell-mud	0	0
21	Gut Creek	Shell-mud	21	7
22	Gut Creek	Shell-mud	85	50
23	Sapelo Sound	Sandy-mud	0	0
24	Sapelo Sound	Shell	0	0
25	Sapelo Sound	Shell-mud	0	0
26	Sapelo Sound	Shell	31	21
27	Sapelo Sound	Shell-mud	0	0
28	Sapelo Sound	Shell	43	20
29	Sapelo Sound	Shell-mud	0	0
30	Barbour Island River	Shell-mud	0	0
31	Gut Creek	Shell-mud	0	0
32	Barbour Island River	Shell-mud	0	0
33	Gut Creek	Shell-mud	0	0
34	Barbour Island River	Shell-mud	0	0
35	Gut Creek	Shell-mud	0	0
36	Major Creek	Shell-mud	19	1
37	Barbour Island River	Shell-mud	0	0
38	Gut Creek	Shell-mud	27	11
39	Barbour Island River	Shell-mud	0	0
40	Gut Creek	Shell-mud	0	0
41	Barbour Island River	Shell-mud	0	0
42	Gut Creek	Shell-mud	22	6
43	Barbour Island River	Shell-mud	0	0
44	Gut Creek	Shell-mud	0	0
45	Barbour Island River	Shell-mud	0	0
46	Gut Creek	Shell-mud	1	<1
47	Major Creek	Shell-mud	38	4
48	Major Creek	Shell-mud	43	5
49	Barbour Island River	Mud	0	0

Table 3. Growth and survival of hard clams, *Mercenaria mercenaria*, planted in test cages in various areas about the Julienton Plantation. Shell length is given in mm ± one standard error

			12 December 1985		14 July 1987	
Station/ Area	Substrate	Habitat	Mean Shell Length	No.	Mean Shell Length	No.
Station 1 Julienton River						
Cage 1	Sand	Intertidal bar	19.5 ± 0.2	70	0	0
Cage 2	Sand	Intertidal bar	19.5 ± 0.2	70	0	0
Station 2 Julienton River						
Cage 1	Sand	Intertidal bar	19.5 ± 0.2	70	61.2 ± 0.9	62
Cage 2	Sand	Intertidal bar	19.5 ± 0.2	70	0	0
Station 3 Julienton River						
Cage 1	Sand	Intertidal bar	19.5 ± 0.2	70	0	0
Cage 2	Sand	Intertidal bar	19.5 ± 0.2	70	0	0
Station 4 Julienton River						
Cage 1	Sandy-Mud	Intertidal bar	19.5 ± 0.2	70	42.8 ± 0.8	23
Cage 2	Sandy-Mud	Intertidal bar	19.5 ± 0.2	70	47.0 ± 0.5	43
Station 5 Sapelo Sound						
Cage 1	Sandy-Mud	Intertidal bar	19.5 ± 0.2	70	55.7 ± 0.7	34
Cage 2	Sandy-Mud	Intertidal bar	19.5 ± 0.2	70	59.8 ± 0.7	66
Station 6 Sapelo Sound						
Cage 1	Sandy-Mud	Intertidal bar	19.5 ± 0.2	70	0	0
Cage 2	Sandy-Mud	Intertidal bar	19.5 ± 0.2	70	0	0
Station 7 Barbour Island River						
Cage 1	Sandy-Mud	Intertidal bar	19.5 ± 0.2	70	44.0 ± 0.4	69
Cage 2	Sandy-Mud	Intertidal bar	19.5 ± 0.2	70	39.7 ± 0.5	61
Station 8 Barbour Island River						
Cage 1	Sandy-Mud	Intertidal bar	19.5 ± 0.2	70	38.4 ± 0.5	18
Cage 2	Sandy-Mud	Intertidal bar	19.5 ± 0.2	70	0	0

(alpha - 0.05). Clams at Station 5 were greater in shell length than those at Station 4, which were not significantly different from those at Station 7, as determined by a Duncan's Multiple Range Test (r = 0.05). Significant differences, as determined by paired T-tests (alpha = 0.05), occurred for each of the samples with replicates. The results of the T-tests are as follows:

Cage Number:	8A	7B	4B	7A	4A	5A	5B	2A	
Mean Clam Size:	38.4	39.7	42.8	44.0	47.0	55.7	59.8	61.2	mm

Those which were not significantly different are underlined.

Oyster Drills

A total of 22 stations along the Barbour Island and Julienton Rivers were sampled for the presence of the oyster drill, *Urosalpinx cinerea* (Figure 21). Drills occurred at 11 stations and were particularly prominent at all stations along the Barbour Island River (Stations 1 - 5) and Sapelo Sound (Stations 6, 7 and 22), while they occurred only at 3 of the 14 (21%) stations along the Julienton River. Furthermore, drills sampled along the Barbour Island River and Sapelo Sound areas were greater in number and size than those along the Julienton River (Table 4).

Other types of oyster drills were not observed within the Julienton Plantation area. Only one shell of the Rough Oyster Drill, *Eupleura caudata*, was found at the junction of Barbour Island River and Sapelo Sound. This shell may well have been washed into the area by tides and currents. No Southern Oyster Drills, *Thais haemastoma*, were observed in the study area.

Whelks

At each station, the presence or absence of whelks was noted. Four whelk species occur in the coastal waters of Georgia: the knobbed whelk, *Busycon carica*; the lightning whelk, *Busycon contrarium*; the channeled whelk, *Busycotypus canaliculatum* and the pear whelk, *Busycotypus spiratum*. *B. contrarium* and *B. carica* occur intertidally in the spring and fall and prey upon clams and oysters (Walker, 1988). Only *B. carica* was noted in the Julienton Plantation area. *B. carica* occurred in low densities all along the Barbour Island River and Sapelo Sound areas. Several *B. carica* occurred at the junction of the Julienton River and Sapelo Sound, but none were observed within the Julienton River area.

Crabs

The mud crab, *Panopeus herbstii*, a serious predator to small clams and oysters, was observed at all stations. Mud crabs are abundant and occur throughout the estuarine system wherever oysters are found.

Table 4. Total number of oyster drills, *Urosalpinx cinerea*, collected, average number per 0.02 m^2 ± S.D. and mean shell length ± S.D. in cm of drills occurring per station within the Julienton Plantation area

Station	Number Collected	$\bar{x}$ No/core	$\bar{x}$ Shell length
1	7	1.2 ± 0.8	3.65 ± 0.18
2	25	4.2 ± 3.3	3.17 ± 0.58
3	20	3.3 ± 2.3	3.47 ± 0.56
4	3	0.2 ± 0.4	3.35 ± 0.37
5	10	1.7 ± 1.4	2.86 ± 0.86
6	3	0.5 ± 0.8	2.95 ± 1.16
7	2	0.3 ± 0.8	3.24 ± 0.62
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	4	0.7 ± 1.6	0.67 ± 0.09
14	0	0	0
15	1	0.2 ± 0.4	1.60
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0
21	1	0.2 ± 0.4	2.61
22	3	0.5 ± 0.5	3.44 ± 0.40

Oyster Parasites

The gastropod, *Boonea* (= *Odostomia*) *impressa*, was observed throughout the Julienton Plantation area. This gastropod is an ectoparasite which feeds upon the gills of oysters. Studies have shown that *Boonea* does retard the growth of oysters (White *et al.*, 1984), and that it is capable of spreading the oyster disease, *Perkinsus marinus* (White *et al*, 1987).

The boring sponge, *Cliona* sp., was observed at all stations on oysters and clams below the spring low water mark. This sponge burrows into shells and removes calcium for the formation of its spicules. The burrowing activity weakens the shell of its host, allowing other predators to more easily penetrate the clam or oyster.

Discussion

The results of this study show that the growth rate of natural clam populations around the Julienton Plantation area results in production of a marketable product in 2 to 3 years, except under extreme environmental conditions (i.e., clam Station 9). These findings agree with those growth rates observed in other naturally occurring clam populations in Georgia (Walker, 1984b; Quitmyer *et al.*, 1985; Walker and Stevens, in press; Walker, 1987). Of the 15 natural clam populations sampled, only clams at Station 9 (Figure 11) required an average of 5 years to reach marketable size. At Station 9, clams occur on top of an oyster wrack, well above mean low water mark, in a dense substrate of oyster shell. It is estimated that they are uncovered from the tide for 6 hours per tidal cycle. Even the lowest growth rate found (i.e., Station 9) for hard clams in the Julienton Plantation is as fast as the average growth rate reported for the Long Island Sound area, where the major hard clam fishery is located (Greene, 1978).

The life span of the hard clam, *Mercenaria mercenaria*, is estimated to be 40 years (Hopkins, 1930; Comfort, 1957). In Georgia, clams were aged to 38 years in this study, to 34 years in a clam population in the vicinity of Little Tybee Island (Walker, 1984b), to 40 years at Cabbage Island (Walker, 1987a), and to 25 years at King's Bay (Quitmyer *et al.*, 1985). In other studies of hard clam populations, clams were aged to 29 years at Cape Lookout, North Carolina (Peterson *et al.*, 1983), to 32 years at Core Sound, North Carolina (Peterson *et al.*, 1985), to 46 years in Johnson Creek, North Carolina (Peterson, 1986), to 20 years in Virginia (Haven and Loesch, 1973), to 15 years in Fishers Island, New York (Malinowski, 1985), and to 8 to 9 years in Barnegat Bay, New Jersey (Kennish, 1978).

In the 15 stations studied around the Julienton Plantation area, littlenecks were dominant. The results differ from those of previous resource surveys of Wassaw Sound (Walker *et al.*, 1980) , the Christmas Creek area (Walker and Stevens, in press), and those of the coastal waters of Georgia (Godwin, 1968; Walker and Rawson, 1984; Walker, 1987), where chowders dominate. The difference in findings can be explained in the small sample size of the 15 stations surveyed in this study. If one adds the data from the other 4 survey stations sampled in this study plus the data from the Walker and Rawson (1984) survey (21 stations with clams) for this area, littlenecks dominate, but to a lesser degree (Figure 20). Furthermore, clams (N = 43) from Station 9, at which the slowest growth rates were recorded, were mostly littlenecks in size but were the age of chowders from other stations.

Differences in the growth of seed clams planted at various sites around the Julienton River area are probably related more to disturbance of cages by currents than to other environmental factors. For instance, the most rapid clam growth occurred in cages 2A, 5A, and 5B. No significant difference in clam growth occurred in cages 2A and 5B, the only two cages which exhibited no signs of disturbance. Most clams were buried in the sediment when the study was terminated. Cage 5A was in good shape at termination, but 2 medium size blue crabs were in this cage, which had been damaged. Several clams were out of the sediment but within the cage and showed signs of attempted crab predation. Furthermore, numerous cracked clam shells occurred and hard clam survival was almost half that of the replicate cage. Clam growth at Station 4 also differed due to disturbance factors. Clams in cage 4B were found to be partially in the sediment, while those in cage 4A were completely without sediment. Both cages at some point were completely without sediment, since 100% of the clams were infested with the Boring Sponge, *Cliona* sp. *Cliona* cannot survive burial and must be exposed to the water to survive and grow. Clams in cage 4A were still infested with live *Cliona* upon termination of the experiment, whereas the *Cliona* was dead on the clams collected from cage 4B. In the areas of greatest currents (i.e., sandy areas), only one cage (2A) out of six was recovered.

It is important to note that all of the clams from Station 4 had been infested by *Cliona*. Although the sponge does not kill the clam or oyster directly, it does weaken the shell in varying amounts depending on the degree of infestation. Of the 34 clams recovered from cage 4A, half were killed by the process of collecting and transporting them back to the laboratory for final measuring. The *Cliona* infestation on clams from this cage was so severe that only gentle finger pressure was required to crush the shells of the clams.

The reason for the observed difference in oyster drill population dynamics between the Julienton River and other areas is unknown. One can speculate that it is due to the location of the Julienton River between two major land masses and the fact that this river receives more rain runoff than the other areas. Increased runoff could reduce the salinity of the Julienton River, while not appreciably affecting the salinity of the other areas. Oyster drills cannot survive salinities below 18 ppt. Thus, the small drills occurring in the Julienton River area may be this year's cohort that migrated into the area after the last major mortality.

Conclusions

(1) Hard clams occur throughout the Julienton Plantation area in commercial quantities.

(2) In the 15 clam populations studied, littlenecks (optimum commercial size) dominated in numbers; however, with increased sampling, it is believed that chowders would dominate.

(3) In general, clams from the Julienton Plantation area grew to commercial size in 2 to 3 years.

(4) Major shellfish predators, whelks and oyster drills, occur along the major rivers and creeks of the higher salinity areas, but were not observed in the Julienton River, an area of lower salinity.

(5) Major hard clam predators of concern to future clam growing projects are the blue and mud crabs.

The Julienton Plantation area has excellent potential for culturing various molluscan species. Data reported herein shows that native clams reach commercial size within 2 to 3 years. This growth rate is comparable to that observed for native clams throughout Georgia. Since seed clams (less than 10 mm size), which are non-native genetically selected strains, can be grown to marketable size in 14 to 18 months in Wassaw Sound, Georgia, one can assume that the same growth rates may be obtained in the Julienton Plantation area. The growth obtained for the 19.5 mm seed clams at stations 2 and 5 supports this assumption.

Hard clam (bottom) cage culture areas within the estuarine system of the Julienton Plantation are shown in Figure 23. Areas 1 and 2 occur on sandflats where cages suffered damage due to currents or were dug up or buried by the shifting sediments. Area 3 appears to be a marginal area, since the substrate is a firm sandy-mud and is well-protected against storms. Test cages planted here were recovered, but had little or no sediment within the cages; however, if cages were periodically checked and reburied, then clams would achieve a faster growth rate. Unfortunately, area 3 lies outside the Julienton Plantation area. Area 4 has the most suitable substrate (sandy-mud) for cage culture, and test cages planted here produced the best overall growth and survival rates. Area 5 has a muddy-sand substrate, which is not as good as a sandy-mud substrate; however, only the side nearest the ocean was tested. Areas nearer the mouth of the Little Mud River are probably suitable for hard clam bottom cage culture.

Due to the excellent growth of hard clams obtained at stations 2 and 5 (see Table 3) and the tremendous growth rate of natural clam populations throughout the Julienton Plantation area, the potential for clam mariculture development is excellent in this area.

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Figure 1. Stations about the Julienton Plantation sampled for hard clam populations.

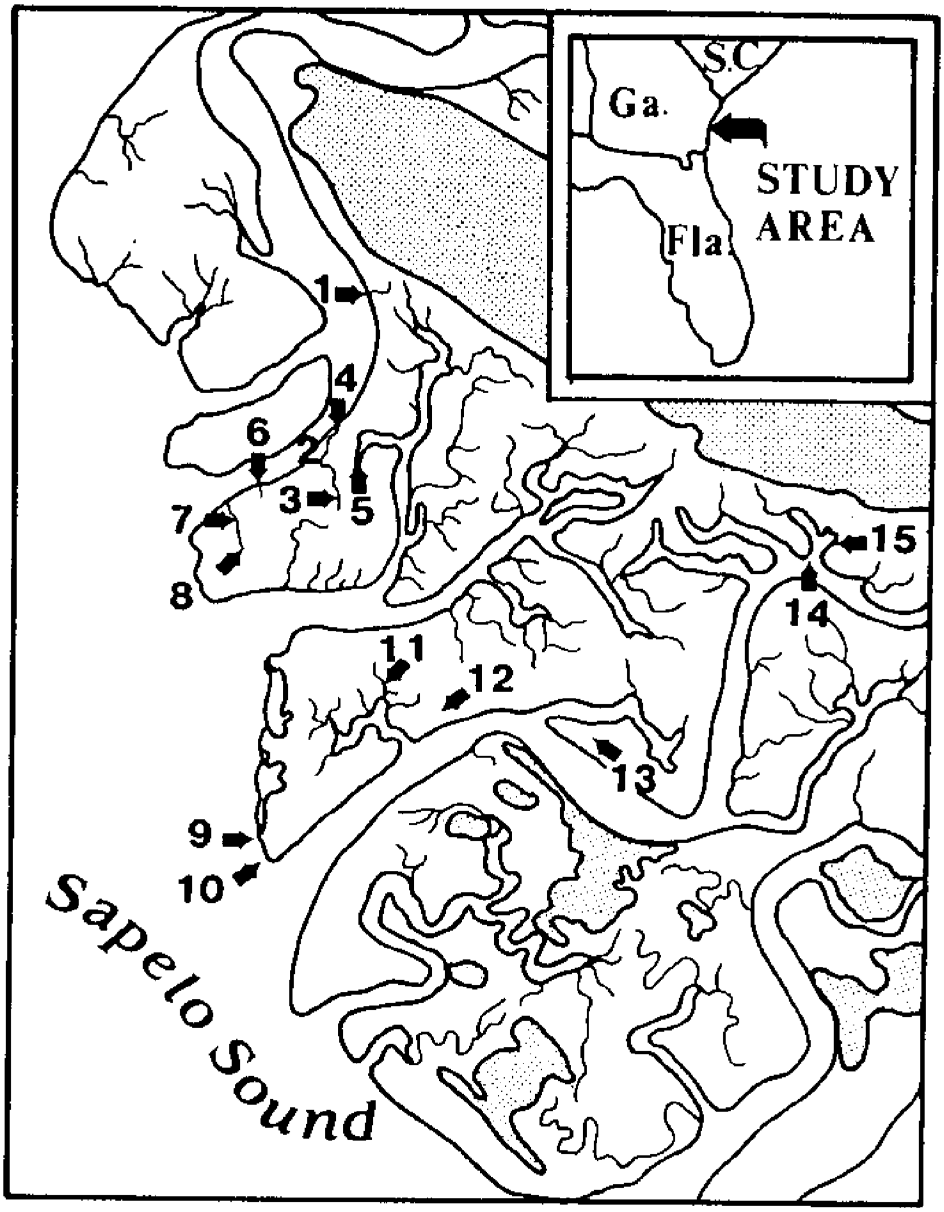

Figure 2. Hard clam, *Mercenaria mercenaria*, populations sampled for growth rate, age, and size class structure.

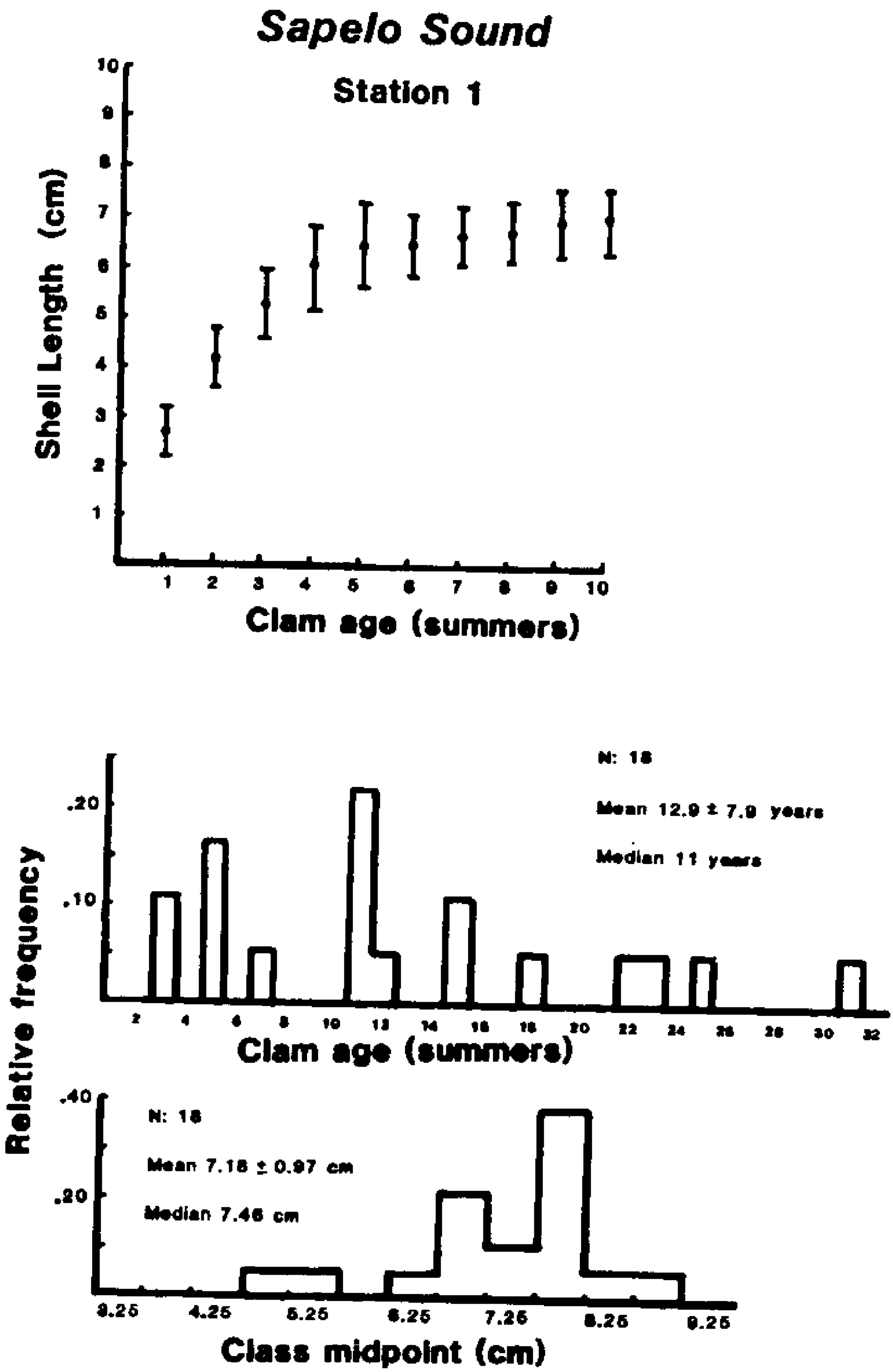

Figure 3. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 1.

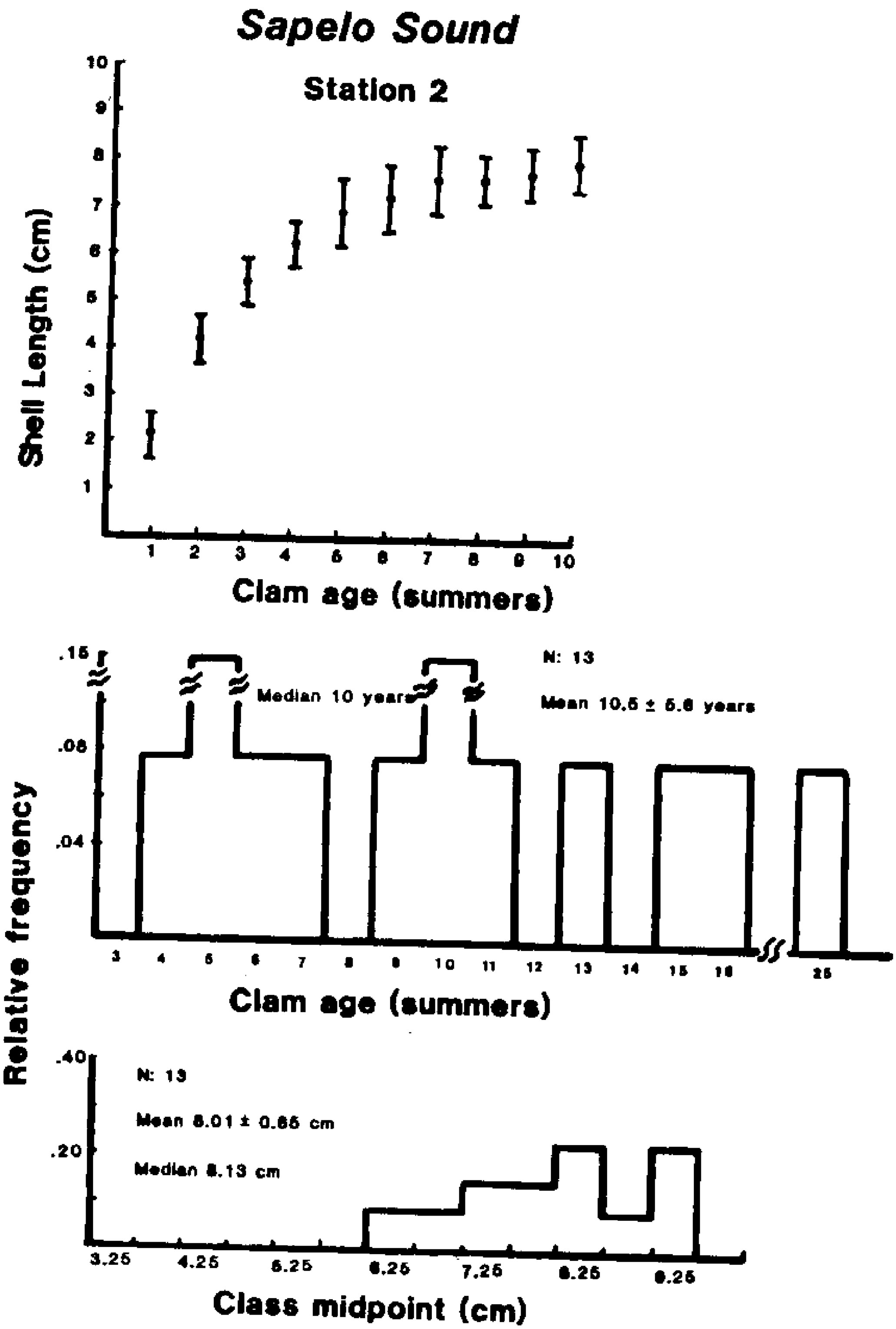

Figure 4. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 2.

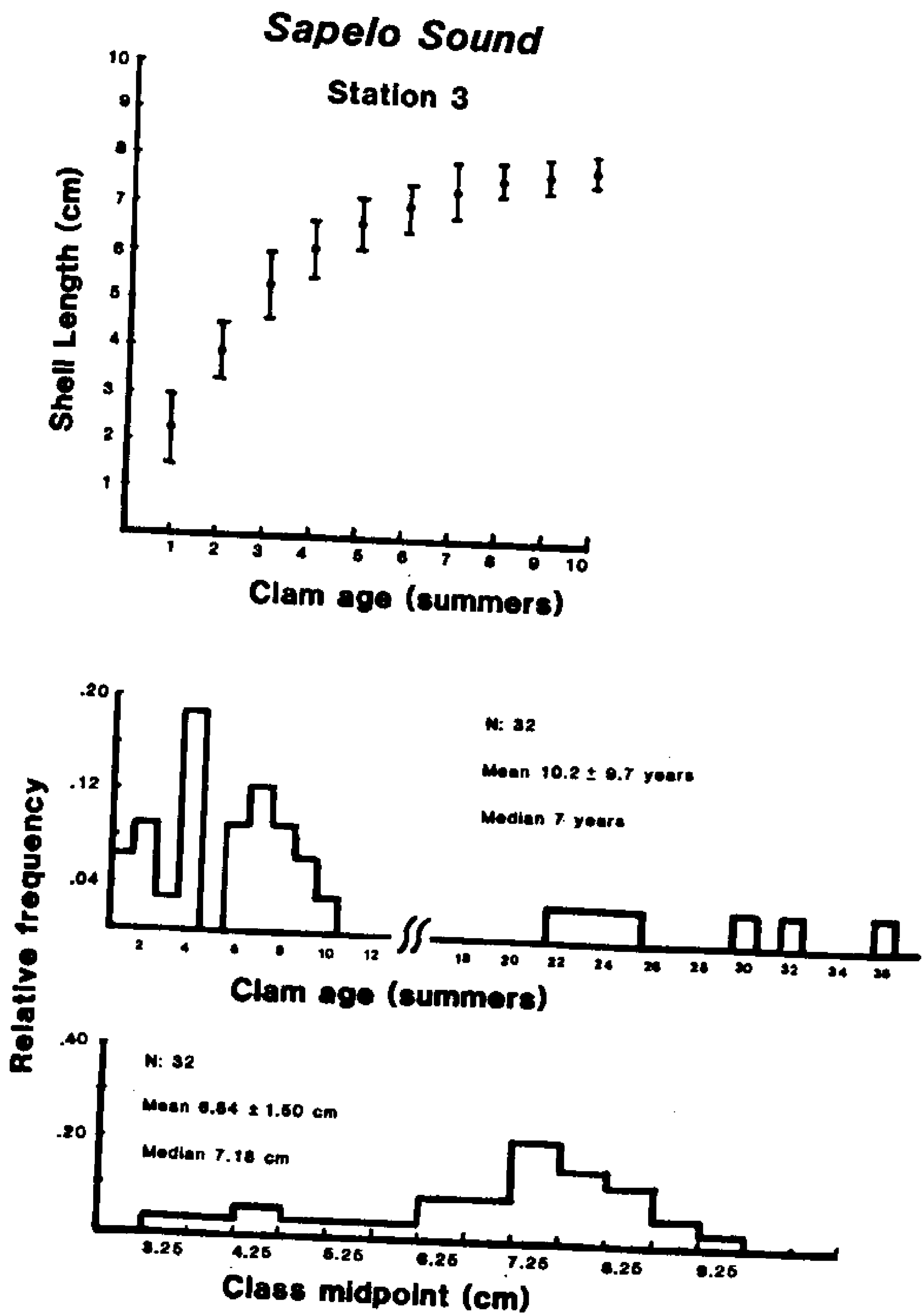

Figure 5. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 3.

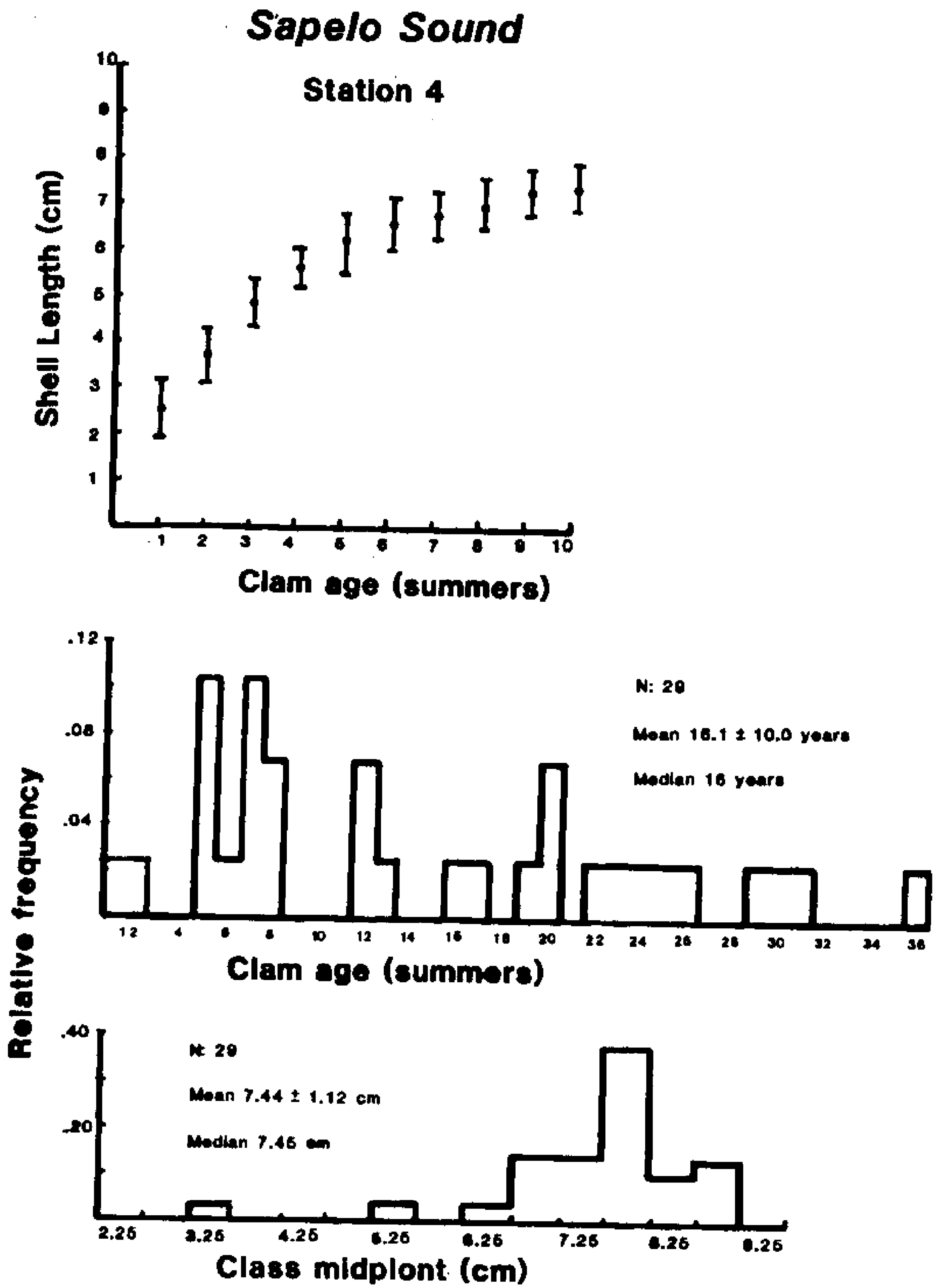

Figure 6. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 4.

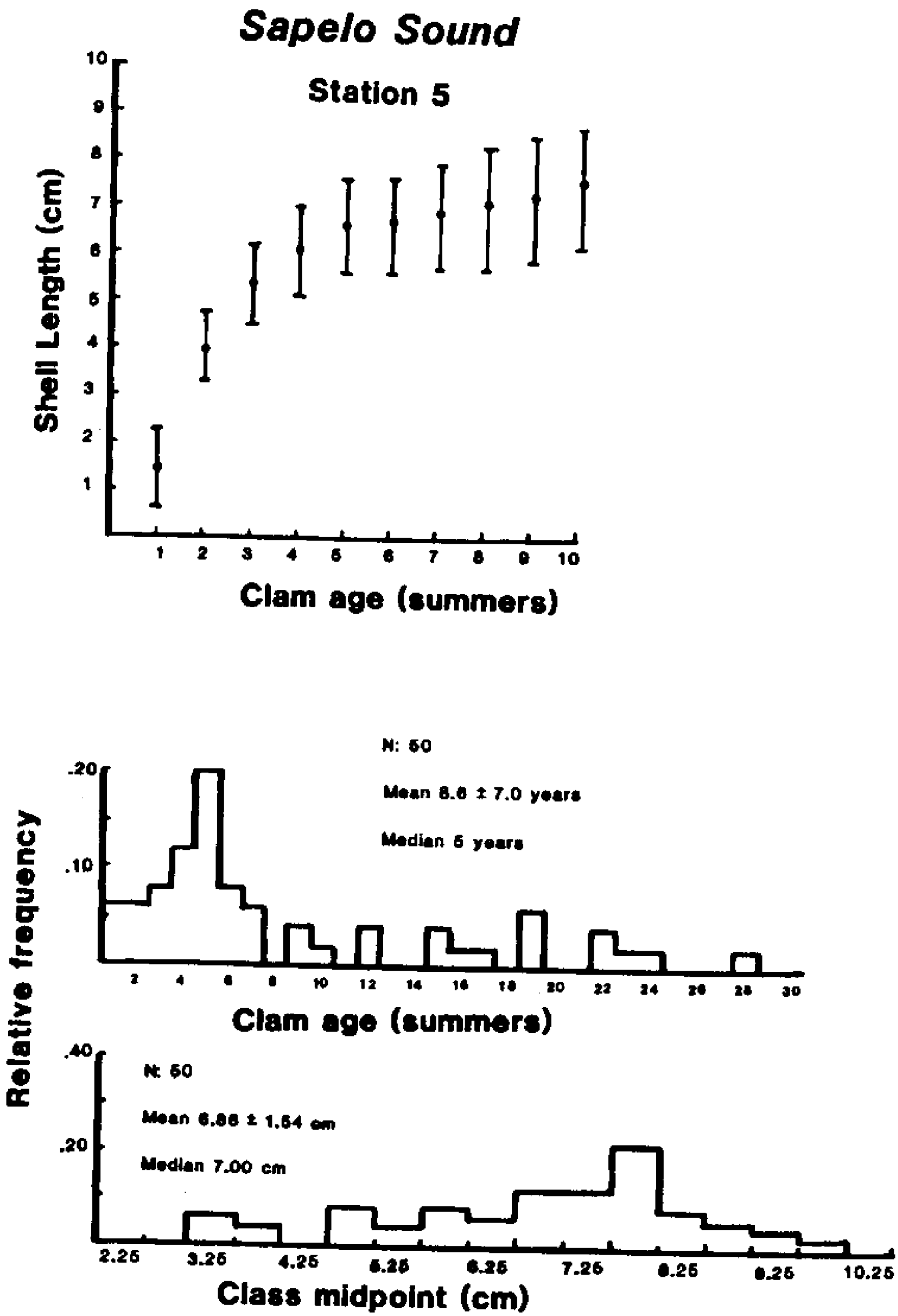

Figure 7. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 5.

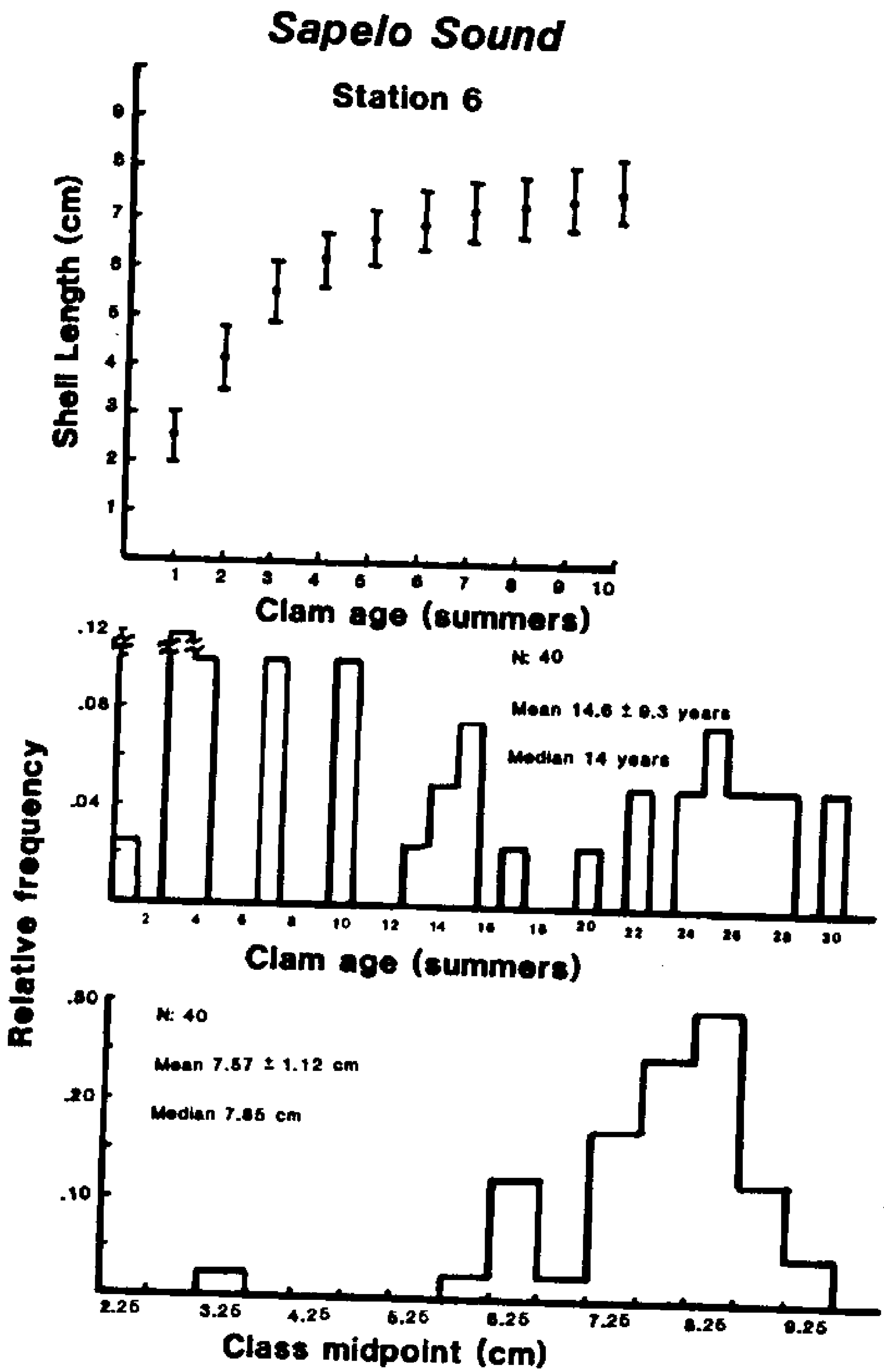

Figure 8. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 6.

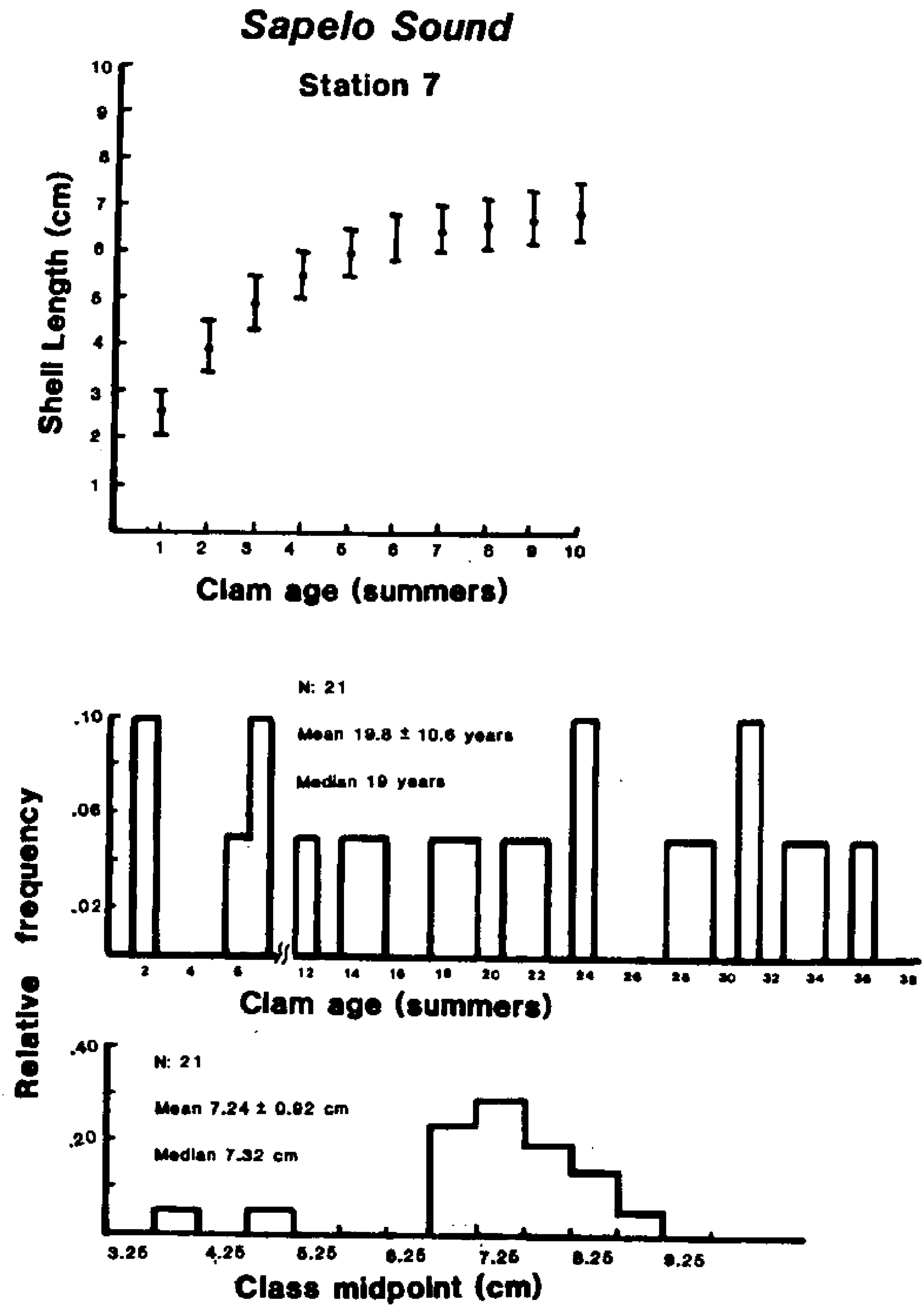

Figure 9. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 7.

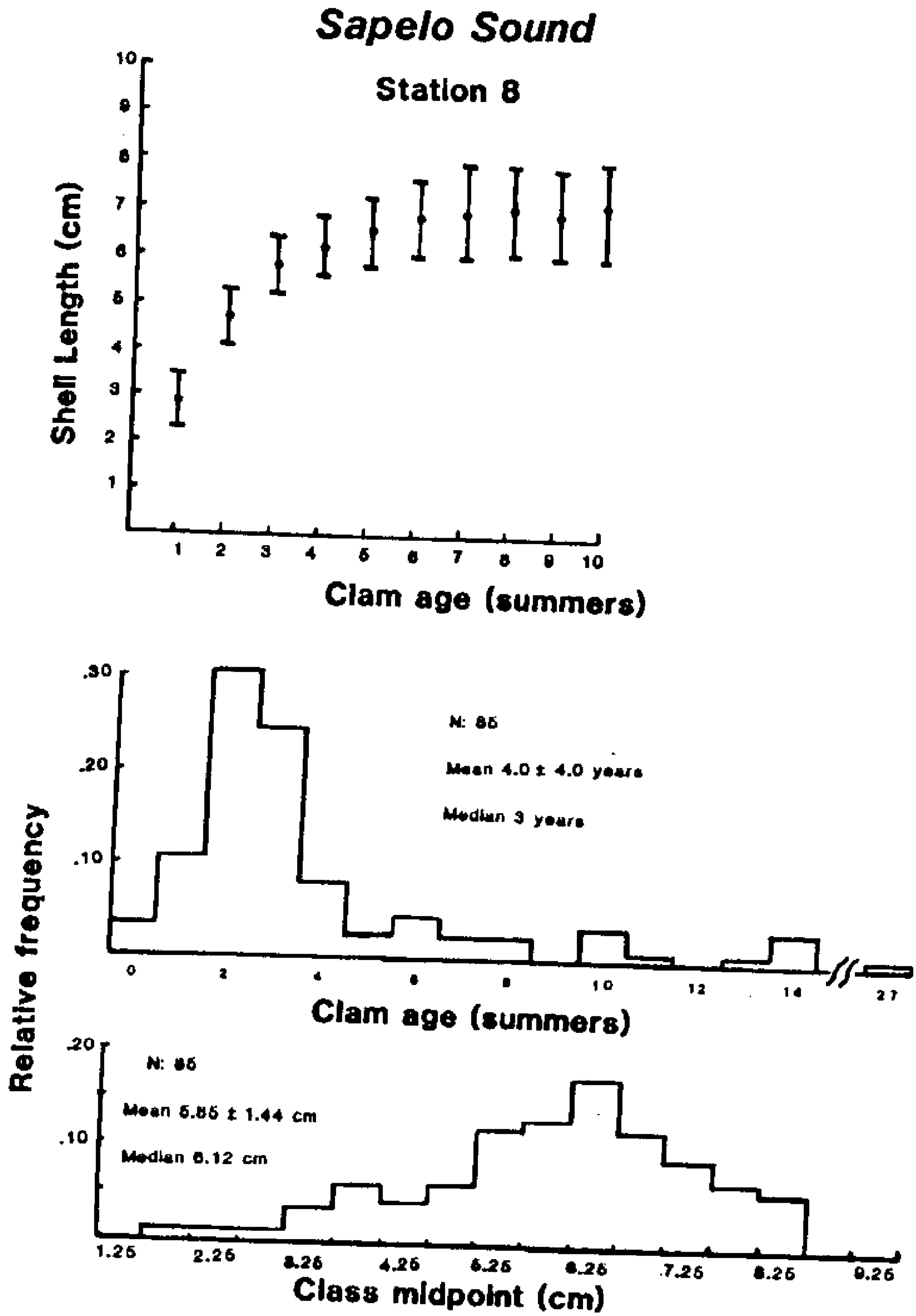

Figure 10. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 8.

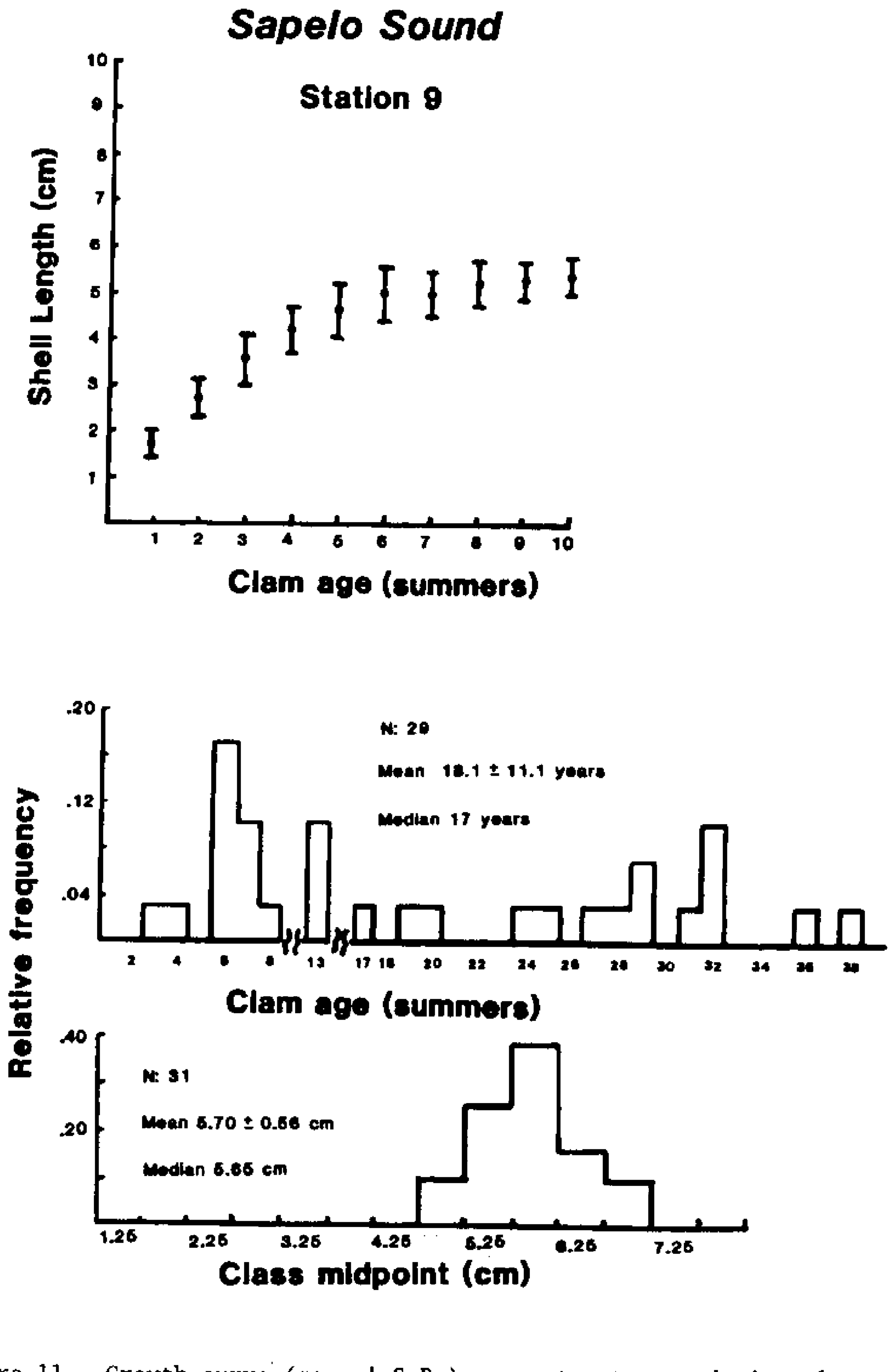

Figure 11. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 9.

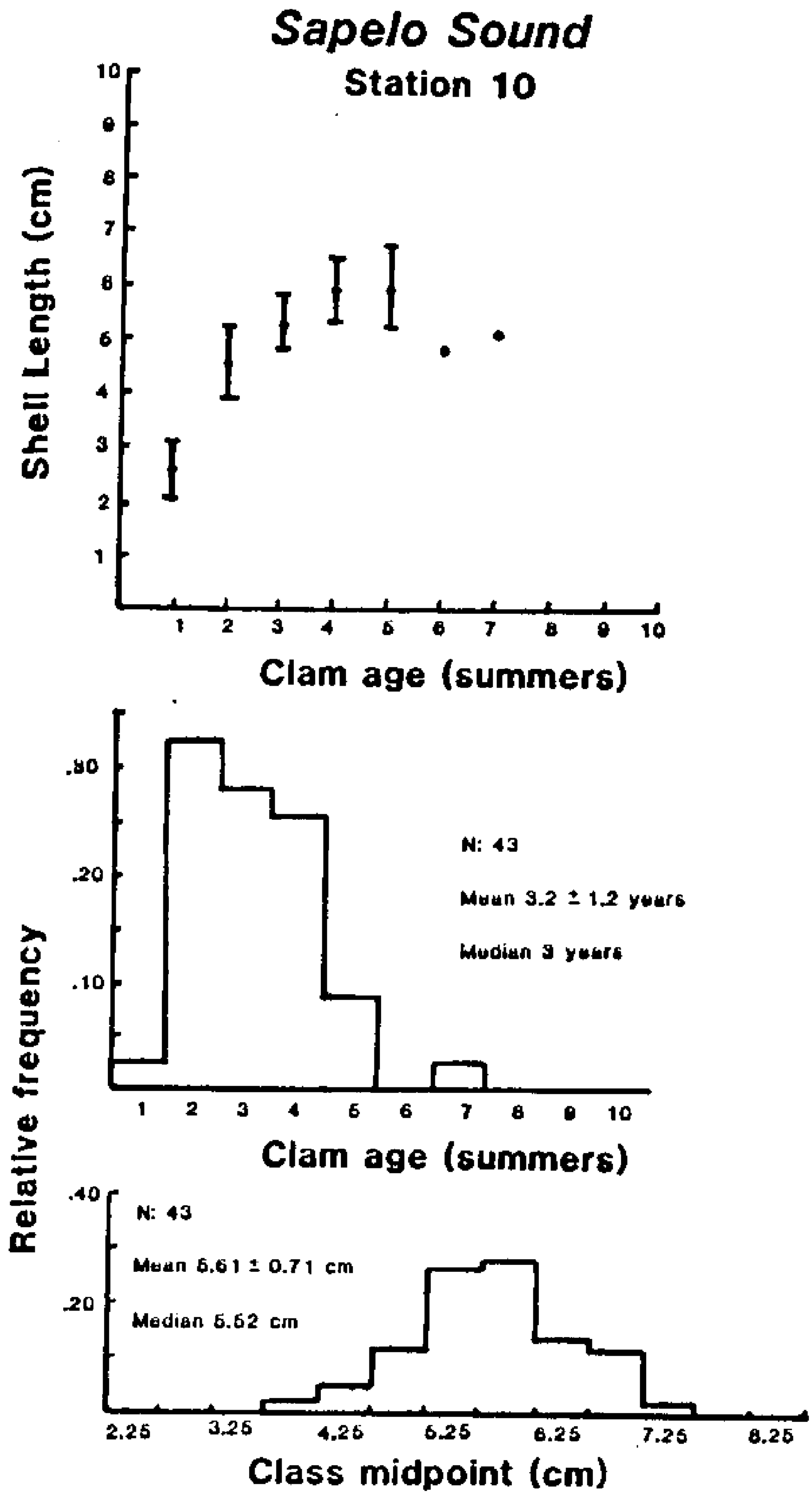

Figure 12. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 10.

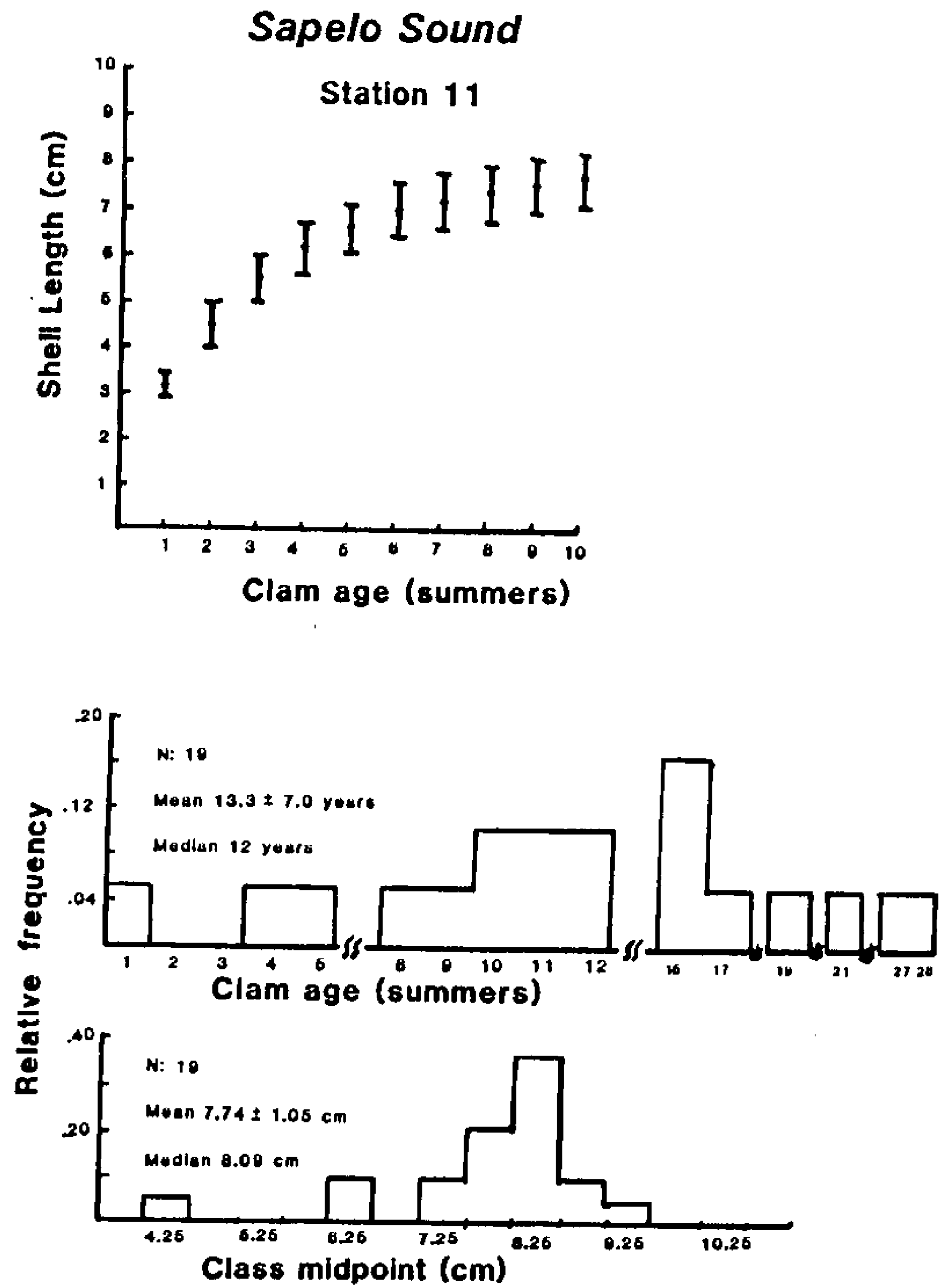

Figure 13. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 11.

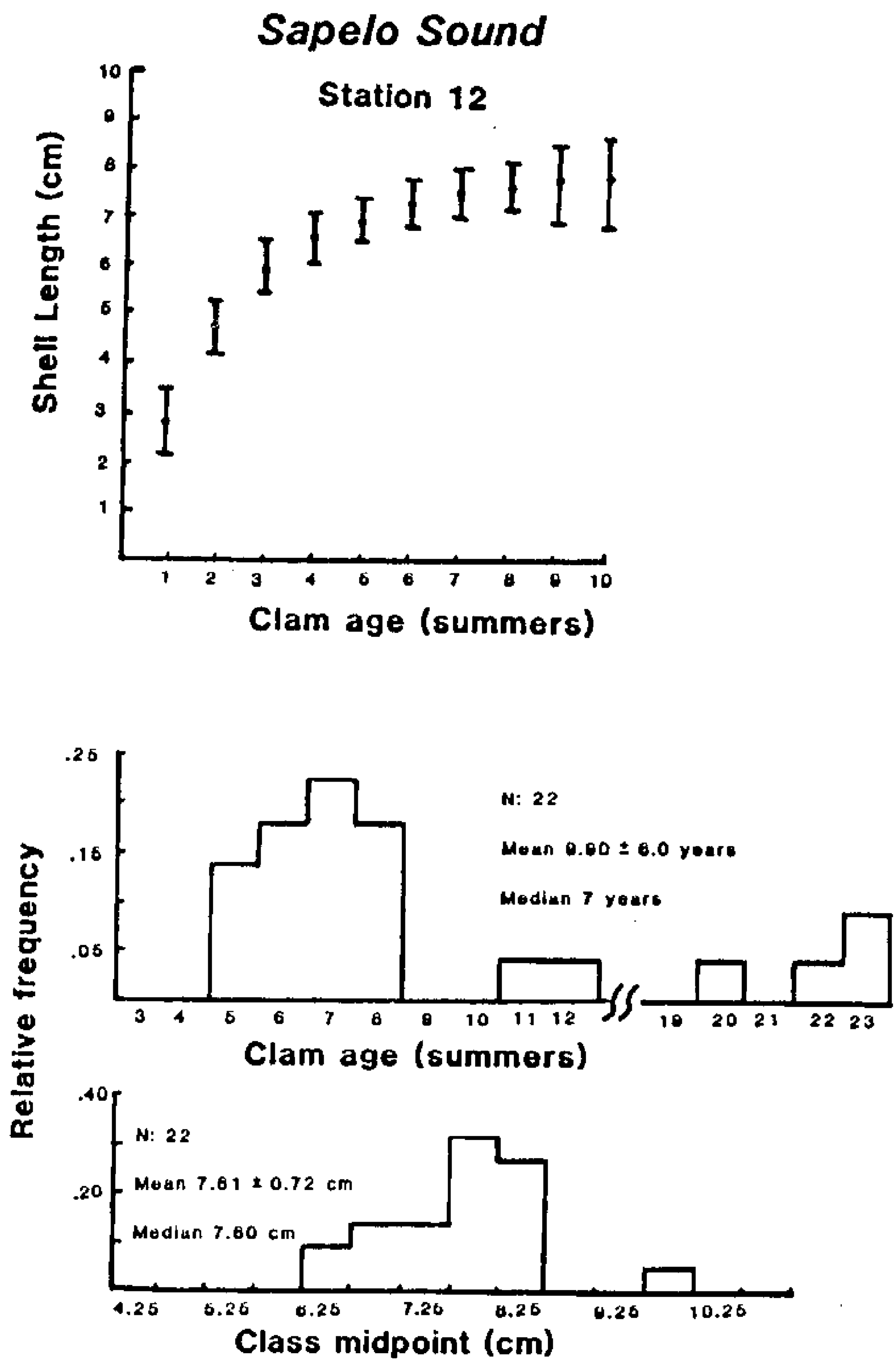

Figure 14. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 12.

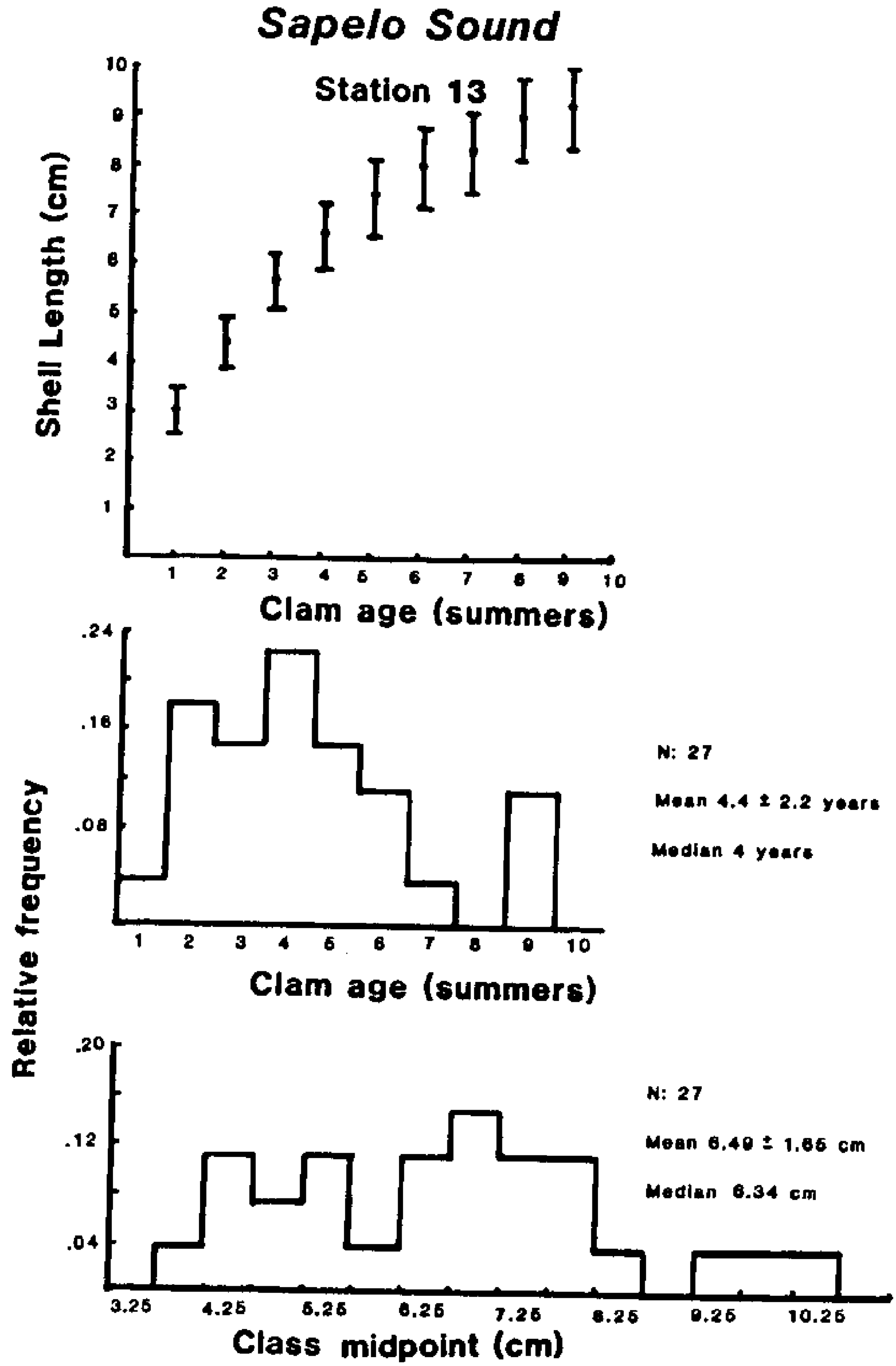

Figure 15. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 13.

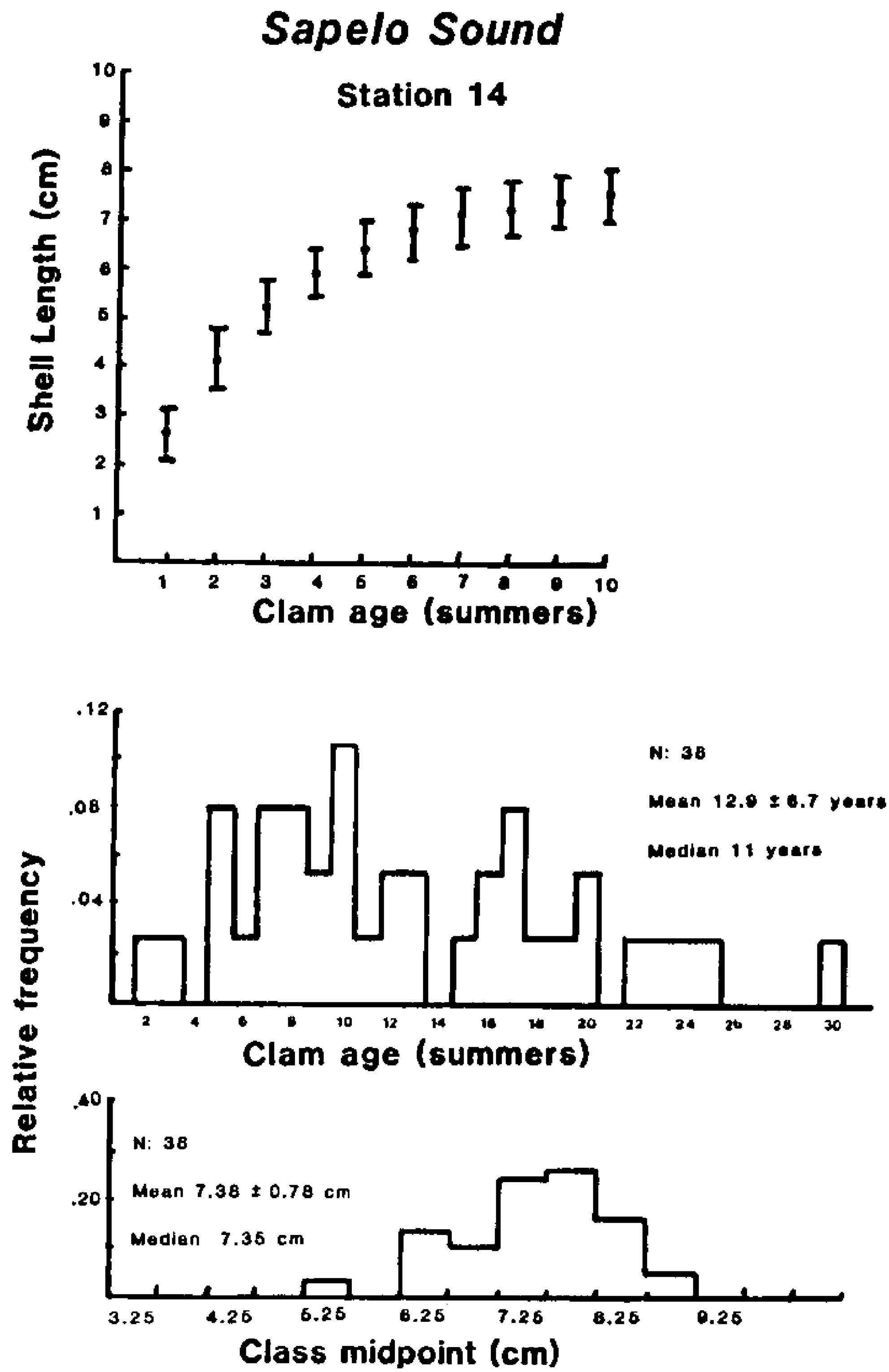

Figure 16. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 14.

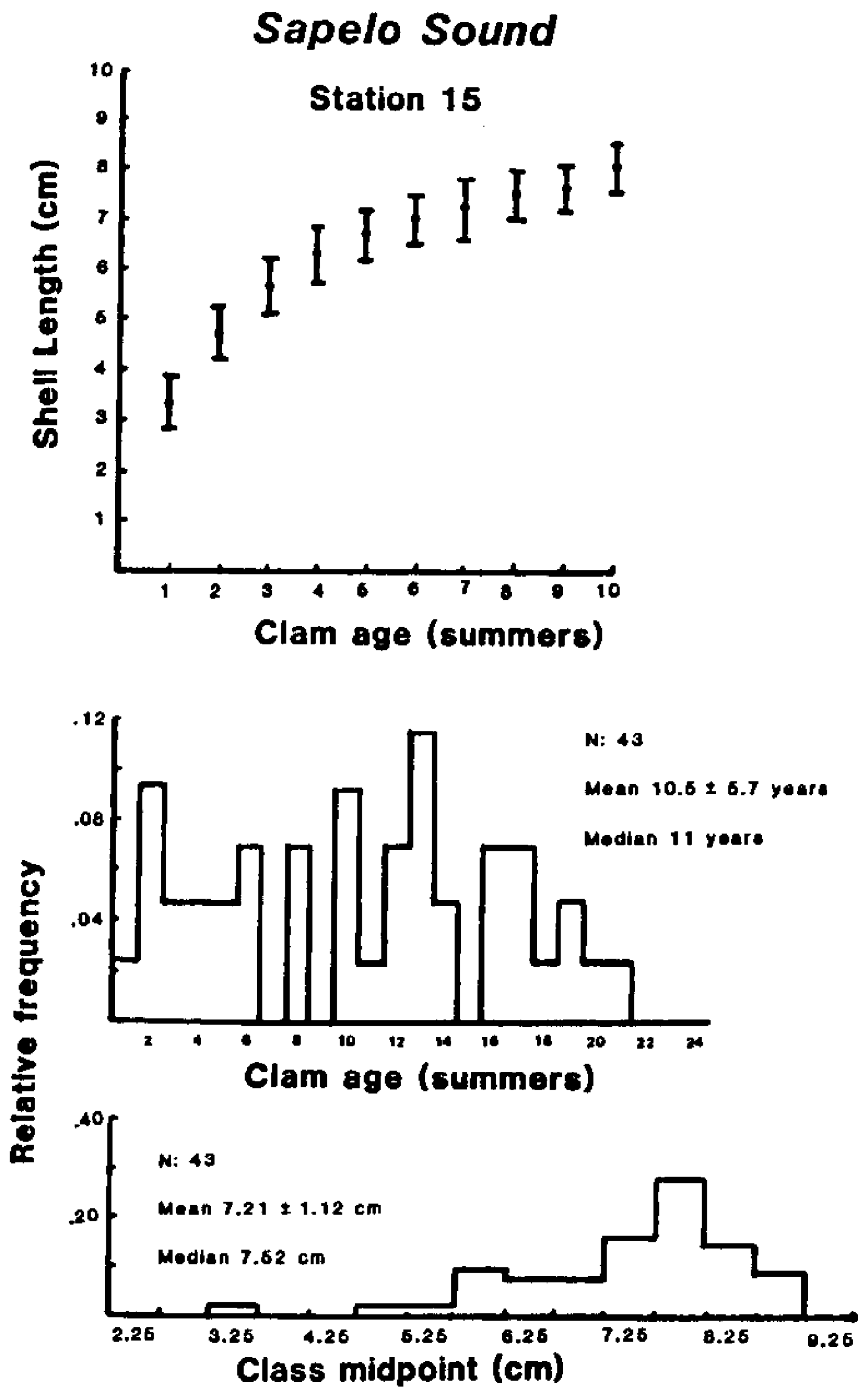

Figure 17. Growth curve (mean ± S.D.), age structure and size class structure of hard clams, *Mercenaria mercenaria*, from Population 15.

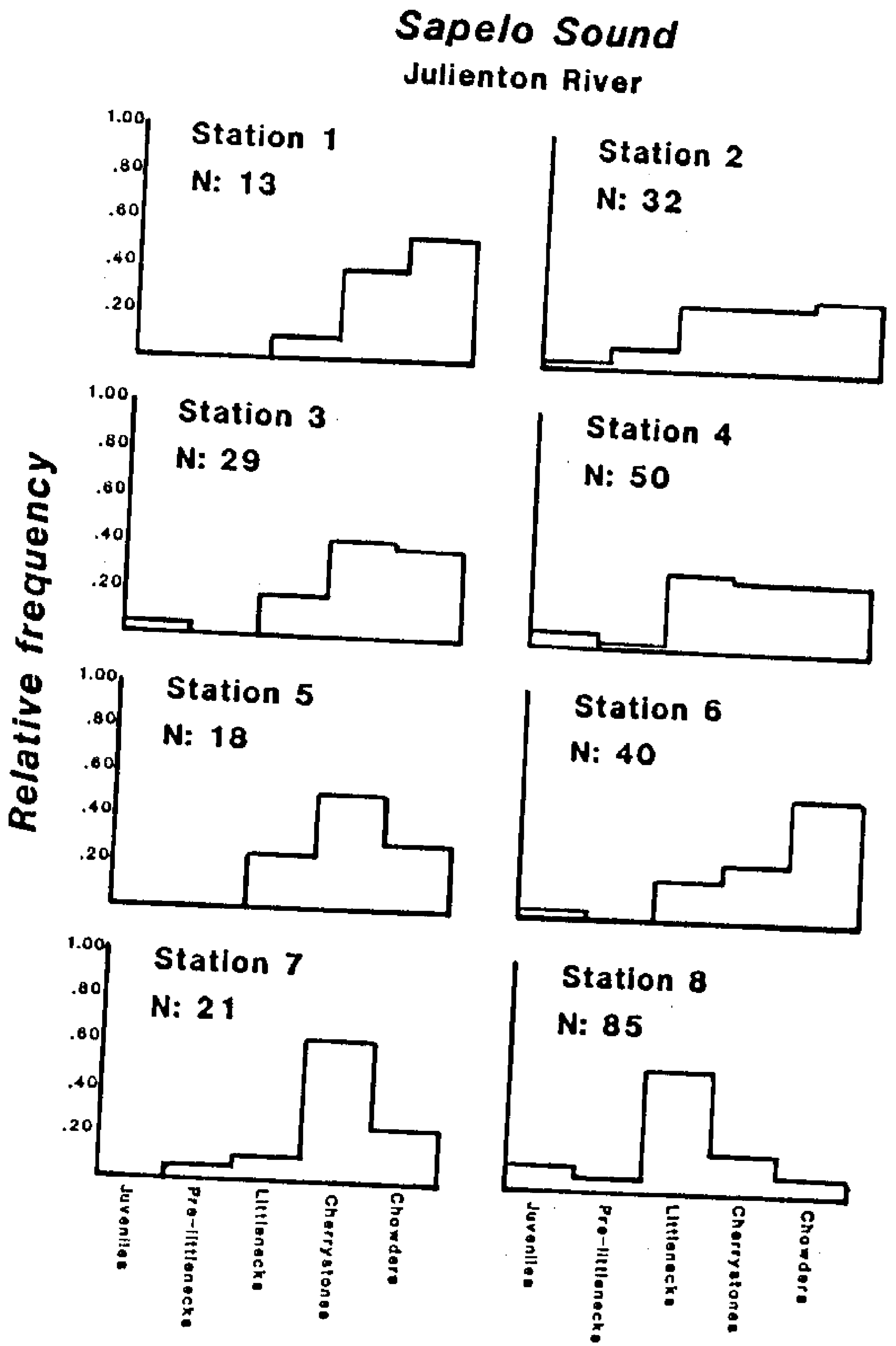

Figure 18. Commercial size grouping of hard clams from Populations 1 through 8.

Sapelo Sound

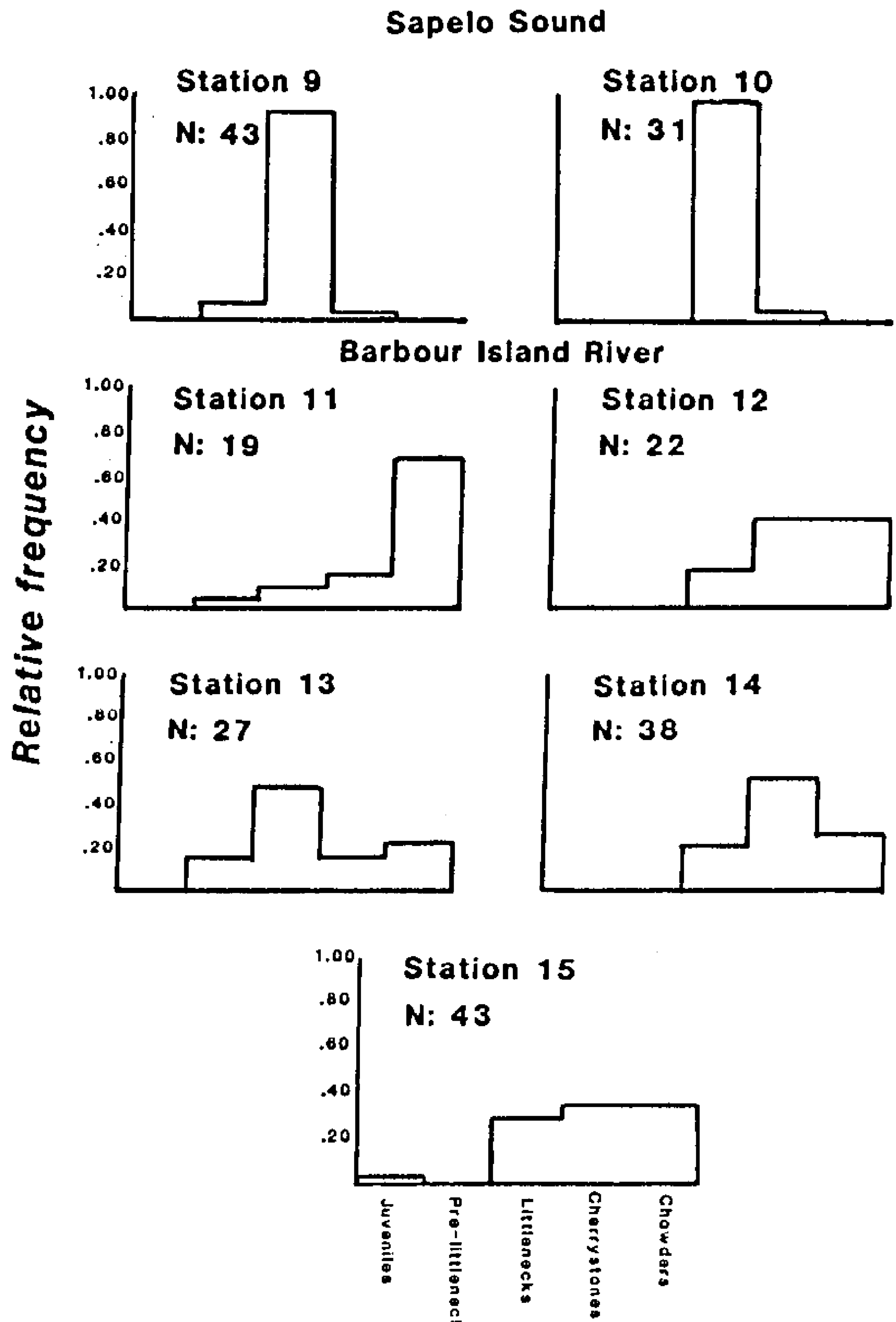

Figure 19. Commercial size grouping of Hard clams from Populations 9 through 15.

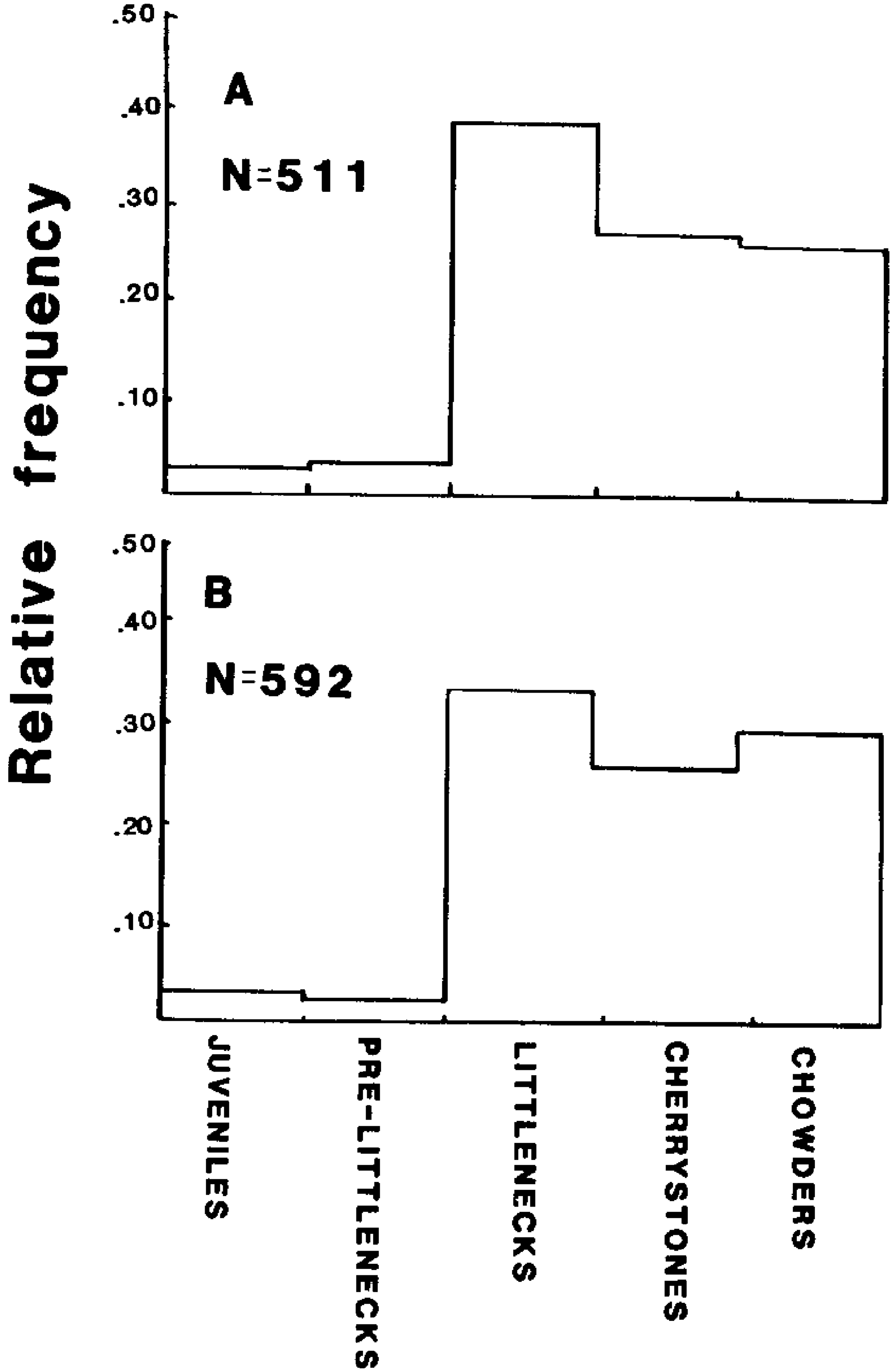

Figure 20. A) Overall commercial grouping of hard clams, *Mercenaria mercenaria*, for clam populations (N = 15) in the Julienton Plantation area. B) Overall commercial grouping of hard clams for all areas surveyed within the Julienton Plantation area.

Figure 21 . Sites about the Julienton Plantation area where two test seed clam cages were placed.

Figure 22. Oyster drill, Urosalpinx cinerea, sampling stations.

Figure 23. Possible areas for future cage culturing of molluscan species.